PN-ACU-297

INTERNATIONAL ENERGY AGENCY

THE CLEAN AND EFFICIENT USE OF COAL AND LIGNITE: ITS ROLE IN ENERGY, ENVIRONMENT AND LIFE

CONFERENCE PROCEEDINGS

HONG KONG • 30TH NOVEMBER - 3RD DECEMBER 1993

OECD
OCDE

AUSTRALIAN DEPARTMENT
OF PRIMARY INDUSTRIES AND ENERGY
MINISTRY OF INTERNATIONAL TRADE AND INDUSTRY OF JAPAN
UNITED STATES DEPARTMENT OF ENERGY
UNITED STATES AGENCY FOR INTERNATIONAL DEVELOPMENT
US-ASIA ENVIRONMENTAL PARTNERSHIP
UNITED NATIONS

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C O N F E R E N C E P R O C E E D I N G S

INTERNATIONAL ENERGY AGENCY
AUSTRALIAN DEPARTMENT
OF PRIMARY INDUSTRIES AND ENERGY
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US-ASIA ENVIRONMENTAL PARTNERSHIP
UNITED NATIONS

INTERNATIONAL ENERGY AGENCY

2, RUE ANDRÉ-PASCAL, 75775 PARIS CEDEX 16, FRANCE

The International Energy Agency (IEA) is an autonomous body which was established in November 1974 within the framework of the Organisation for Economic Co-operation and Development (OECD) to implement an international energy programme.

It carries out a comprehensive programme of energy co-operation among twenty-three* of the OECD's twenty-five Member countries. The basic aims of the IEA include:

i) co-operation among IEA participating countries to reduce excessive dependence on oil through energy conservation, development of alternative energy sources and energy research and development;

ii) an information system on the international oil market as well as consultation with oil companies;

iii) co-operation with oil producing and other oil consuming countries with a view to developing a stable international energy trade as well as the rational management and use of world energy resources in the interest of all countries;

iv) a plan to prepare participating countries against the risk of a major disruption of oil supplies and to share available oil in the event of an emergency.

* *IEA participating countries are: Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Japan, Luxembourg, the Netherlands, New Zealand, Norway (by special agreement), Portugal, Spain, Sweden, Switzerland, Turkey, the United Kingdom, the United States. The Commission of the European Communities takes part in the work of the IEA.*

ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT

Pursuant to Article 1 of the Convention signed in Paris on 14th December 1960, and which came into force on 30th September 1961, the Organisation for Economic Co-operation and Development (OECD) shall promote policies designed:

— to achieve the highest sustainable economic growth and employment and a rising standard of living in Member countries, while maintaining financial stability, and thus to contribute to the development of the world economy;

— to contribute to sound economic expansion in Member as well as non-member countries in the process of economic development; and

— to contribute to the expansion of world trade on a multilateral, non-discriminatory basis in accordance with international obligations.

The original Member countries of the OECD are Austria, Belgium, Canada, Denmark, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, the Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, Turkey, the United Kingdom and the United States. The following countries became Members subsequently through accession at the dates indicated hereafter: Japan (28th April 1964), Finland (28th January 1969), Australia (7th June 1971), New Zealand (29th May 1973) and Mexico (18th May 1994). The Commission of the European Communities takes part in the work of the OECD (Article 13 of the OECD Convention).

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FOREWORD

These Proceedings consist of the papers presented at the IEA Second International Conference on the Clean and Efficient Use of Coal and Lignite: Its Role in Energy, Environment and Life, which was held in Hong Kong on 30th November-3rd December 1993. The Conference was jointly sponsored and organised by the International Energy Agency, the Australian Department of Primary Industries and Energy, the Ministry of International Trade and Industry of Japan, the United States Department of Energy, the United States Agency for International Development, the US-Asia Environmental Partnership, and the United Nations. Supporting organisations were: China Light and Power Company, Exxon Energy, Hong Kong Electric Company, the World Energy Council and the United States Energy Association. Over 250 senior representatives from 27 countries and economies participated in the Conference. Experts from the ministries and public entities of IEA countries and the Asia-Pacific region were actively involved, in particular those responsible for decision-making on energy and environment policy, coal technology programmes and trade. Other participants included executives and managers of the coal industry, electric utilities, engineering and equipment supply companies, financing institutions, and R&D organisations.

The Conference was the successor event to the IEA International Conference on Clean and Efficient Use of Coal: The New Era for Low-Rank Coal which was held on 24th-27th February 1992 in Budapest, Hungary. Energy and electricity demand in the Asia-Pacific region has experienced extraordinary growth rates in the 1980s. In order for the Asia-Pacific region to meet increased power generation requirements, a concerted effort is being made to develop indigenous energy resources. Coal and lignite resources are available in several countries and represent a major energy option. In this context, general aims of the IEA Conference in Hong Kong were: to provide data on the economic, environmental, safety and technical aspects of modern day coal and lignite production and use throughout Member countries and identify the technological options for the Asia-Pacific region; suggest methods for analysing energy needs of individual countries; analyse factors that will influence technological choices; increase collaboration among industry and governments from IEA Member and other Asia-Pacific countries; facilitate the transfer to and incorporation of clean use of coal technologies in the region.

Conference participants looked at a wide range of specific options for improved technologies for coal and lignite production and use, as well as means for financing technology deployment, establishing and enhancing international collaboration, meeting regional needs, and developing environmental response strategies for governments and industries. "Best practice" clean coal technologies applicable to the Asia-Pacific region were identified while opportunities emerged for the increased understanding of the technical and non-technical barriers to introduction of such technologies.

The analyses, evaluations and suggestions that were debated at the Conference, and are contained in this volume of Proceedings, may not necessarily reflect the views of the IEA, the OECD and their Member governments. It is hoped, however, that these proceedings will make a significant contribution towards better understanding of the prospects for clean coal technology progress and R&D initiatives that can be considered at the national, regional and international level.

Jack Siegel
Acting Assistant Secretary
Fossil Energy
US Department of Energy

Sergio F. Garribba
Director
Energy Technology and R&D
International Energy Agency

ACKNOWLEDGEMENT

On behalf of the International Energy Agency, we would like to express sincere appreciation for the support given to this IEA Second International Conference on the Clean and Efficient Use of Coal and Lignite: Its Role in Energy, Environment and Life, by other sponsors and organisers: the Australian Department of Primary Industries and Energy, the Ministry of International Trade and Industry of Japan, the United States Department of Energy, the United States Agency for International Development, The United States-Asia Environmental Partnership, and the United Nations. Without their effort and the resources that they contributed, the Conference would not have been possible, neither would it have been the outstanding success it was. We would also like to thank China Light & Power Company Ltd, Exxon Energy Ltd, Hong Kong Electric Company Ltd, the World Energy Council, and the United States Energy Association who provided the Conference with support and additional means to ensure participation from non-Member countries of the Asia-Pacific region.

Further, the vital role played by the Conference Steering and Organising Committees and their individual members must be acknowledged, including the dedication of Dr Jack Siegel, Acting Assistant Secretary for Coal Technology, US Department of Energy, who acted as a promoter and catalyser. The work of Dr John Tilley, the Division Head for International Technology Collaboration, Mr James Tapper and Mr Henry Bottomley of the IEA's Secretariat, and the drive displayed by Ms Barbara McKee of the United States Department of Energy were determinant to the outstanding development and outcome of the event. Finally, special thanks go to the many Conference speakers, Session and Workshop Chairmen, Rapporteurs and Panellists for having contributed to the stimulating discussion and for formulating the proposals and ideas which are reflected in the pages which follow.

Sergio F. Garribba
Director
Energy Technology and R&D
International Energy Agency

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OPENING SESSION AND KEYNOTE SPEECHES

FORMAL OPENING OF THE CONFERENCE

by Sergio F. Garribba
Director
Energy Technology and R&D
International Energy Agency

Distinguished Conference participants, ladies and gentlemen, good morning to all of you. It is a pleasure and an honour to be here with Dr Jack Siegel, Assistant Secretary for Fossil Energy of the United States Department of Energy, to co-chair this IEA Second International Conference on the Celan and Efficient Use of Coal and Lignite: Its Role in Energy, Environment and Life.

On behalf of the International Energy Agency, I also want to express our gratitude to those who contributed to the design, planning and organisation of this event: the Australian Department of Primary Industries and Energy, the Ministry of International Trade and Industry of Japan, the United States Department of Energy, the United States Agency for International Development, the United States - Asia Environmental Partnership, and the United Nations. And I will not forget our co-sponsors, China Light and Power Company, Exxon Energy, Hong Kong Electric Company, the World Energy Council, and the United States Energy Association. For those of you who may not know the International Energy Agency (IEA), I should recall that the IEA is an inter-governmental organisation which was established in 1974 after the first oil shock in the framework of the Organisation for Economic Co-operation and Development (OECD) to promote the collective energy security of its Member countries and their environment through the establishment of free and open markets as a fundamental point of departure. The shared objectives of IEA Member governments are: to improve the world's energy supply and demand structure by developing alternative energy sources and increasing the efficiency of energy use; to maintain and expand systems for coping with oil supply disruptions; to operate a permanent information system on the international oil market and other sources of energy; to assist the integration of environmental and energy policies; to approach energy developments in a global context through co-operative relations with non-Member countries and international organisations. Countries co-operating as IEA Members are: Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Japan, Luxembourg, the Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, Turkey, the United

Kingdom and the United States. The European Commission also participates in the IEA's work.

This is the second IEA International Conference on the Clean and Efficient Use of Coal and Lignite. The first Conference was held in Budapest, Hungary in February 1992 and generated and added momentum to a host of collaborative initiatives between entities from our countries and the corresponding interests in the countries of Central and Eastern Europe, which after years of communist rule are finding their way towards a market-based economy.

The Conference that we have here during these three days in Hong Kong is aimed at establishing once more a bridge towards the countries of South East Asia and the Pacific Rim. In the announcement it was said that aims of this Conference are: to discuss current coal technology options to meet future energy needs of the Asia-Pacific region through increased use of coal and lignite; to learn about the economic and environmental issues, regulations and legislation affecting the use of coal and the market deployment of clean coal technology; to receive first-hand country-specific information on current energy situations and their anticipated evolution; to debate means for financing projects in the region; and to participate in the formation of international technology partnerships and transfer of knowledge. In essence, our shared goal is to develop a stewardship between those countries that intend to rely upon coal as a basic energy resource for their energy security, better environment and life quality. This Conference, I believe, will be an excellent forum to discuss the issues that are in front of us and to prepare options and practical mechanisms for enhanced international co-operation and promote progress in coal and lignite use and technology.

As you can see from the Conference programme, after the welcome remarks, and during the entire morning session, we will have a series of keynote speeches that will set the tone of the Conference and define its leading themes. In the afternoon, another plenary session will address the Asia-Pacific coal use strategies, in particular the needs, plans and opportunities which characterise the present energy and economic context. Then, there will be seven regional forums on opportunities for international collaboration. Government policy makers and industry executives of the People's Republic of China, India, Indonesia, Republic of Korea, Malaysia, The Philippines, Thailand and Vietnam will provide attendees with first-hand information on and insight of coal development projects and prospects in their respective countries. Tomorrow, a second plenary session will focus on how to integrate clean coal technology into the energy systems of the Asia-Pacific region. Next, a first series of five parallel workshops will address key themes such as project financing, technology options and their evaluation, emissions control and coal preparation, regional needs, and environmental strategies. Each workshop will have two co-chairs and a rapporteur who should summarise the results of the discussion. Finally, a panel comprising various members of the press will put forward suggestions on how to inform the public and gain public acceptance.

The second series of five parallel workshops will be held during the morning of the third and last day of the Conference. The leading themes will include international co-operation and partnership, technologies for coal desulfurisation and integrated gasification combined cycles, coal pyrolysis and fluidised bed combustion, regional needs and public outreach, and again, the environmental issues and strategies. The Conference will continue in the morning with a third plenary session consisting of a panel of experts who will further debate how to respond to the environmental challenges in front of us and take advantage from opportunities. In the afternoon, we will have the closing session with reports from all the workshops and the closing speeches. This is a dense programme, prepared to offer plenty of opportunities for investigation, exchange of information, and new ideas upon which to build a better future for the IEA region and the countries of the world.

Thank you Conference participants, ladies and gentlemen, for your attention. I declare this Conference open. I will now give His Excellency Mr Gordon Sin, Secretary for Economic Services, Hong Kong Governor's Office, the floor for the welcome to the Conference. Mr Sin, please have the podium.

INTRODUCTORY REMARKS OF

DR. SAMUEL SCHWEITZER
U.S. AGENCY FOR INTERNATIONAL DEVELOPMENT
AT

IEA Second International Conference on the
Clean and Efficient Use of Coal and Lignite

HONG KONG
December 1, 1993

Good morning:
The Honorable Christopher Patten, Governor of Hong Kong;
Your Excellency, Mr. Wang, Minister of Coal Industry,
People's Republic of China;
Your Excellency, Mr. Salve, Minister of Power, India;
Mr. Ji Chaozhu, Under Secretary General for Development Support and
Management Services, United Nations;
Mrs. Helga Steg, Executive Director, International Energy Agency;
and, many distinguished guests[1]:

Ms. Margaret Carpenter, USAID Assistant Administrator for Asia and the Near East regrets very much not being able to be with us today. She has asked me to address you on her behalf.

The U.S. Agency for International Development is pleased to have this opportunity to co-sponsor this critically important conference.

We would like to thank and congratulate the organizers and co-sponsors of this conference: especially the International Energy Agency, Australia, Japan, the United Nations, the U.S. Department of Energy, and the many participating nations. You have assembled a remarkable program and an impressive audience.

Clearly, one of the most significant problems facing Asia is how to provide the energy required for sustainable development while improving the environmental quality of the region.

USAID firmly believes that partnerships between host countries, donor nations, multilateral development banks, and the private sector are the key to overcoming this problem. We recognize that private sector innovation and resources are important engines for development.

Cooperative action with the private sector enables the public sector to magnify the impact of development assistance funds. Consequently, we are pleased that so many high level representatives have chosen to attend this conference.

As you may know, the U.S. Government, under President Clinton, is firmly committed to addressing environmental issues -- including global climate change, environmental degradation and biodiversity protection -- whose continued deterioration will undermine the sustainable productivity of both man and nature.

USAID's new development strategy places great emphasis on the goals of achieving sustainable economic development and protecting the environment. The future role of coal must be seen in relation to both goals. We who are attending this conference must find ways to ensure that clean coal technologies and practices are rapidly deployed through the region. Hopefully, this conference will enable us to find ways to establish new forms of collaboration between governments and the clean coal technology industry.

We at USAID are convinced that this conference will improve our understanding of how the clean and efficient use of coal can contribute to environmentally sustainable development in Asia, and wish all of you a very successful and productive conference.

WORLD ENERGY OUTLOOK AND TECHNOLOGY CHALLENGES

by Sergio F. Garribba
Director
Energy Technology and R&D
International Energy Agency

1. Introduction

The present keynote paper is extracted from the recent IEA's World Energy Outlook to the year 2010. This outlook is part of the IEA Secretariat's periodic review of the medium and long-term trends for world energy demand and supply under a number of assumptions regarding the price of crude oil, economic growth, and a host of other variables. The paper is organised into three parts. First, there are the key assumptions regarding future economic trends and world energy prices. Second, is the energy demand outlook and the expected projections for the different energy sources, oil, natural gas, coal and solid fuels, nuclear and renewable energy. These projections are not a prediction of what will happen, rather they are a tool for policy makers to increase understanding about the way energy markets may work. Third, is the issue of greenhouse gas emissions, with the role of technology progress and international co-operation.

Forecasting energy developments is fraught with considerable uncertainty. The projections of the IEA's Energy Outlook are based upon an econometric model as adjusted by the best judgement of the IEA's Secretariat concerning, among other things, the availability of oil, natural gas and coal reserves, and their associated costs of production, and the future developments in transportation, power generation and other technologies. In addition, there are further determinants of energy markets that are impossible to predict with confidence. These include policy changes, the geological potential of unexplored regions, technological breakthroughs , the availability of non-commercial fuels in the countries of the rest of the world, government policies with regard to environment, and the future preferences of energy

users. The links between energy supply and demand, energy prices and economic activity are also imperfectly understood. Price and macroeconomic assumptions and their evolution in time depend upon a number of circumstances. In particular, the economic future of the New Independent States (NIS) and countries of Central and Eastern Europe is hard to predict. Because of all of these variables and the very long-term nature of most energy decisions, the following outlook is intended only to be indicative of the general direction and possible evolution of worldwide energy trends. Its seeming numerical precision, therefore, must not be seen in isolation from the assumptions made or from the above noted uncertainties. Other scenarios are possible.

The reference case energy projections given here can be seen as a likely outcome only if the many assumptions on which these projections are based come to reality. One of the key assumptions in this outlook is that the policy framework, as currently enacted, prevails. The policies adopted will depend to some extent on the underlying energy and environment outlook. Yet, it is unlikely that no new policy initiatives will be adopted over the next several years. In order to indicate the possible effects of policy, selected sensitivity analysis is needed for instance, to show the effects of lower oil prices, or how carbon taxation and other environmentally-related measures may work. However, it is beyond the scope of this keynote paper to examine detailed policy packages that could ultimately modify or even reverse many of the trends presented.

2. Macroeconomic Assumptions

Notwithstanding current uncertainties about short term economic prospects, the IEA's Outlook to 2010 expects modest gross domestic product (GDP) growth when compared to past trends. This general slowdown in growth reflects the maturing of OECD economies, particularly in the OECD Pacific countries, where long-term GDP growth slows to 2.9 per cent per year compared with 4.2 per cent growth from 1971 to 1991. Western Europe and North America are expected to grow at an average rate of just over 2 per cent over the next 17 years.

The current economic slowdown in the OECD is expected to have an adverse short-term impact on growth in the rest of the world. In the longer term, however, the developing countries are assumed to grow at an average of 5.1 per cent per annum, although this hides considerable regional variations. For example, China is assumed to grow at 7.6 per cent per annum, East Asia at 5.8 per cent, and Africa at 3.4 per cent. In general, the growth prospects for the non-OECD Asian economies remain the brightest. Nevertheless, the NIS and the

countries of Central and Eastern Europe, do not lend themselves to the kind of economic analysis undertaken for the OECD and the developing countries. Historical data for the principal energy flows in the era of central planning provide little guidance during a period of transition to a market economy or to energy production and use once the transition is complete. Furthermore, the dissolution of the Soviet bloc and the ending of the rouble-dominated bilateral trade between the NIS and Central and Eastern Europe and, later, the collapse of inter-republic trade associated with the break-up of the NIS introduced a number of logistical and financial constraints on the supply side of many of these former centrally planned economies, the effects of which are likely to impinge on domestic energy demand for some time.

In view of the uncertainty surrounding both the NIS and some countries of Central and Eastern Europe, the projections herein used represent a best guess of the likely path of energy production and use for the period to 2010. In many countries in Central and Eastern Europe, where reforms started earlier, GDP has already fallen significantly. It is assumed not to fall as dramatically in the next few years as the NIS and Central and Eastern European economies are also assumed to grow at a faster rate thereafter. The hypothesis is that GDP in Central and Eastern Europe will show more lively growth into the first decade of the next century. GDP in the NIS is assumed to fall rapidly until 1995 when GDP will be no more than 65 per cent of its 1990 level. Industrial output and energy demand will follow the decline of GDP with a substantial contraction of heavy industry. The NIS economy is assumed to recover after 1995 but, even by 2010, it would only be 12 per cent larger than in 1990. With progressing market reforms, and as energy prices continue to approach world levels, the energy structure of the region moves towards that of OECD economies. Thus, during the recovery process, energy demand growth is concentrated on light industry, the residential and commercial sector, and transportation. Consequently, energy intensity in the NIS and Central and Eastern Europe resumes it decline after 1995.

Oil production in the NIS is currently below 7.5 million barrels per day, down from a peak of 12.5 million barrels per day in the years 1987 and 1988. This is expected to fall further over the medium term before picking up in the later part of the outlook period. But oil consumption is assumed to continue falling until 1995, before beginning the raise in the late 1990s and beyond. As a result, net oil exports from the NIS are assumed to remain in the region of 2 million barrels per day. Gas consumption is also expected to show some reduction by 1955. This and the growing potential importance to the Russian economy of gas revenues mean that it is likely that gas exports from the NIS will be able to meet a large proportion of incremental demand in both OECD Europe and Central and Eastern European countries.

3. Energy Price Assumptions

The reference case outlook is based on an average IEA imported crude oil price rising gradually to $30 per barrel by 2005, and remaining constant thereafter. Unless otherwise stated all prices refer to constant 1993 US dollars. A 1993 price of $30 is close to the average price between 1974 and 1992 and just over half the level of the 1980-81 oil price peak of nearly $55 per barrel. To reflect possible capacity pressures, the rise in prices is assumed to be faster in the 1990s.

The above reference case oil price is significantly below that of the IEA Secretariat's 1991 energy outlook where it was assumed that oil prices would rise to slightly above $38 by 2000 ($35 in $1990), and stay at that level beyond that date. The reduction in the assumed reference oil price reflects, to some extent, an optimistic supply outlook (i.e. geological prospects), as many countries that were basically closed to OECD-originated capital and technology until very recently, are gradually opening up. Also major producers such as Saudi Arabia currently seem to be paying more attention to maintaining their market share rather than to supporting a specific crude price level.

An alternative crude oil price assumption which is examined in the IEA's World Energy Outlook (and not presented in this keynote paper) has crude oil prices, in real terms, averaging $20 per barrel throughout the period. This is approximately or slightly above the current price level. The flat real price scenario implies a more substantial increase in demand over the outlook period and, consequently, an increased call on the production of regions with large, relatively inexpensive oil resources, like Middle East and Venezuela. In addition, the low oil price scenario would reflect greater optimism on the part of industry regarding improvements in oil exploration and production technology. Yet, there is little doubt about the geological potential to satisfy the world's oil requirements under this scenario, but the timely undertaking of the large investments required and the willingness of some countries to allow the required sharp increase in the exploitation of their oil reserves may be questioned.

The assumption of very smooth oil price increases should not be interpreted as a prediction of smooth developments in the oil markets. There is no reason to expect that the oil price will be any less volatile over the next 17 years than it has been since 1974. Indeed, the weakened link between crude oil prices and the prices that consumers of oil-derived products face has led to an oil demand that is rather insensitive to price changes and may have increased the role of supply responses and the scope for price volatility. The link between crude oil prices and the prices of oil-derived products in OECD countries has been weakened by the

introduction over many years of significant taxes on most products. For example, the price of crude oil can be as little as 10 per cent of the price of gasoline produced from a barrel of oil.

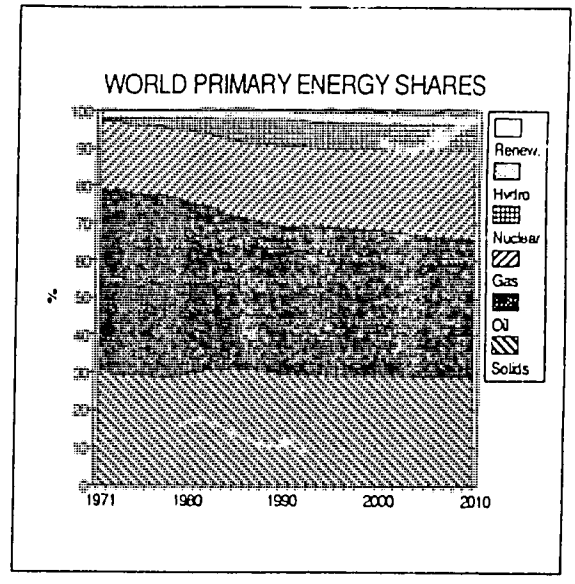
Concerning natural gas, the producer gas price in the United States is assumed to rise rapidly in the 1990s and to reach a plateau of $3.5 per million BTU. This trend reflects a sharp change in the perception of the availability in North America of gas resources at a relatively moderate cost. The prices at which gas is imported into Europe and Japan are expected to rise broadly in line with crude oil prices. In thermal equivalent terms, LNG is assumed to remain the most expensive form of primary energy in Japan. Little growth in the prices of internationally traded coal is anticipated, despite the growth of imports into Europe and Japan. The increase in coal demand in North America will necessitate a substantial rise in the minemouth price. Regardless, coal will remain the least expensive form of primary energy in the OECD region.

4. The Energy Demand Outlook to 2010

Under the reference case scenario, OECD total energy demand is forecast to grow at a moderate average rate of about 1.3 per cent per year over the period to the year 2010. Energy demand in the NIS and Central and Eastern Europe will slightly exceed its 1990 level by 2010. Between now and 2010, total energy demand in the rest of the world is projected to grow at an average rate of 4.0 per cent per annum, which is significantly faster than in the OECD. This would imply a fall in the OECD share of world energy consumption from 53 per cent to 46 per cent. Rapid growth in energy demand among developing countries is projected to occur for several reasons: rapid growth in population and economic activity; increasing industrialisation and road transportation; and diminishing availability of non-commercial sources of energy. The less developed countries, especially, consume significant quantities of non-commercial biomass fuels at present. The consumption of these fuels is difficult to estimate. However, the present outlook assumes that incremental demand in the rest of the world will increasingly be met by commercial-type energy.

The share of oil in total world energy requirements is expected to continue to decline as it has since 1973. The share of oil in OECD countries would also diminish from about 42 per cent in 1990 to 38 per cent in 2010, and a similar change is projected for the rest of world. The share of natural gas in total world energy requirements is expected to rise by about 3 percentage points, from 21.6 per cent to 24.2 per cent, with the largest increase occurring in the rest of world (which excludes the NIS and Central and Eastern Europe), namely from 12.6

per cent to 17.6 per cent. Solid fuels' contribution to total world energy requirements is expected to remain fairly constant at about 29 per cent. Moreover, on a worldwide basis, the shares of nuclear and hydro will remain relatively constant and satisfy smaller percentages of world energy requirements.



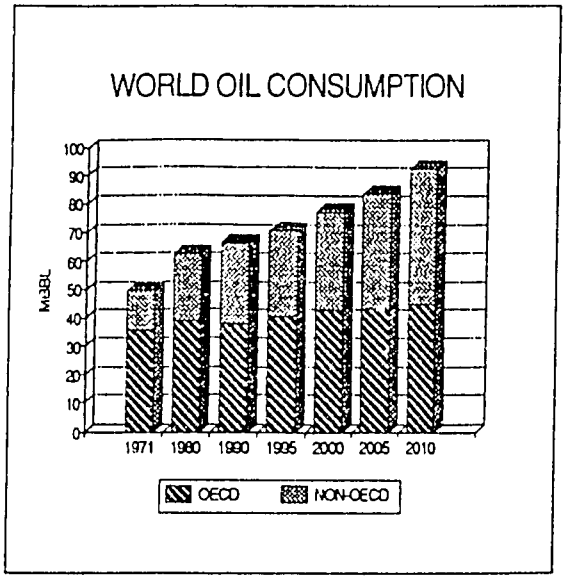
5. Oil

The IEA Secretariat's analysis points to a moderate rise in world oil demand over the period to 2010, under the reference case assumption of oil prices rising to $30 per barrel by 2005 and remaining flat thereafter. World oil demand would be expected to rise at an average rate of about 1.9 per cent per annum over the period, with the rate of growth being higher over the medium term and lower over the latter part of the period. Oil demand is expected to rise rapidly in the countries of the rest of the world (3.5 per cent per annum), largely because of rapid population growth, urbanisation and greater transportation needs. One of the reasons for the relatively rapid growth in oil use is the lack of established infrastructure for natural gas (e.g., pipelines, port facilities, etc.). Demand will increase less in OECD countries (0.8 per cent per annum). As a result, the non-OECD share of world oil consumption could rise from 44 per cent in 1990 to about 52 per cent in 2010.

In the reference case, the increase in OECD oil demand is expected to come mainly from the transport sector (road and air transport) which would grow at an average rate of about 1.5 per cent per annum over the outlook period. It accounts for almost all of the incremental oil demand in the OECD. The trend towards a lighter barrel, together with the many recent changes in legislation regarding the quality of transportation fuels, implies large investment requirements in the refinery sector.

With OECD oil production expected to decline, future growth in oil demand is projected to be met by non-OECD oil production with the main growth area continuing to be the Middle East. The ongoing trend towards liberalisation in upstream regimes will facilitate the expansion of OPEC and non-OPEC production with the attendant benefits of supply diversification. IEA

governments can assist in this by encouraging a sound basis for investment in production capacity in non-OECD countries, and, in particular, in the New Independent States, to arrest the decline in their production. Successful completion and implementation of the European Energy Charter and other co-operation agreements may contribute to achieving this objective.

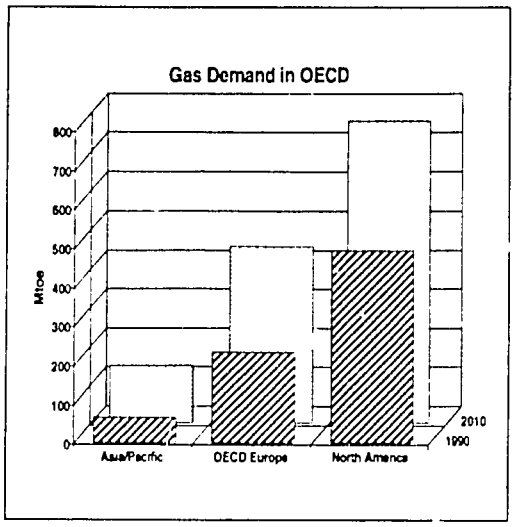


Continuing growth in oil demand and reduced product exports from the Middle East and the New Independent States has led to increasing refinery throughput and a corresponding decrease in spare capacity. However, the refinery industry demonstrated its flexibility in the Gulf crisis and this flexibility has been enhanced by continued investment in upgrading facilities and by the beneficial effects of more transparent markets. While most of the additional global refinery capacity in the coming decade is expected to be built in those non-OECD regions with the highest oil demand growth, most of the substantial investments in the OECD refinery industry would assist in meeting stricter environmental standards.

6. Natural Gas

Demand for natural gas is expected to grow rapidly in most IEA countries over the next two decades. This anticipation of expanded gas use mirrors, in some respects, the rapid post-Second World War increase in oil use: ease of handling and other technical and economic attributes were to oil in the fifties and sixties, as the technical, resource and environmental attributes are to gas in the current policy and economic environment. The expansion of natural gas could entail significant environmental benefits by reducing atmospheric emissions. In the OECD region, the fastest growing area will be in gas-fired power generation by utilities and cogeneration by independent producers. The possibilities of natural gas playing a more important role as a vehicle fuel before the end of the century are improving. In the longer term there are prospects of reducing the share of oil in the tansport sector, while in the shorter term there will be use in the production of oxygenates for gasoline reformulation.

World natural gas markets tend to be regional and largely unconnected, with different resource prospects, transportation systems, costs and demand patterns. The regional nature of gas markets is an important factor that increasingly binds OECD energy markets to neighbouring non-OECD natural gas producers and consumers. The further development of these regional gas markets will depend on the cost of developing the gas and transporting it, and on the value attached to natural gas in the end-use.

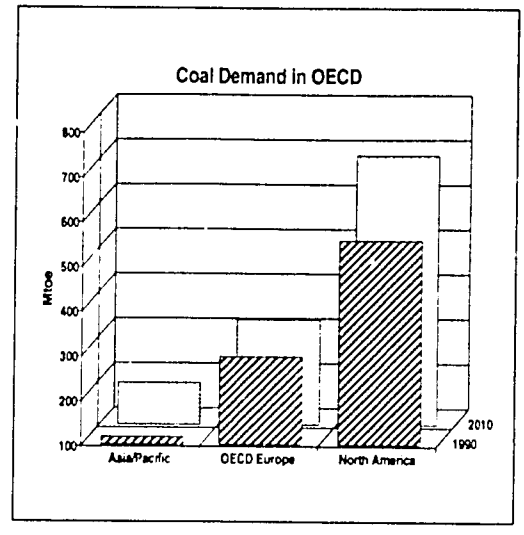


Physical reserves of natural gas in the areas supplying the IEA countries are abundant and overall the IEA is less reliant on gas imports than it is for oil. However, the distribution of reserves varies among Member countries. Also, many Member countries are counting on the increased use of natural gas, along with energy efficiency, to help achieve their environmental goals. The consequence, except perhaps in North America, will be a greater dependence on imported gas, with a tendency for more costly supplies to come from more remote areas. This has implications both for prices and for energy security. In certain regions, longer and larger supply chains, with more transit countries involved, inevitably complicate the process of delivering gas to markets. As to price, there will be increased focus on more cost effective solutions both in production and in transportation but even then there is likely to be some upward pressure. The cost of producing and transporting new gas supplies to the market especially in the case of LNG, may present an obstacle to additional major expansion of the gas market.

The development of more competition in the production, transportation, trade and sale of natural gas would help to ensure the exploration, development and production of gas resources when and where commercially justifiable and would encourage flexibility in the natural gas industry and in gas markets so that adaptation to changing circumstances can take place. The long-term availability, deliverability and security of sources of gas supply will, of course, have to be taken into account. Governments will need to satisfy themselves that adequate steps have been taken by the gas industry (for instance, in diversification of supplies, investment in storage and development of new technologies) to ensure that gas supplies are as reliable as possible. It is projected in the reference case that the share of NIS natural gas in total

gas consumption of OECD Europe will be maintained at current levels. Consequently, the foreign exchange potential from natural gas will most likely exceed the importance of oil for the NIS.

7. Coal and Solid Fuels



Sources of coal and solid fuels are widespread, providing both secure indigenous supplies to those countries with such resources and the opportunity for coal importers to make commercial arrangements with a diversity of suppliers. Over the period since 1973, coal has increased its share of total OECD primary energy consumption from 22 per cent to 25 per cent, mainly due to the substitution of steam coal for fuel oil in electricity generation. In addition, international trade in coal is highly competitive. The prices of internationally traded coal are determined mainly by supply and demand in coal markets rather than by movements in oil prices, as was demonstrated during the Gulf crisis when traded coal prices and volumes were largely unaffected by events. Considerable progress has been made in the last several years in reducing barriers and other distortions, and in restructuring of high-cost coal production heretofore supported by government financial aids. Many barriers to trade nonetheless remain: these need to be further reduced with a view to their elimination, although the social, economic and regional impacts of mine closures require continuing attention.

According to the most recent IEA's Coal Information report, coal demand fell 1.2 per cent in the OECD countries in 1992 compared with 1991. As total primary energy supply grew slightly (0.6 per cent) coal's share of this supply fell slightly to 21.3 per cent. Total electricity generation rose to 7.248 TWh in 1992, a gain of 0.6 per cent over 1991. Coal-fired electricity generation, which accounts to over 70 per cent of coal consumption, was up 0.4 per cent, while generation from natural gas and nuclear power rose 5.5 per cent and 1.1 per cent, respectively. Generation from oil fell 0.5 per cent. World steel output declined by 2.6 per cent in 1992 to 717 Mt.

Conversely, world hard coal production in 1992 is estimated to have increased by less

than 1 per cent over 1991 levels to reach 3.499 Mtce. Production in OECD countries contributed 35 per cent of total world production; about the same level as in 1991. The main developments in 1992 included in the continued decline in production in Central and Eastern Europe, Russia and the Ukraine (down 27 Mtce in 1992), the continued restructuring of the coal industries in the European Union, particularly in Germany and the UK, and the rise in production in several non-OECD countries, mainly in Asia, such as China, India and Indonesia. China remained the world's largest coal producer with an output of 1 095 Mtce in 1992.

About 11.5 per cent of world hard coal production in 1992 was traded on the international market, reaching 403 Mtce, for a gain of less than 1 per cent over 1991. The overall trend masked the diverging developments in seaborne trade and overland trade, however. The overland trade, largely consisting of trade between the United States and Canada, within the European Union and within Central and Eastern Europe, declined, while seaborne trade rose further to 361 Mtce, about 5 Mtce above 1991 levels. Worldwide total steam coal exports, at 235 Mtce, were 12 Mtce higher than in 1991, although seaborne trade rose by 14 Mtce. Australia and South Africa remained the largest exporters, with about 25 per cent and 20 per cent of the total market, respectively. The United States' exports declined. Indonesian steam coal exports more than doubled to reach 13.4 Mtce.

As to the future, adequate low-cost, high quality coal supplies will be available into the next century. It can be recalled that based upon the IEA's Energy Outlook projections, coal and solid fuels' share in total energy requirements is expected to remain fairly constant at about 29 per cent worldwide, and 25 per cent in OECD countries. Coal consumption in the rest of the world is expected to more than double between 1990 and 2010, with an average growth rate of 3.7 per cent per annum. This implies about a 45 per cent increase in worldwide solid fuel demand.

The growth in the developing countries which actually represents a deceleration when compared with the previous twenty years, will be spread unevenly among the various regions. Strongest growth is expected in East and South Asia where coal will play an increasingly important role in power generation as well as maintaining its share of final energy demand. China, the country with the largest hard coal reserves in the world, is expected to continue to expand both its production and consumption of solid fuels (3.0 per cent per annum to the year 2000, and 2.8 per cent thereafter). It is anticipated that in view of the modernisation of the Chinese economy which is assumed to proceed throughout the forecast period, the weight of power station use in total coal consumption will continue to increase. Growth in coal consumption will also be robust in India, where coal will form the mainstay of the electricity

sector as well as an important form of energy for both industry and households.

In the NIS and countries of Central and Eastern Europe, dislocations associated with institutional changes, together with the major contraction of the intra-bloc trade have resulted in a sharp contraction of the national economies and of domestic coal consumption. As with the other sectors of the economy, coal production and use are undergoing major structural changes in order to be competitive in the new economic environment. Both production and consumption of coal in this region are expected to decline over the outlook period. It should be kept in mind, however, that coal for most of the NIS and countries of Central and Eastern Europe represents a major if not the only indigenous energy resource. A fact which is likely to be a mitigating element in the decline of coal use.

OECD total coal production between 1991 and 2000 is forecast to grow at 0.6 per cent per year to approximately 1460 Mtce (870 Mtoe) in 2000. Beyond this, growth is expected at an annual rate of 1.3 per cent to 2010. There are, however, considerable regional differences. Coal production in North America is forecast to grow 1.3 per cent per annum to 2000. In Australia, the level of coking coal production in 2000 is forecast to remain almost unchanged compared to its 1991 level, while steam coal output increases by 43 per cent. A large share of the incremental steam coal production would be exported. These long-term production and export increases will depend to a certain extent on the development of new mines, which actually will only be triggered by adequate price levels. In the European Union, coal production is expected to drop by an annual average of nearly 3 per cent. A general trend toward restructuring of the coal industry is now a common feature of most Western European countries.

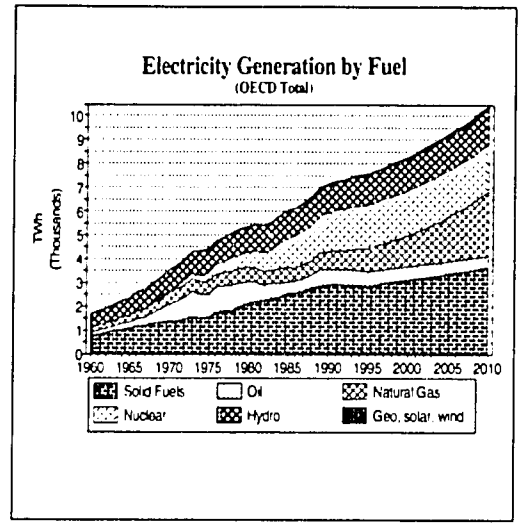
In general, the power generating sector will remain the overwhelmingly predominant market for coal throughout the period. Consumption of solid fuels in power stations in the OECD is forecast to increase by an average of 1.5 per cent per annum to 2010. With the deceleration in the rate of expansion expected for nuclear capacity, coal will remain the major alternative for base load generation. This should be particularly the case once oil and gas prices start rising in real terms with hard coal prices following only very partially. The cost effectiveness of hard coal vis-à-vis hydrocarbon fuels, especially in North America, and its siting flexibility when compared with brown coal or hydro should ensure, environmental standards notwithstanding, hard coal's share of power generation at a high level even after the turn of the century.

Nevertheless, coal and solid fuels are affected by tightening environmental requirements and competition from other fuels. Available technologies are extensively used to control

particulates, SO_2 and NO_x emissions. Coal burning electricity generating plants with additional environmental control facilities are broadly competitive with other baseload plants in many countries, though competition from gas is increasing. Noxious and CO_2 emissions from coal-firing can be reduced by using clean coal technologies that have higher conversion efficiencies and cleaner-burning characteristics. It is the responsibility of coal producers, electric utilities and plant manufacturers to ensure the commercial availability of these technologies.

Governments will need to recognise the economic and energy security advantages of the low-cost, extensive and secure availability of coal together with the variety of high efficiency technologies now available and in prospect for its cleaner use in the light of concerns over possible impacts on climate change. Progress in expanding international co-operation, information exchange, and technology commercialisation and transfer can contribute to raising the efficiency of coal production and use in developing countries and countries in transition to market economy, as well as in IEA countries.

8. Power Generation



Electricity demand in the OECD continues to grow strongly. Its share of total final energy consumption has more than doubled since 1960 and appears bound to increase. Substantial new generating capacity will be required even with significant improvements in end-use and generating efficiency. The environmental debate tends to focus on the electricity sector, a highly visible and easily regulated source of pollutants. In fact, further electrification has the potential to benefit both the environment and economic growth — electricity is a clean source of energy at its point of use and opportunities for mitigating its environmental consequences exist on the supply side as well as through improving the efficiency of fuel consumption, changing the fuel mix, and introducing and strengthening demand side management practices.

Electricity, in its generation, transmission and end-use, is a major area of technology progress. Governments have a special role in ensuring that safety, efficiency and the reduction of pollutant emissions are overriding attributes of new technologies. There are many advantages from electricity interconnection and trade in terms of security of supply and economic efficiency. Governments should encourage their electrical industries to participate with neighbouring utilities, where inter-connectable, to maximise the efficiency of plant utilisation. The move towards a separation of the various elements of the vertically-integrated electric utility industry in some countries is increasing the scope for competition in generation and affecting the fuel mix of the new generating capacity being developed. While the choice of fuel for new generating capacity will be based on local circumstances, well-diversified fuel sources will be required to improve energy security. Governements need to address public opposition to siting new facilities that will otherwise limit the availability of future capacity.

Since electricity can be produced from a variety of fuels, it can also contribute to energy security, so long as fuel switching capabilities are maintained. Electricity is also the only effective way of using such sources of energy as nuclear and some renewable. But due to the limited expansion of power generation from nuclear and hydroelectric sources, and the limited economic viability of other renewable sources, total fossil fuel-based generating capacity in the OECD will grow faster than total capacity (by 1.6 per cent per annum in the 1990s and by 2.7 per cent per annum thereafter). As a result, the share of the fossil fuel capacity will increase from 61.2 per cent in 1990 to 65.5 per cent in 2010. Among the fossil fuel-based capacities, oil capacity is expected to decline slightly in all OECD regions, while coal and gas capacities are expected to increase significantly: gas capacity by 4.9 per cent per annum and coal capacity by 1.3 per cent per annum. In North America and Europe, gas will account for a large share of new base load capacity. In Japan, on the contrary, new coal plants are less expensive than combined cycle gas plants and, thus, coal capacity will increase faster than natural gas capacity.

Electricity demand in the OECD is forecast to rise by 2.2 per cent per annum (versus an average GDP growth rate of 2.4 per cent). An increasing amount of output will come from natural gas, which is forecast to represent almost a quarter of all OECD electricity output by 2010 compared to just over 10 per cent at present. All regions show an increase in the share of electricity generated by natural gas, but it is the most spectacular in Europe. From a share of 6.5 per cent in 1990, natural gas rises to 13.6 per cent of electricity output in 2000 and 23.7 per cent in 2010.

In the developing countries, electricity demand is forecast to grow by 5.5 per cent per annum. The growth in electricity demand will mainly be met by coal, which increases its share

in the output mix from 38.3 per cent in 1990 to 43.9 per cent by 2010, although gas also enjoys and increase in share from 8.9 per cent to 15 per cent. As it has been said, the result of the abundance of coal reserves in some developing countries and of the capital constraints which prevent significant nuclear or hydro expansion, is that growth in the non-OECD electricity demand is inexorably linked to an increase in coal inputs to power generation and all that this entails for carbon emissions.

The future of electricity generation in the NIS and Central and Eastern Europe is even more problematic to predict than it is for oil and natural gas production, primarily because of the uncertainty surrounding the future of nuclear facilities in that region. The outlook for nuclear power in the region reflects on one hand concerns about nuclear safety, the reduced need for power generation brought about by economic restructuring and inadequate availability of funds for investment in large capital projects such as power plants. On the other hand, some Central and Eastern European countries with limited indigenous resources are concerned about a secure supply of electricity. In aggregate, nuclear power is assumed to decrease from around 40 gigawatts of installed capacity at present to just over 30 gigawatts by 1995. Thereafter, some new nuclear plants will be built which gradually increases total installed capacity to more then 40 gigawatts by the end of the outlook period.

Conversely, in the OECD region, nuclear energy will continue to make a substantial contribution to the diversification of energy supplies as it is a proven technology that emits no sulphur dioxide, nitrogen oxides or greenhouse gases in power generation, thereby providing one means of response to the environmental challenges now confronting the planet. However, given the serious public concerns over nuclear safety and waste disposal, nuclear's share is declining. Since 1985, there has been a slowdown in the rate of growth of nuclear capacity. Indeed, as the rate of closures of nuclear stations increases towards the end of the decade, and given the current low rate of addition to nuclear capacity, it is expected that nuclear power's share of total electricity generation may have reached a temporary peak. Some IEA countries intend to continue their nuclear construction programmes because they consider nuclear energy to be an important contributor to energy security and that it can play a significant role in reducing the growth of greenhouse gas emissions. Other countries are not developing nuclear power either because they have ample supplies of other fuels or for what they perceive as its potential adverse health and safety consequences. Also, in some countries the economics of nuclear power have appeared less favourable, compared with other sources such as natural gas. In a number of countries the development of nuclear power is effectively in abeyance as these issues are debated. But, all IEA countries appear to agree on the necessity for continuing to apply the highest available standards of nuclear safety and to co-operate with the appropriate

international organisations. Losing the nuclear option would reduce the diversification opportunities that enhance energy security, and could increase the difficulty of meeting growing electricity demand economically and addressing global climate change.

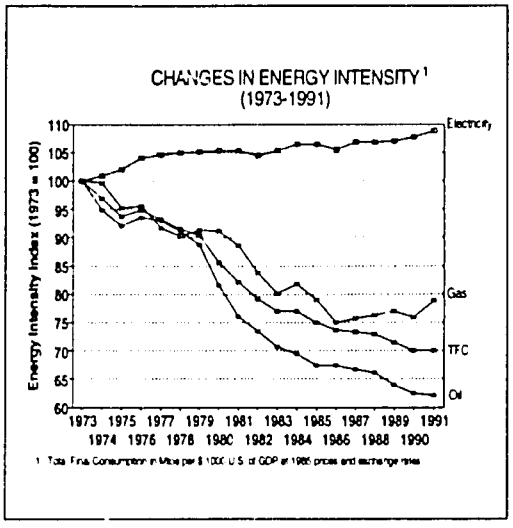
On the other hand, with regard to the amount of energy that renewable energy technologies presently contribute in most of the OECD countries, it is apparent how such an amount is quite small compared to the technical potential of the physical resource base. The limited technology progress, coupled with uncertainties regarding the economic viability of renewable energy resources, market factors and institutional constraints, account for their relatively small contribution. The main renewable source of electricity is hydroelectricity, though little potential remains for the development of hydro in the OECD region. Thus, its share of electric generation in IEA countries is expected to remain at its current level of around 16 per cent. Non-hydroelectric renewable energy resources, in particular biomass, geothermal, wind, and solar energy, are increasing their contribution to the electricity generating mix, albeit slowly and from a low baseline.

But new renewable energy technologies have a long-term economical and market potential. Heightened concern about pollutant emissions and growing recognition that renewable energy can further energy security and promote environmental objectives provide an impetus to efforts to develop, demonstrate and deploy renewable energy technologies. Incorporating such external factors as environmental and energy security concerns into energy system costs might enable renewable energy technologies to display improved economics, and therefore contribute a more significant proportion of their technical potential. Furthermore, because of the technological and economic challenges associated with facilitating the market entry of renewable energy technologies, the pace of application may depend highly on the degree of government support and international co-operative effort given to this strategic area.

9. Energy Intensity and Efficiency

IEA Member countries have improved the energy intensity of total final consumption (i.e. energy consumption per unit of real GDP) by 32 per cent since 1973 through changes in energy efficiency, structural and output changes in the economy, and fuel substitution. An examination of intensity trends by energy type (i.e., oil, natural gas, electricity) shows the change was not uniform among energy sources. Oil intensity improved the most, reflecting the importance that IEA Member countries have placed upon both improvements in end-use efficiency and substitution away from oil. Natural gas intensity also improved but electricity

intensity increased, in part due to the larger share of electricity in total final consumption.

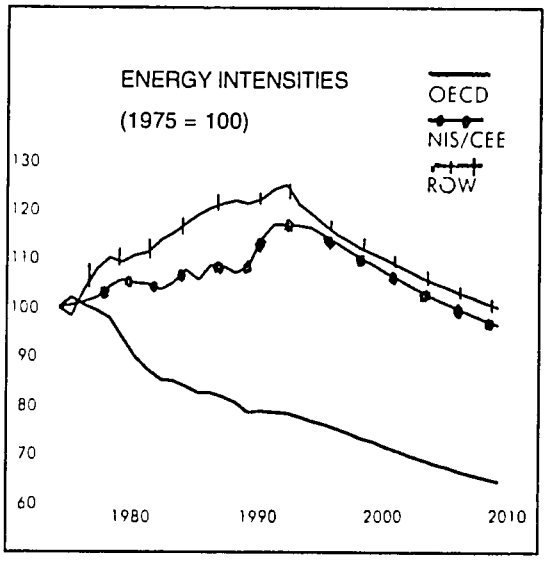


Over the entire 1973-1991 period, the pace of change in energy intensity varied, exhibiting a particularly strong improvement between 1979 and 1983, while in recent years it has been slightly less than the average exhibited over the entire period. In the years to 2010, overall energy intensity is expected to continue to decline at an annual rate of about one per cent. This decline is due to further technological advances, the ongoing move in OECD economies toward less energy intensive sectors, and continued investments in energy efficiency. It also reflects the long-term price effects associated with the 1970s oil price increases through the continued roll over and replacement of old capital stock with newer more energy efficient equipment. The rate of decline in the OECD is expected to be less than the average in the previous twenty years.

The apparent peaking in energy intensities of developing countries in the years 1990-1991 appears to be the result of the recession and not of any shift from the decline in energy intensity which had started in 1988-1989. In the developing countries energy intensity rose by over one per cent per annum from 1971 to 1990. In part, this can be viewed as the result of population and economic pressures which, together with limited financial resources, tend to reduce the flexibility of developing countries to take maximum advantage of improvements in energy production, distribution and consumption technologies. The projections for total energy demand for the rest of the world as a whole imply a decline in energy intensity for the period to 2010 of around one per cent per annum although this estimate disguises some large regional variations. Significant energy intensity improvements are expected to continue in China, at about the same rate as in the recent past. Intensities in East Asia and Latin America are also expected to decline as a result of structural changes and efficiency gains. In the Middle East and South Asia, however, the reverse trend is likely to be evident. In the former, most pressure for higher intensities will come from the industrial sector where continued development of resource based activities, especially petrochemicals, will be important. In the latter, continued development of energy intensive industry will play a major role, as will the development aspirations of a rapidly growing population. There is much scope for energy intensity

improvement in Africa, where energy demand is dominated by South Africa, Nigeria and the principal North African oil exporters. The ending of South African isolation will play a significant role in increasing access to newer technologies. Elsewhere, movement towards market-based economies should lead to increased price induced conservation, although overall improvement in energy intensity in the region will be relatively slow. The net result according to this view is a decline in world energy intensity.

Interest in energy efficiency has been rekindled in Member countries in recent years. Improving energy efficiency has appeared increasingly to be a promising strategy for achieving simultaneously the goals of energy security, environmental protection and economic growth. Most IEA countries that have declared targets for greenhouse gas emissions, have placed great reliance on accelerated gains in energy efficiency to generate the required emissions reductions, especially of carbon dioxide.



While there is a large technical potential for increased energy efficiency, there exist significant barriers to its achievement. Reliance on market forces alone is unlikely to achieve the necessary level of efficiency improvement implicit in most environment-oriented energy policies.

Some Member countries have therefore strengthened their energy efficiency programmes. For example, financial incentives have been introduced or revived in certain countries. Energy consumption standards have been revised and extended both geographically and by category. Included are minimum performance standards on appliances, such as refrigerators, washing machines, lighting systems and motors, and on buildings, including homes, offices, commercial enterprises and factories. Voluntary agreements between government and industries have been established. More attention has been given to consumer information activities. In the electric utility industry, demand-side management programmes have been more widely pursued.

While these policies are encouraging, much more attention to technology progress and energy efficiency incentives are needed. Analysis to date has identified transport and electricity as the energy consuming sectors perhaps requiring the greatest policy attention, partly because

of their dominance as sources of emissions, but also importantly, because they are the sectors with the highest current and projected rates of growth. Increased emphasis should be given to promoting cost-effective energy efficiency investments in the building sector. Governments may wish to ensure that reliable statistics are available on energy end-use, the costs of new technologies and the actual energy efficiency potential they offer. Such market information is an essential prerequisite to evaluating of efficiency programmes and to developing policies to accelerate energy efficiency improvement in the economy. Moreover, efforts are needed to share policy experience and approaches with developing countries and countries in transition to a market economy.

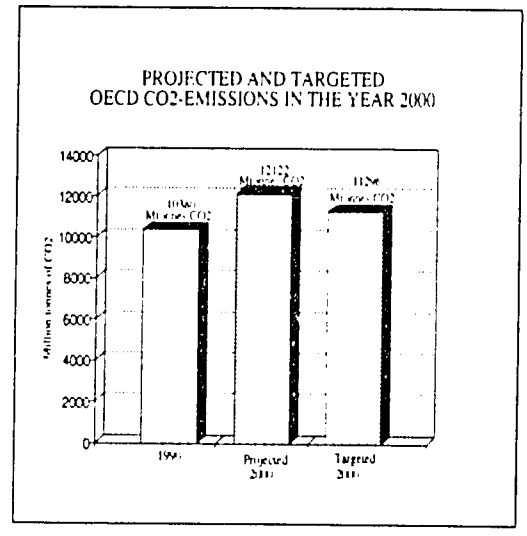
10. Energy and Environment

A broad range of environmental concerns exists among countries, most of these concerns have clear energy implications. Developing countries are troubled about clean water and air and adequate waste disposal. The NIS and countries of Central and Eastern Europe focus on environmental legacies and inefficient, obsolete infrastructure. In non-OECD countries, the problems are more those of having adequate funds and of building the capacity to take the needed corrective or preventive actions.

These preoccupations, in the context of the intense competition for scarce financial resources, are vastly different from those animating environment policy in OECD countries (e.g., acid rain, climate change and ozone depletion, which of course will affect all countries). Technological and management solutions exist for preventing or mitigating the "conventional" environmental effects from the energy sector, such as SO_2 and NO_x emissions. These will remain important areas for action. For OECD countries the issues are finding the most effective and economically efficient means by which to proceed and the ranking and timing of the needed actions. There are often direct links between the environmental concerns, the adequacy or type of energy supply, and the inefficiency of energy use.

It is the issue of climate change, however, that is the focal point of continuing international debate. With a view to the continuing globalisation of the world's economies, the United Nations Conference on Environment and Development (UNCED) in Rio de Janeiro on 3rd-14th June 1992 underscored the necessity of linking economic growth and the environment as part of global sustainable development and energy's key role in that pursuit. The Framework Convention on Climate Change signed by most countries of the world at UNCED poses the biggest challenges for energy policy makers. OECD countries and countries in transition to a

market economy have assumed obligations under the Framework Convention on Climate Change to "adopt national policies and take corresponding measures... to modify longer-term trends in anthropogenic emissions" of greenhouse gases. Most OECD countries have not yet fully identified the set of measures which would enable them to reach their goals. In preparing and implementing response strategies, countries will want to choose the best combination of policies and measures available to them, drawing upon a mix of the instruments. These include: information, regulation and voluntary agreements as well as economic instruments (taxes, charges and subsidies). In addition to signing the Convention, several OECD countries have made other climate-related policy commitments, mainly adopting greenhouse gas (GHG) emissions stabilisation or reduction targets, developing national emissions inventories, implementing national programmes to mitigate climate change and communicating progress on these actions.



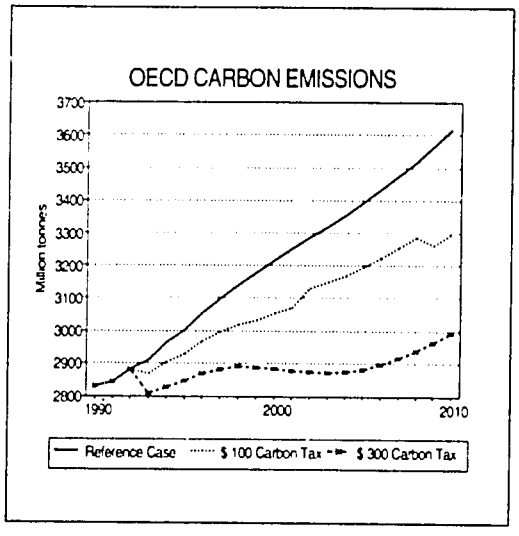
The international discussion of climate change policy instruments, notably carbon and energy taxes, and of their economic effects is intensifying. While some IEA countries have adopted carbon taxes, most OECD countries are reluctant to introduce carbon taxes unilaterally because of the uncertainty about their effects, such as those on international trade competitiveness. On their side, many non-OECD countries, especially the fossil fuel exporters, are concerned about the possible distributional effects on their economies. Others argue that such taxes could result in barriers to trade in energy and energy-efficient technologies and result in investment distortions.

Economic analyses on the potential effects of carbon taxes yield important conclusions bearing directly on policy making. They generally agree that it would take substantially different levels of tax between regions and countries to meet, in each IEA country separately, any international goal of stabilisation of CO_2 and other GHG emissions. To continue to be effective in keeping emissions stabilised, these taxes would have to be increased. The figure compares emission growth rates under the imposition of a $ 100 carbon tax by 2010 and under a $ 300 tax per tonne of carbon emitted. In both cases, nearly a third of the tax is assumed to be imposed in 1993 with the remainder added in increments. These are in addition to any other

excise or other taxes currently in place. A $ 100 per tonne carbon tax corresponds to almost $ 12 per barrel for oil equivalent. It can be seen from the graph that emissions in 2010 under the $ 100 tax fall to 3300 million tonnes compared to 3620 million tonnes in the reference case. This is still well above the 1990 level of 2830 million tonnes per year. Under a tax of $ 300 per tonne of carbon (applied in the same pattern as the $ 100 tax), emissions decline to 2990 million tonnes, somewhat above the 1990 level. The most important reson for this apparent insensitivity of emissions to high levels of carbon taxes is the relatively modest impact of the taxes on the prices that energy consumers pay.

In order to emphasize the potential for divergence from the reference case, an efficiency driven scenario has also been constructed by the IEA Secretariat. Under this scenario, commercially available and environmentally-friendly technologies are implemented to a much greater extent than in the reference case, where the rate of take-up to technology is based on historical trends. In this scenario, by 2010 emissions in Europe and North America are nearly stabilised at 1990 levels by 2010 while in OECD Pacific some growth in emissions still occurs.

Beyond these analyses however, different models yield vastly different outcomes. For example, wide ranges result for estimates of projected CO_2 emissions from region to region. Also, GDP losses associated with sizeable cuts in CO_2 emissions vary among models.



All projections show that actions taken which would stabilise GHG emissions in OECD countries would have little effect on the level of world emissions - mainly because of the very strong economic growth and resulting increase in emissions taking place in countries outside the OECD where there is as yet no comparable serious intent to stabilise or reduce emissions. It is the recognition of this, and the fact that some of the most costly emissions reduction options are in the industrialised countries, which leads policy-makers to solutions which engage both OECD and non-OECD countries in an effective, least-cost way.

Along this approach three steps can be as in the following. First, the topic of energy

subsidies is getting more attention as governments seek policies with the least costs. It appears that eliminating certain energy subsidies (for instance, those keeping energy costs below costs of production) would result in a significant reduction in emissions and yield net economic benefits, especially outside the OECD region, where the largest subsidies exist. The economic inefficiency of providing environmental financing to countries with large energy subsidies seems evident.

As a second step, technological progress should be accelerated to prepare less carbon-intensive options. The need continues for greater understanding of the energy market effects of policies and of their impact on particular sectors. The transport and electricity sectors in particular, appear as requiring special attention. Third, whatever sets of policies are chosen by countries as part of an international response to global environmental commitments, industry's involvement will be essential. Compensation mechanisms could be designed whereby emissions reductions credits resulting from foreign industry investments can be transferred. This could help achieve joint implementation with developing countries and countries in transition to a market economy, where often the lowest cost options are to be found.

11. Energy Research and Technology

The needs for new and efficient energy technology occur against the background of the expected change in the energy market as well as environmental concerns. Decision makers and industry in Member country governments have their own priorities for energy technology development and deployment which reflect specific national circumstances. However, collectively across the IEA Member countries, the strategic focus for the next ten to twenty years may rest on technology directions that include: more efficient energy end-use and environmentally conscious equipment and processes; demand-side management; advanced technologies for clean coal supply and use; improved natural gas transportability and conversion; enhanced hydrocarbon exploitation; environmental protection in the oil chain; extensive use of new and renewable energy sources and their integration into the conventional energy systems; feasibility demonstration of advanced nuclear and fusion systems; optimal resource use in electricity production; "clean car" technologies and alternative transport fuels; and mitigation of emissions of greenhouse gases and their disposal.

Since energy R&D generally is an evolutionary and not a revolutionary process, spectacular breakthroughs cannot be anticipated. R&D and the necessary demonstration and commercial implementation of new solutions take time. There are also major long-term

technology advancements which cannot be justified for private sector investment because of the time involved, the high capital and manpower requirements, and the uncertain outcome. Examples comprehend several renewable energy technologies, hydrogen fuels and nuclear fusion power. Conversely, potentially important and promising energy technology advancements do not attract private sector initiative because of uncertainties and barriers to the eventual market deployment. A critical issue is the respective roles of the private sector and governments in fostering R&D and applying the resulting new and improved energy technologies. The appropriate roles will change during the course of the technology R&D and commercialisation cycle. Governments should continue their policies of providing support for energy R&D until it becomes feasible to transfer the activities to the private sector for final demonstration and implementation. In addition, governments should actively pursue their efforts to identify and remove barriers to technology adoption.

The perception that national energy R&D is the only means for developing new and improved energy technology is diminishing with the growing costs of the programmes and the increasing world wide basis for business activities and technological innovation. While IEA Member countries and their energy industries compete in the short-term perspective, they may prefer to co-operate through integrated multilateral programmes with a view to responding to the global energy security and environmental issues. Intensified international collaboration will provide a means to accelerate progress in developing new and improved technologies by sharing limited financial and human resources, and broadening the prospects of market deployment in all countries.

It should be repeated that energy technology advancement is critical to achieving Member countries' objectives of energy security, while protecting the environment and ensuring sustainable development. The development and effective deployment of advanced technologies, as well as improvements to existing technologies, have the potential to significantly reduce and alter future energy requirements in all countries and thus help achieve these broader objectives. Thus IEA countires are called on to reinforce the existing technology co-operation initiatives, establish appropriate new collaborative agreements on critical energy technologies, and prepare flexible and effective mechanisms for joint international R&D work. An important element of the collaboration activities will continue to be the establishment and maintenance of mechanisms and facilities to identify, compile and disseminate technical, economic and environmental information on current and emerging technology options. To achieve this purpose, since its origin the IEA has created a legal mechanism for the collaborative energy technology projects and programmes it sponsors. These projects and programmes are set up under international Implementing Agreements and adjusted to suit the requirements of the individual participants.

Implementing Agreements set down the commitments of the contracting parties and establish a management structure. The Implementing Agreements contain provisions concerning the handling and protection of information and intellectual property rights and they keep records on special arrangements for the commercial exploitation and distribution of the benefits to participants.

12. Co-operation with Non-Member Countries

The expanding interdependences in the global energy system suggest that IEA Member country interests can also be pursued through improved contacts and co-operation with selected non-Member countries to help them plan and develop efficient and environmentally sound energy supply and end-use systems.

The importance of non-Member countries has grown significantly over the past years as their energy activities more and more affected IEA Members' own interests. Four major developments seem to illustrate this. First, non-IEA Member countries are playing and will play an increasingly important role in determining global energy demand. Second, a greater portion of global energy-related environmental problems will be concentrated in the non-Member regions, as incremental energy demand growth there continues to outpace that in IEA countries. Third, in a number of key areas, IEA energy supplies are more frequently sourced in non-Member countries, and Member countries' energy logistical systems are increasingly tied to them. And fourth, more and more non-Member countries are reaching a stage of development or transition where their energy policy concerns are leading them to seek various forms of relations with the IEA, including in some cases eventual full IEA membership.

Thus, the IEA is substantially engaged in co-operating with non-Member countries to help them develop energy strategies and adopt energy policies that will enhance IEA Member countries' energy security and environmental objectives, as well as those of the non-IEA region. IEA Member countries'energy policy advice may provide users in the non-IEA region with a better understanding of the potential benefits of the technology options, as well as possible investment regimes and institutions that can encourage and efficiently manage structural adjustment, and facilitate the energy technology adoption and absorption process.

In designing a broad programme and expanded contacts, the IEA has focused on several instruments for co-operation: country surveys to analyse the energy situation and to provide policy recommendations; conferences and seminars designed to address specific energy issues

relevant to non-Member regions; and focused studies or special missions. Other instruments for co-operation include expanded statistical exchange and collaboration in the area of energy technology. A significant element in this dialogue with non-Member countries is the mechanism for participation in international energy R&D collaboration and technology information dissemination. The IEA has created an "associate contracting party" status in the Implementing Agreements which represents an innovation and an opportunity for mutual sharing of experiences and know-how.

But in its relations with non-Member countries, the IEA will continue to maintain a balanced and selective approach, tailoring relations with individual non-Member countries to the prevailing circumstances and ensuring that such contacts further IEA objectives. The most important criterion in deciding upon such relationships is that the non-Member country be a major producer or consumer of energy, whose actions are likely to bear directly upon IEA Members' own energy security interests and environmental concerns. At the same time, there will always be special circumstances; for example, regional energy security or transboundary environmental concerns related to the NIS and Central and Eastern European countries, which have already elicited IEA involvement.

Within this context, the Asia-Pacific region has the potential for significantly increased energy co-operation. The IEA's efforts to assist non-Member countries with their energy and environmental policies must recognise the differences among countries' states of development and policy priorities. IEA Members' experiences with similar issues can be highly relevant. The Republic of Korea has approached the IEA and requested closer association with a view to seeking OECD and IEA membership towards the mid 1990s. In response, the Agency is developing a number of co-operative activities with Korea. The IEA has also expanded it contacts with the Dynamic Asian Economies as they more closer to the OECD world, as well as with the large Asian energy producing and consuming countries and with the Russian Federation. Furthermore, the IEA has increased its contacts with Latin America, which shows signs of fundamental transformation and revival of its economies including a clear trend towards a more market-oriented energy sector. The challenge for energy policy makers will be to respond to aspirations for sustainable economic growth, energy security and environmental protection. Technology advancement and co-operation may represent the most appropriate and effective instrument.

Coal and Lignite: The Needs and Concerns of Developing and Industrialising Nations

C. Ji. Under-Secretary General, United Nations, New York

ON BEHALF OF UNDER-SECRETARY-GENERAL JI CHAOZHU, WHO REGRETS THAT HE IS UNABLE TO ATTEND THIS MOST IMPORTANT CONFERENCE, I WELCOME ALL THE PARTICIPANTS AND EXTEND HIS SINCERE GOOD WISHES FOR YOUR SUCCESS. SINCE YOUR AGENDA IS DIRECTLY RELATED TO THE TECHNICAL ASSISTANCE OBJECTIVES OF THE UNITED NATIONS, MR. JI HAS ASKED ME TO READ A BRIEF STATEMENT ON HIS BEHALF.

THIS WEEK WE ARE CONVENED TO DISCUSS TECHNOLOGIES FOR THE SAFE, CLEAN AND ECONOMICAL USE OF COAL. COAL IS, OF COURSE, AN ABUNDANT SOURCE OF ENERGY, AND ONE THAT HAS SERVED MANKIND'S NEEDS THROUGHOUT RECORDED TIME. IT SUPPLIES SOME 30 PERCENT OF GLOBAL ENERGY AND ITS SHARE IS LIKELY TO INCREASE SIGNIFICANTLY WORLDWIDE, PARTICULARLY IN DEVELOPING COUNTRIES. CHINA AND INDIA WILL CONTINUE TO BE MAJOR COAL CONSUMERS, AND OTHER ASIAN COUNTRIES ARE ALSO INCREASING THEIR COAL PRODUCTION. IN AFRICA AND LATIN AMERICA, NEW COAL PRODUCERS ARE APPEARING, INCLUDING TANZANIA, EGYPT, AND COSTA RICA, AND EVEN IN THE OIL-RICH ARAB WORLD. AND FINALLY, THE COUNTRIES OF EASTERN EUROPE, WHICH HAVE TRADITIONALLY RELIED ON COAL, WILL BY NECESSITY CONTINUE TO BE MAJOR COAL CONSUMERS IN THE NEAR FUTURE, EVEN IN THE FACE OF THE CURRENT ECONOMIC SLOWDOWN AND OFFICIAL ENERGY POLICIES EMPHASIZING THE SHIFT AWAY FROM COAL.

NOWHERE IS THIS MORE EVIDENT THAN IN THE USE OF COAL AS SOURCE OF ELECTRICITY GENERATION. GLOBAL DEMAND FOR ELECTRICITY SERVICES WILL CONTINUE TO INCREASE, SUBJECT ONLY TO CONSTRAINTS ON ECONOMIC GROWTH, AND THAT WILL COMPETE STRONGLY WITH OTHER ENERGY SOURCES

IN MANY COUNTRIES. FIFTEEN YEARS FROM NOW, SIX OF EVERY TEN KILOWATTS OF ELECTRICITY PRODUCED WILL BE GENERATED BY COAL.

THESE PROJECTIONS SHOULD GIVE US ALL PAUSE FOR REFLECTION. THE ENVIRONMENTAL DEVASTATION PRODUCED BY STRIP MINING OF MINERALS ALONE IS ENORMOUS, EXCEEDING IN QUANTITY AND INTENSITY ALL OTHER FORMS OF MAN-MADE LAND DESTRUCTION". WORLD-WIDE, THE ANNUAL MOVEMENT OF SOIL AND ROCK RESULTING FROM MINERAL EXTRACTION MAY BE AS HIGH AS 3000 BILLION TONS, COMPARED WITH APPROXIMATELY 24 BILLION TONS OF SEDIMENT CARRIED INTO THE OCEANS BY THE WORLD'S RIVERS, INCLUDING THE NILE, THE MISSISSIPPI, THE AMAZON AND THE YELLOW RIVER. COAL ALONE ACCOUNTS FOR MORE THAN 5 BILLION TONS ANNUALLY, ENOUGH TO COVER ALL OF HONG KONG'S 403 SQUARE MILES UNDER A PILE TEN FEET HIGH.

EVEN BASIC ENVIRONMENTAL CONTROLS, SUCH AS PHYSICAL COAL CLEANING TO REMOVE ASH AND SULFUR, CARRY THEIR OWN ENVIRONMENTAL PRICE TAG. THE QUANTITY OF POLLUTANTS DISCHARGED TO A STREAM FROM CLEANING A TON OF COAL WILL BE ABOUT THE SAME AS THE QUANTITY FROM MINING A TON OF COAL. ACCORDING TO ONE ESTIMATE, APPROXIMATELY 2,000 GALLONS OF WATER IS NEEDED TO WASH ONE TON OF COAL. IN A WORLD WHERE WATER QUALITY AND QUANTITY THEMSELVES ARE BECOMING MORE PROBLEMATICAL, WE MUST NOT LOSE SIGHT OF THE NEED FOR SOLUTIONS THAT CONSIDER TOTAL HUMAN AND ENVIRONMENTAL COSTS.

IN THE PAST, COAL DEVELOPMENT WAS CONSTRAINED PRIMARILY BY COMPETITION FROM OTHER FOSSIL FUELS AND THE HUGE CAPITAL REQUIREMENT FOR THE BASIC INFRASTRUCTURE. TODAY, HOWEVER, COAL IS

ALSO CRITICIZED AS A MAJOR SOURCE OF ENVIRONMENTAL DEGRADATION AT THE LOCAL, REGIONAL AND GLOBAL LEVEL. AT THE SAME TIME, ALONG WITH THE INCREASED UNDERSTANDING OF THE ADVERSE IMPACTS OF COAL COMBUSTION, A GREATER UNDERSTANDING HAS DEVELOPED ABOUT HOW THIS CRITICAL ENERGY SOURCE CAN BE EMPLOYED IN AN ENVIRONMENTALLY SOUND MANNER. SPURRED BY THE CURRENT CONCERN OVER POTENTIAL GLOBAL WARMING, IT IS INCREASINGLY URGENT THAT THESE ADVANCED TECHNOLOGIES, THE "CLEAN COAL TECHNOLOGIES", MUST BE DEVELOPED TO PROMOTE THE CLEAN USE OF COAL.

CLEAN COAL TECHNOLOGIES: THE UN PERSPECTIVE

THE CONCEPT OF *CLEAN COAL TECHNOLOGIES* IS OFTEN INVOKED TO INCLUDE THE VARIETY OF METHODS FOR REDUCING THE EMISSIONS OF SULPHUR DIOXIDE, OXIDES OF NITROGEN AND PARTICULATES FROM POWER PLANTS FUELED WITH COAL, OR METHODS WHICH REDUCE THE AMOUNT OF THESE POLLUTANTS THAT ARE GENERATED DURING COMBUSTION.

THE UNITED NATIONS APPROACH, WHICH IS MORE BROAD-BASED, CONSIDERS CLEAN COAL-BASED TECHNOLOGIES AS COMPRISING ALL TECHNOLOGICAL INNOVATIONS WHICH REDUCE ENVIRONMENTAL IMPACTS THROUGHOUT THE COAL FUEL CYCLE. THE UN FRAMEWORK THUS INCLUDES MINING AND TRANSPORTATION ACTIVITIES, IN ADDITION TO PRE-COMBUSTION, COMBUSTION, CONVERSION AND POST-COMBUSTION TECHNOLOGIES.

UN STRATEGIES IN CLEAN COAL TECHNOLOGIES

IN THE 1970S AND 1980S, UN TECHNICAL COOPERATION PROJECTS FOCUSED ON EXPLORATION FOR NEW RESERVES IN HITHERTO UNEXPLORED AREAS AND

IMPROVING PRODUCTION EFFICIENCIES IN COAL PRODUCING COUNTRIES. THE PROGRAMME EXPERIENCED CONSTRAINTS DUE TO TOTAL NEGLECT BY FINANCIAL INSTITUTIONS AND GOVERNMENTS IN MANY DEVELOPING COUNTRIES IN THE COAL SECTOR. THE TWO OIL SHOCKS HAD SOMEWHAT FACILITATED PROMOTION OF COAL DEVELOPMENT IN THE LATE 1980S. THE TWO MAJOR COAL PRODUCERS IN ASIA, CHINA AND INDIA, BEGAN TO TURN TO THE UNITED NATIONS TO REQUEST TECHNICAL ASSISTANCE IN THEIR COAL MINING OPERATIONS, WITH INCREASING EMPHASIS ON ENVIRONMENTAL CONCERNS. PROGRAMMES HAVE ALSO BEEN ESTABLISHED IN PERU, MONGOLIA, ROMANIA AND YUGOSLAVIA. ADVISORY MISSIONS WERE DISPATCHED TO INDONESIA, THAILAND, NORTH KOREA, VIETNAM, TANZANIA, COSTA RICA, MEXICO, EGYPT, OMAN, COLOMBIA, ECUADOR AND ZAIRE. WE FORESEE A RAPIDLY EXPANDING TECHNICAL COOPERATION PROGRAMME IN THESE COUNTRIES IN THE NEAR FUTURE. WITH STRONG EMPHASIS OF MULTILATERAL FUNDING AGENCIES ON ENVIRONMENTAL ISSUES, THE THRUST OF THESE PROGRAMMES WILL MOST LIKELY BE ON ENVIRONMENTAL ASSESSMENT, CONTROL AND MANAGEMENT.

THE 1991 **STOCKHOLM INITIATIVE ON ENERGY, ENVIRONMENT AND SUSTAINABLE DEVELOPMENT** CONSULTATIVE MEETING, OR "SEED", JOINTLY ORGANIZED BY THE UN AND THE GOVERNMENT OF SWEDEN, SENT A UNANIMOUS MESSAGE TO THE PREPARATORY COMMITTEE OF UNCED THAT INCLUDED IMPLEMENTING COST--EFFECTIVE AND ENVIRONMENTALLY SOUND SUPPLY-SIDE ENERGY EFFICIENCY MEASURES TO IMPROVE SUPPLY RELIABILITY AND HELP EASE ENVIRONMENTAL IMPACTS OF ENERGY USE. AT PRESENT, IMPROVING ENERGY EFFICIENCY IS THE MOST ECONOMICALLY PRACTICAL SHORT-TERM SOLUTION TO THE CARBON DIOXIDE EMISSIONS PROBLEM. NEW

TECHNOLOGICAL BREAKTHROUGHS ARE STILL NEEDED THAT SUBSTITUTE OTHER SOURCES OF ENERGY FOR FOSSIL FUELS. HOWEVER, THE REDUCTION OF SULFUR OXIDES, NITROGEN OXIDES AND OTHER POLLUTANTS CAN BE ACHIEVED THROUGH ACCELERATED RESEARCH AND ADOPTION OF CLEAN COAL TECHNOLOGIES, AS WELL AS THROUGH PROPER POLICY INITIATIVES BY GOVERNMENTS.

AGENDA 21, FOSTERED BY THE 1992 EARTH SUMMIT CONFERENCE IN RIO, HAS FOCUSED ON THESE INITIATIVES BY RECOGNIZING THE NEED TO COORDINATE ENERGY DEVELOPMENT WITH SOCIAL AND ECONOMIC DEVELOPMENT IN AN INTEGRATED MANNER. IN PURSUING THESE GOALS, AGENDA 21 EMPHASIZES THE NEED TO TAKE INTO FULL ACCOUNT THE NEEDS OF DEVELOPING COUNTRIES FOR THE ACHIEVEMENT OF SUSTAINED ECONOMIC GROWTH AND THE ERADICATION OF POVERTY. I WOULD LIKE TO PRESENT A FEW OF THESE CONCERNS TO GUIDE OUR DISCUSSION THIS WEEK.

AGENDA 21 STATES THAT ACTIVITIES TO PROMOTE SUSTAINABLE ENERGY DEVELOPMENT SHOULD GIVE "*SPECIAL ATTENTION TO THE REHABILITATION AND MODERNIZATION OF POWER SYSTEMS, WITH PARTICULAR ATTENTION TO DEVELOPING COUNTRIES*". IN MANY CASES, EMPHASIS ON MAINTENANCE AND REHABILITATION OF EXISTING FACILITIES OVER NEW EXPANSION, IN CONJUNCTION WITH INCREASED ENERGY EFFICIENCY FOR EXISTING PLANTS, IS NOT ONLY SOUND, SAFE AND ECONOMICALLY BENEFICIAL, BUT ALSO ENCOURAGES INTERNATIONAL COOPERATION. PROPONENTS OF CLEAN COAL TECHNOLOGIES MUST BE CAREFUL TO BALANCE THE BENEFITS OF UPGRADING THE OLD AGAINST BUILDING THE NEW.

KEEP IN MIND THAT THE CONCEPT OF CLEAN COAL TECHNOLOGIES GOES FAR BEYOND THE CAPITAL, HARDWARE AND SOFTWARE TO CONSTRUCT AND IMPLEMENT A PROTOTYPE OR "DEMONSTRATION" FACILITY. TRUE TECHNOLOGY TRANSFER ALSO REQUIRES AN UNDERSTANDING OF THE INSTITUTIONAL MILIEU, AS WELL AS PHYSICAL ASPECTS, OF PROJECTS IN THE DEVELOPING COUNTRY. IN THIS SENSE, TECHNOLOGY IS NOT JUST HARDWARE AND SOFTWARE, BUT ALSO THE SUPPORTING INSTITUTIONAL ARRANGEMENTS AND INCENTIVE STRUCTURES. INCLUDED IN THIS IS LONG-TERM CAPACITY-BUILDING THROUGH TRAINING OF TECHNICAL AND MANAGERIAL STAFF. ANY SO-CALLED "TRANSFER" THAT DOES NOT SERIOUSLY ADDRESS THESE CONCERNS IS DOOMED TO FAILURE, AND, IN ADDITION, REPRESENTS A PROFLIGATE WASTE OF SCARCE RESOURCES.

AS YOU WELL KNOW, THE UTILITY INDUSTRY IS SEEN AS VERY CONSERVATIVE, IN BOTH DEVELOPING AND INDUSTRIALIZED COUNTRIES. AS A RESULT, "NEW" TECHNOLOGIES HAVE HAD TO ESTABLISH A PROVEN TRACK RECORD BEFORE THEY WILL ATTRACT INVESTORS. TO A GREAT EXTENT, THIS IS AN ISSUE OF PERCEIVED RISK, AND ASSURANCE MUST BE GIVEN THAT THE NEW TECHNOLOGIES WILL WORK EVERYWHERE. ONE SOLUTION IS FOR DEVELOPERS OR VENDORS TO FULLY PROVE THE TECHNOLOGY IN A DEVELOPED COUNTRY FIRST, AND TO LENGTHEN THE "MIGRATION TIME" TO THE RECIPIENT COUNTRIES. FOR THE PRIVATE SECTOR, IT IS CHEAPER AND LESS RISKY TO PROVE THE TECHNOLOGY AT HOME FIRST. IN THE LONG RUN, NOBODY BENEFITS FROM THE FAILURE OF EXPENSIVE "DEMONSTRATION" PROGRAMMES.

THE ABILITY TO ATTRACT FOREIGN EXCHANGE OR JOINT-VENTURE INVESTMENT PARTNERS IS CRITICAL TO THE IMPLEMENTATION OF CLEAN COAL TECHNOLOGIES. YET MANY COUNTRIES FACE THE PROBLEMS OF MISSING OR

OUTMODED INFRASTRUCTURE; THIS IS PARTICULARLY TRUE IN MANY ECONOMIES IN TRANSITION. WITHOUT THE ACCOMPANYING INSTITUTIONAL CHANGES, THE NEEDED FOREIGN INVESTMENT WILL NOT BE FORTHCOMING.

THIS SAME INVESTOR COMMUNITY IS INCREASINGLY INCORPORATING ENVIRONMENTAL GUIDELINES IN PROJECT EVALUATION; COMPLIANCE WITH EXISTING REGULATIONS IN THE COUNTRY IS A BASIC REQUIREMENT. IN ADDITION, THE INVESTOR-PARTNER TEAM CAN DRAW UPON INFORMATION AND NEW TECHNOLOGIES THAT PROMOTE ENERGY EFFICIENCY, WHICH OFTEN IS ACCOMPANIED BY REDUCED ENVIRONMENTAL IMPACT. SINCE THE ENERGY EFFICIENCY CONVERTS TO AN ECONOMIC INCENTIVE FOR THE OWNER-OPERATOR, ALL PARTIES CAN BENEFIT. A KEY GOAL FOR THE UNITED NATIONS, AS WELL OTHER MULTILATERAL AND BILATERAL ORGANIZATIONS, IS TO FOSTER THE PARTICIPATION OF THE PRIVATE SECTOR.

WHAT HAS THE RESPONSE BEEN TO AGENDA 21 SINCE THE EARTH SUMMIT CONFERENCE? UNFORTUNATELY, AT LEAST IN THE ELECTRICAL POWER SECTOR OF DEVELOPING COUNTRIES, THE ANSWER IS "VERY LITTLE". IN PART, THIS RESULTS FROM IMMEDIATE NEEDS SUCH AS POTABLE WATER AND PUBLIC HEALTH, OF DEMONSTRABLE BENEFIT AT THE NATIONAL LEVEL, THAT COMPETE WITH EQUALLY COSTLY BUT MORE DIFFUSE ENVIRONMENTAL OBJECTIVES, IN COMBINATION WITH RESOURCE LIMITATIONS FOR GOVERNMENT. WE MUST ASSIST THESE COUNTRIES IN UNDERSTANDING AND EVALUATING THE TRADEOFFS BETWEEN SHORT-TERM COSTS AND LONG-TERM BENEFITS. OTHERWISE THEY WILL FACE THE DILEMMA POINTED OUT, IN THE WORDS OF A USA TELEVISION COMMERCIAL, THAT "THERE IS NEVER ENOUGH TIME TO DO IT RIGHT....BUT THERE IS ALWAYS ENOUGH TIME TO DO IT OVER AGAIN".

OF COURSE, UNDERSCORING ALL PLANNING FOR CLEAN COAL TECHNOLOGIES IS THE PROBLEM IS UNCERTAINTY. UNCERTAINTY OVER FUEL PRICES. UNCERTAINTY OVER THE RELIABILITY AND AVAILABILITY OF NEW ELECTRICAL CAPACITY. UNCERTAINTY OVER ENERGY DEMAND PROJECTIONS. AND, UNCERTAINTY OVER POTENTIAL INTERNATIONAL ENVIRONMENTAL REQUIREMENTS FOSTERED BY CONCERN OVER THE PROSPECT OF GLOBAL WARMING. FOR EXAMPLE, MANY OBSERVERS ARE PREDICTING SOME FORM OF CARBON TAX TO FOLLOW ON THE HEELS OF AGENDA 21. THIS WILL HAVE CONSIDERABLE IMPACT ON, AND CREATE MORE UNCERTAINTY FOR, THE PLANNING PROCESS FOR ELECTRICAL POWER SYSTEMS. UTILITIES IN DEVELOPING COUNTRIES ARE LOOKING FOR INFORMATION TO GIVE THEM SUFFICIENT LEAD TIME FOR EXPANSION PLANNING, INCLUDING THE ADOPTION OF CLEAN COAL TECHNOLOGIES.

IF ENVIRONMENT IS THE KEY QUESTION OF THE 90S, THEN INFORMATION IS KEY TO THE ANSWER. WHETHER IT INVOLVES TECHNOLOGY TRANSFER, FINANCIAL AND INVESTMENT ISSUES, OR ENVIRONMENTAL QUALITY, THE INTERCHANGE OF IDEAS, THE SHARING OF EXPERIENCES, AND THE IDENTIFICATION OF STATE-OF-THE-ART METHODOLOGIES FOR CLEAN COAL TECHNOLOGIES, ALL CONTRIBUTE TO THE KNOWLEDGE BASE AND CAPACITY-BUILDING PROCESS. I ENCOURAGE YOU TO BEND YOUR EVERY EFFORT TO EXPAND THE KNOWLEDGE FRONTIER, AND TO KEEP THE VISION OF AGENDA 21 CLEARLY BEFORE YOU. IN A WORLD INCREASINGLY BESET WITH CONCERNS OVER GLOBAL WARMING, LIMITED FINANCIAL RESOURCES, AND RISING ECONOMIC EXPECTATIONS OF THE DEVELOPING WORLD, WE CAN AFFORD TO DO NO LESS.

ENERGY FOR TOMORROW'S WORLD

by
Ian Lindsay
Secretary General, World Energy Council

1. ORIGIN

The WEC Commission "Energy for Tomorrow's World - the realities, the real options and the agenda for achievement" was launched at the 1989 14th Congress in Montreal in order to represent the global energy sector, its probable development over the next 30 years and above all to demonstrate what the sector can and cannot achieve in the interdependent context of the sustainable development of the economy, energy, and environment. The emphasis of the report is on the "realities" of the energy world over the next 30 years. We have above all avoided producing another computer driven demand/supply exercise by extrapolation. the world has had enough of those in recent times.

The Commission was launched primarily for three reasons:

- to ensure that energy per se was properly represented following publication of the UN Brundtland Report in 1987 which raised the whole question of the earth's sustainable development, but which devoted less emphasis to energy's role of providing the services of heating, power, cooking, lighting, refrigeration and mobility than many thought desirable;

- in anticipation of the out-turn of events at the UN Rio Earth Summit in 1992. It is interesting to note that neither the RIO Declaration nor Agenda 21 made any substantial mention of energy. The subsequent RIO Climate Convention (signed by 167 nations and ratified by 18 as at June 1993) however does make considerable reference to energy. It requires developed nations to lead by example in taking precautionary action to protect the environment against indicated CO_2 emissions targets. The developed nations are also to provide the technology and financial assistance to the developing countries to enable them to avoid creating dangerous levels of atmospheric greenhouse gas concentrations. Such financial assistance was quantified by UNCED at some US$ 125 billion annually - that is to say, more than double the present total aid flow from north to south.

- because the WEC had since 1973 worked on global supply/demand perspectives and produced in 1978 its first major global report "Looking Ahead to 2020". its 1989 edition called "Energy Horizons 2000-2020" raised as many questions as it answered and required more analysis in order to be able to "aim off" on a number of major issues. These included possible environmental costs, likely degrees of efficiency achievement, possible financing constraints and above all a re-examination of developing countries demand requirements.

  Additional complicating factors also came into play:

  - nuclear development after Chernobyl
  - possible pinch points on global oil and gas resources
  - the impact of changes to markets following deregulation and privatisation in many parts of the world
  - the potential and timing of development for harnessing renewable, and particularly new renewable, energy sources
  - and the ubiquitous threat of potential global warming together with the related costs of precautionary measures which could be taken until final scientific proof was available.

All these, and other factors dictated that the Commission should be led by energy operatives; by a non-governmental, multi-energy organisation; and by one which not only had the breadth of representation but also the ability to deal objectively with the complicated inter-related elements involved. Regional views do not necessarily share global priorities or views, and it was important to initiate this project at regional grass roots level. In the absence of others who could fit these requirements the WEC had no option but to offer to do the job.

2. OBJECTIVES

The Commission's aim is "to identify a realistic framework for the solution of regional and global energy issues, whereby adequate sustainable energy at acceptable costs can be supplied to meet the needs of all people, using optimal production and end-use efficiency, whilst achieving socially acceptable care and protection of the environment".[1]

This admirable aim, so easy to produce on paper, was to prove a colossal job; much greater than the WEC or anyone else first realised, and considerably more difficult when it came to suggesting remedies than to identifying the maladies.

3. ORGANISATION

The horizon year was set at 2020, although as the Commission progressed it became apparent that several features required to be examined beyond that date. In its Epilogue the Commission takes a number of elements and issues through to 2050 and in some cases to 2100 in order to keep pace with other major global work such as that of the IPCC. These elements all reinforce the main Commission message that remedial action should be initiated now.

The total cost of the exercise has been estimated at US$ 5 million donated in terms of man hours, travel, accommodation and the costs involved in setting up and running the small UK Project Management Unit which led and coordinated the project. A total of some 500 specialists contributed to the final regional and global reports.

The Commission work was initiated through nine inter-disciplinary regional coordination groups comprising not only representatives of all forms of energy but also economists, financiers, environmentalists, consumers and government and were coupled with balanced national representation of the region.(2)

The whole Commission was supervised by a Board of 50 eminent multi-disciplined personalities, and the Project Management Unit, headed by the Executive Director, consisted of six staff loaned by corporations from five countries, and assisted by four part-time advisers.

Finally the work process was unique. No organisation other than the WEC had the spread of membership (100 member countries), nor the multi-energy base, and the WEC was thus able uniquely to conduct the Commission "bottom-up" and "top-down" through an iterative process which examined regional priorities and views before synthesising them into its final Gobal Report.

4. STRUCTURE

Although a qualitative document, the nature of the Commission required the incorporation of a quantified framework. This was constructed, after the first phase of the work, by defining four Cases to reflect the main initial regional data.(3)

These cases not only project possible development, but they help to prepare for change. They measure dimension but are not forecasts. They assist in interpreting emerging trends and unify themes from among the disparate regional views. They also provide information for the creation of opportunities and development. Above all, they are offered to orientate and influence the ideas of energy policy makers in both industry and government. In brief, they change mental maps.

During the three-year lifespan of the Commission profound political and economic changes have occurred in the world. The Berlin Wall came down and the Soviet empire collapsed. The extent of their pollution damage and the inadequacies of these command and control systems were exposed. Pacific Rim economic growth excelled even its own previous records, and was followed by a major economic upturn in Latin America. China and India have embarked, particularly the former, on a pathway of breathtaking industrial development and consumerism. China with a GDP of US$ 1.7 trillion now has the third largest economy in the world, and will probably have the largest within the next decade.

Privatisation and deregulation of individual markets have occurred across the world. These in turn are increasingly being thwarted internationally by regional and economic trade barriers. The pace of change has been, and is, enormous. But it has been possible to accommodate the energy repercussions of all these changes, thanks to the adoption of this simple four-case Commission infrastructure.

None of the cases portrays "business as usual", and all were built on the same UN population projections (Median Case) up to 2020 and beyond. Above all else it is this underlying "explosion" of global population, set to rise from 5.5 billion in 1990 to 8.1 billion in 2020, and mainly in the developing world, which provides the basis for the energy perspectives highlighted in the four Cases.

The Base or Reference Case (B) is an update of that used in the WEC's original 1989 Energy Horizons. To this Base Case have been added a variant Reference Case (B_1) with lowered energy intensities, moderate technology transfer and with reduced institutional change. A High Economic Growth Case (A) projects very high economic development, particularly in the developing countries (+2% p.a. per capita income growth). An Environmentally Led Case (C) completes the Commission framework.

This Environmentally Led C Case contains very high energy intensity figures, technology transfer and institutional changes, and includes 12% - 14% of global energy supplies derived from new renewable sources. It is considered to be at the extreme limits of what could be achieved within the Commission's time frame, but ironically it is the only Case which comes near to accommodating the target of the Rio Climate Convention to stabilise developed country greenhouse gas emissions at their 1990 levels by 2000.

The results of the four Cases confirm what many have long believed, that the world in the space of the next 30 years will probably almost double its consumption of energy, and that some 85% of this increase will occur in the currently defined developing countries which will contain 90% of the population increase.(4)

From a total global energy consumption of 8.8 gtoe in 1990 the four Cases provide a range of possible demand from 17.2 gtoe in the high economic growth case to 11.3 gtoe in the Ecologically Led Case (which is considered to be virtually unachievable). The most likely 2020 global demand range would appear to lie between 16.0 gtoe and 13.0 gtoe, i.e. increases of between 48% and 82% respectively over 1990 consumption.(5)

Fuel mix projections are always speculative, but those of the Commission demonstrate that all forms of energy will be required, if demand is to be met. The fuel mixes shown, although they represent very considerable increases over 1990 in many cases, are considered to be both available and operationally possible despite long development lead times - except for Case C where the degree of penetration by new renewable energy forms is questionable.(6)

Vastly increased energy consumption will also mean major increases in greenhouse gases. The IPCC estimated total 1990 CO_2 source emissions at 200 gtC of which 194 gtC were absorbed by sinks. Fossil fuel burning produced 5.5 gtC and traditional fuel use another 0.4 gtC. Energy use therefore accounted for about 6.0 gtC or some 3% of total CO_2 sources.(7)

This 3%, however, represents the crucial element in the balance to determine whether anthropogenic sources of CO_2 create serious global climate change.

The Commission estimates 2020 emissions to increase by between 40% and 90%, (discounting the environmentally led case) over those for 1990. CO_2 concentrations measured in parts per million by volume increase by between 17% and 22%.

5. TEN PRINCIPAL MESSAGES

(i) The overall message of the Commission's Report is the need for change. With world population expected to double in the coming decades, and urban populations more than trebling, we cannot carry on using energy in the ways we currently do.

Demands for the services which energy provides - heating, cooling, lighting, cooking, mobility and motive power - will rise massively. Energy is a provider of basic needs and services. It is an essential ingredient of economic growth and social development. The challenge is to balance the growing need for energy with avoidance of environmental impacts which could eventually become overwhelming.

Meeting this challenge requires change. but change can only come about slowly and we need to initiate that change <u>now</u> if we are to achieve successful, sustainable development.

Take, for example, efficiency levels included in the Commission. Such changes will, if they are to succeed, require the acceleration of the roll-over of capital goods. This itself in turn will require accelerated depreciation to permit this to happen in developed countries, and considerable additional financing in the developing countries.

(ii) Within the huge global energy consumption increases well over 85% is attributable to the developing world. This can only be a good thing in alleviating poverty and encouraging economic growth. It will, however, require many changes if consumption is to equate to demand. Many of these changes could mean greatly increased commercial opportunities for the developed world.

The corollary is less encouraging: because of the dimensions of population increases, some regions, for example Sub Saharan Africa, may well not achieve greater per capita energy consumption than they had in 1990. Economic stagnation could result, with the attendant risk of possible destabilisation.

(iii) The Commission found that the development of the rational use of energy on a cost/benefit basis was an immediate priority. Interestingly, it is the change of capital stock (the modernisation or replacement of equipment) which appears to achieve results, rather than the express alteration of regulation or price.

Much has been written into the Commission to demonstrate the potential benefits of energy efficiency and these will occur in step fashion across the globe as countries become more efficient also in their use of labour and capital. It is now up to government to ensure that desirable energy intensity indicators are achieved.

(iv) The development of technology to assist in meeting global energy requirements and to manage the environment is of overriding importance. Technology transfer requires to be speeded up, preferably through the market system, and with proper protection for intellectual property. The industrialised world has a major responsibility to develop the required technologies for the future and to make them globally available.

(v) Fossil fuels, particularly coal with some 250 years of reserves at current consumption rates, will continue to provide the bulk of needs. oil at 43 years and natural gas at 67 years appear to come under pressure only towards the end of the period but import dependency on oil, gas and coal will increase and supply lines will lengthen.

(vi) Nuclear power is currently faced with a dilemma. The world will require to use all forms of energy to satisfy demand during the next 30 years but public acceptance currently curbs development in many countries. The Commission assumes, after considerable debate, that nuclear power will develop on the basis that solutions will be found for the whole fuel cycle including operational safety, effective international inspection and acceptable storage of spent fuel. However, this may not happen, in which case it is coal and to a lesser extent gas which will substitute.

(vii) The Commission's views on the development of renewable energy forms are realistic and balance out the over-enthusiastic views expressed in many parts of the world on these fuel sources.

Renewable energy contributed some 18% of the world's 1990 consumption, mainly as major hydro and traditional biomass. On the one hand great opportunities exist to expand the former. For example, Africa currently exploits only 4% of its possible hydro sites, having such potential as the Inga Scheme on the Zaire River with a potential capacity of up to 40 GWE. On the other hand, it is clearly difficult to define traditional biomass in many parts of the world as being truly sustainable.

The specially commissioned WEC study on "new" renewable energy sources (solar, wind, tidal, etc.) came up with the realistic conclusion that if little or no government development support was available, the 2% of global supply currently derived from such sources might double to 4% of the expanded global consumption by 2020. If government and particularly supragovernment support is given, however, this latter figure could rise much higher to between 12% and 14% of global supply, but this would be unlikely to occur within the next 30 years.

(viii) No realistic possibility exists to meet the indicated global stabilisation objectives for greenhouse gas emissions written into the Rio Climate Convention. The Commission can see no way at the moment to obtain comprehensive worldwide abatement action without massive north/south assistance. That this assistance could in part take the form of the provision by OECD states of cheap finance to export their own "state of the art" energy equipment and technology to the developing world appears as merely one of the front runners to assist with this issue. But here again a major commercial opportunity presents itself. The overall problem of an effective global climate convention, however, remains unsolved, and may remain so for some time to come. In the interim the Commission advocates taking practical and cost effective precautionary measures for environmental protection now.

(ix) The developing countries place high priority on local and regional pollution issues. Confronted with the Commission's 14 key issue points only one region out of nine worldwide placed global CO_2 problems among its priorities. Understandably, developing countries will not sacrifice economic growth by allocating scarce resources to global environmental concerns.

(x) Finally, energy represents some 5% of global GDP and consumes 15% of global financing. Although difficult to identify, some constraints to financing do appear, particularly among certain developing country regions. Massive global investment in energy systems will be required, possibly as much as US$ 3 trillion p.a.(1993 money) by the beginning of the next century. This compares with 1990 world GDP of some US$ 21 trillion. Suffice it to say that competition for international financing will become increasingly competitive and it will increasingly be unable to cover all energy requirements. Much more local capital than hitherto will be needed. This will require radical changes to institutions, markets, training and energy management, if such local finance is to be raised and channelled into attractive energy investment in many parts of the world.

6. SUMMARY

In conclusion, the Commission has identified a number of key issues and offered at least partial solutions for them. Like many projects it may have its weak points - it has possibly under-estimated developing countries' requirements; the assumption that oil and gas reserves will come under pressure early next century inducing price rises, may or may not materialise; and the lack of more specific messages as an agenda for achievement, may be seen by some as deficiencies. However, the Commission has clearly identified the main priorities and required action for global energy development and it has demonstrated the likely pathway of such integrated energy development over the next 30 years.

The developing countries require above all else economic growth, fuelled by adequate finances and adequate energy. In Central/Eastern Europe and the former Soviet Union, the priorities are to modernise existing energy systems, effect the transition to desirable market conditions and improve greatly both efficiency and pollution control. In the OECD countries the emphasis is on greater efficiency and the development of technology.(8)

All this is admirable, but the Conclusions and Recommendations to the 15th 1992 WEC Congress made the overriding point succinctly when it stated that

> "The challenge for the world's institutions is to rise above these different priorities and to progress on all fronts, rather than allow sectoral or political differences to inhibit necessary progress".[9]

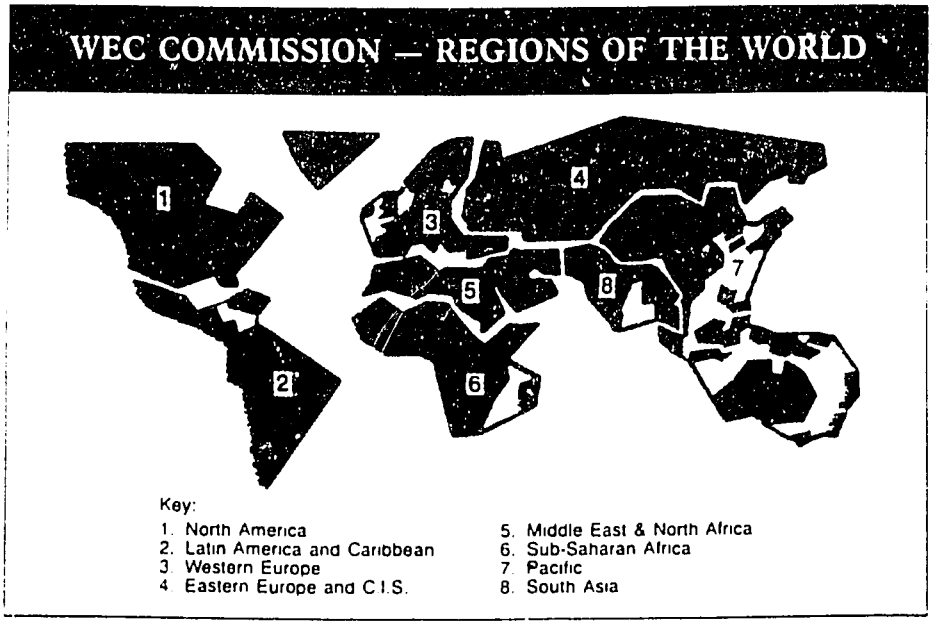
Such a challenge appears today to become even greater in the decades after the Commission's time horizon year of 2020 - hence the inclusion of the Commission's Epilogue, which highlights the many factors contributing to energy's potential major strategic problems after 2020. It serves to emphasise that the next 30 years are essentially ones of managing energy transition, particularly when placed in the context of energy's notoriously long development lead times, in order to fit the global energy sector to surmount those future problems.

By producing such a Commission and by performing this service for world leadership, the WEC has established itself firmly and convincingly as a major player on the world stage.

(1)

"The Commision's aim is to identify a realistic framework for the solution of regional and global energy issues, whereby adequate sustainable energy at acceptable costs can be supplied to meet the needs of all people, using optimal production and end-use efficiency, whilst achieving socially acceptable care and protection of the environment."

(2)



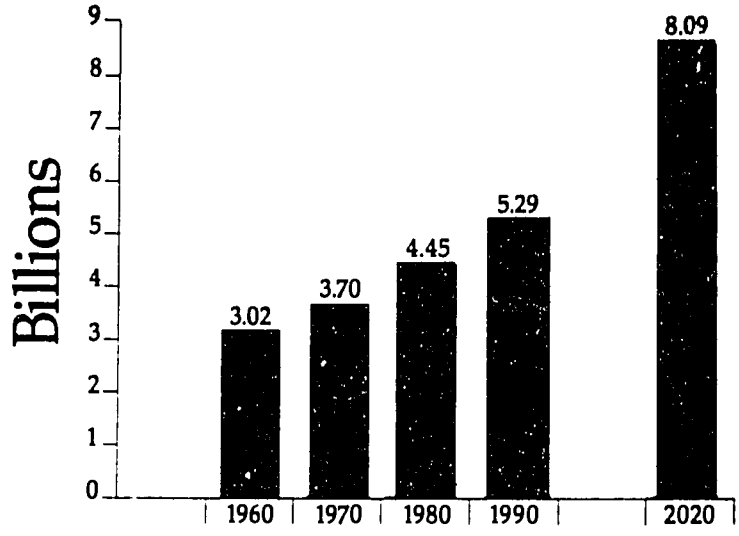
(3)

4 CASES

- High Economic Growth
- Modified Reference
- Reference
- Ecologically Led

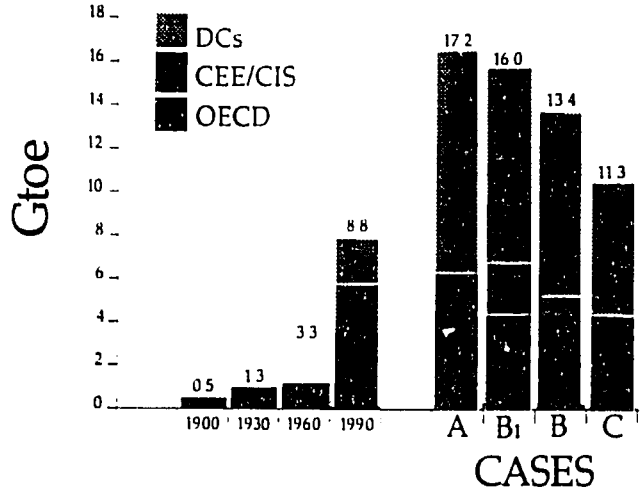
(4)

World Population



(5)

Energy Demand to 2020



(6)

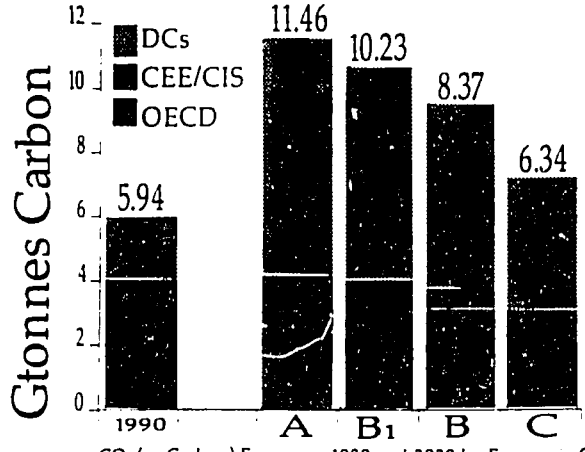
Fuel Mix

	1960	1990	in 2020			
			A	B1	B	C
Coal	1.4	2.3	4.9	3.8	3.0	2.1
Oil	1.0	2.8	4.6	4.5	3.8	2.9
Natural Gas	0.4	1.7	3.6	3.6	3.0	2.5
Nuclear	—	0.4	1.0	1.0	0.8	0.7
Large Hydro	0.15	0.5	1.0	1.0	0.9	0.7
"Traditional"	0.5	0.9	1.3	1.3	1.3	1.1
"New" Renewables	—	0.2	0.8	0.8	0.6	1.3
Total	3.3	8.8	17.2	16.0	13.4	11.3

Energy Mix - Annual Past And Future Global Fuel Use (Gtoe)

(7)

CO_2 Emissions



CO_2 (as Carbon) Emissions 1990 and 2020 by Economic Group

(8)

SUMMARY

- The Developing Countries require economic growth, fuelled by adequate energy.
- In Central/Eastern Europe and the CIS the priorities are to modernise existing energy systems, effect the transition to desirable market conditions and improve greatly both efficiency and pollution control.
- In the OECD countries the emphasis is on greater efficiency and the development of technology.

(9)

The challenge for the world's institutions is to rise above these different priorities and to progress on all fronts, rather than allow sectoral or political differences to inhibit necessary progress."

Conclusions of the Madrid Congress, 1992

CLEAN COAL PRODUCTION AND RATIOANAL USE OF COAL IN CHINA

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1. Economic development and environmental protection are the major topics concerned worldwide at present. The Chinese government pays great attention to environmental protection while devotes itself to develop economy. Environmental protection is China's basic national policy.

After the U.N. environment and development congress last year, the Chinese government approved ten items of policy for economic development and environment control. It points out: to increase the proportion of coal cleaning and processing; to increase utilization ratio of energy; to control CO_2 emission and reduce air pollution so as to coordinate economic development and environmental protection. Not long ago, the second national meeting of prevention and hardness of industrial pollution which held in Shanghai, calls that clean industrial production to protect environment and guarantee the continuous development of economy should be pursued. The China's Mininstry of Coal Industry always pays great attention to the development of coal cleaning and processing, actively adjust product structure, develop comprehensive utilization and deep processing of coal, to increase heat energy utilization ratio of coal, reduce environment pollution and increase profit. We have built new coal washing plants, transformed and expanded a batch of existing coal washing plants with annual throughput increase of 10-20 mt.

Coal is the major primary energy in China, it makes up about 75% of China's energy production and consumption (Table 1 and 2), 2 to 3 times higher compares with other countries (Table 3), 2.8 times more than the figure of 27.3% which is the proportion of coal in the structure of world primary energy (Table 4). China's raw coal output accounts for 24.04% of the total world coal output, therefore, China pays special attention to the development of clean coal technology.

Table 1. Proportion of Coal in Consumption Mix of Primary Energy, 1990

Category	Coal	Oil	Natural gas	Hydroelectric
Proportion	76.0%	17.0%	2.0%	5.0%

Table 2. Proportion of Coal in Production Structure of Primary Energy, 1992

Name	Coal	Oil and natural gas	Hydroelectric
Proportion, %	74.2	21	4.8

Table 3. Proportion of Coal in Consumption Mix of Primary Energy in Some Major Coal Producing Countries, %

United States	France	Britain	the European Community	Former Soviet Union	China
23.1	33.2	30.6	22.4	24	76.1

Table 4. Change of Production Structure of World Primary Energy

Item \ Year	1950	1960	1970	1980	1990*
Total Production, mtce	2560.3	4243.0	7150.0	9291.8	11476.1
Structure, %					
Coal	57.9	46.5	31.6	28.2	27.3
Oil	30.8	37.4	47.9	48.3	38.6
Natural Gas	9.6	14.1	18.3	20.2	21.7
Hydroelectric and Nuclear Energy	1.7	2.0	2.2	3.3	6.7
	100.0	100.0	100.0	100.0	100.0

* Figure of primary energy consumption for 1990

2.China has a long history in research and technology development of effective coal utilization. Clean coal technology includes roughing, fine and finishing processing of coal, thus complete the whole work of coal cleaning.

Now, I would like to introduce China's basic status from coal production point of view:

(1). Status of coal washing and processing

By 1992, China has 190 ccal washing plants, among which, 127 are coking coal washing plants (Fig. 1). The total throughput of washing plants is 204.6 mt, it's development trends to linear raising (Fig. 2). The development of coal washing and processing play an active role to coal mines to incraese economic benefit, the profit due to washing increased from 650 million Yuan (chinese currency) in 1985 to 2.4 billion Yuan in 1992 (Fig. 3).

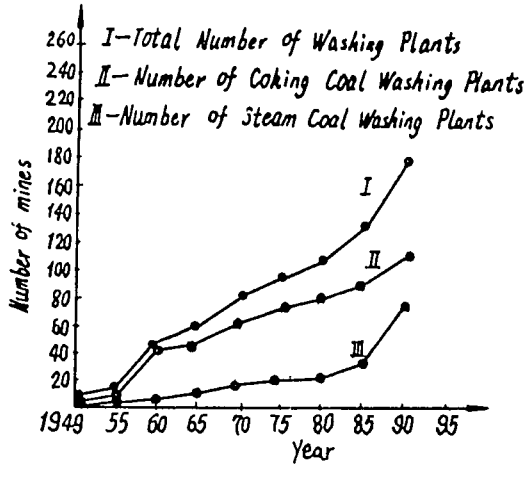

Fig 1. Current number of washing plants and increase year by year

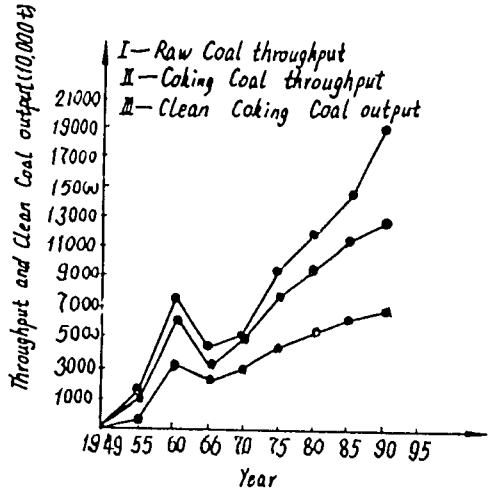

Fig 2. Raw coal , coking coal throughput and increase year by year of clean coal output

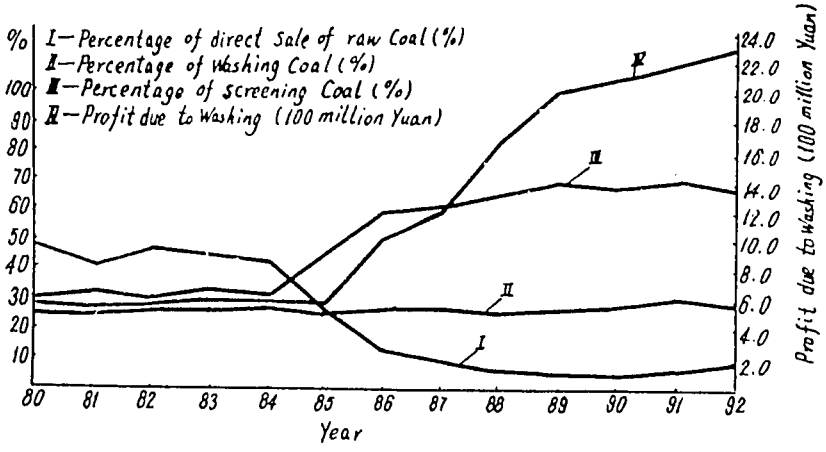

Fig 3. Curve of commercial coal structure produced by China's state controlled coal mines and profit due to washing

But, the proportion of coal washing in China is very low (Table 5).

Table 5. Washing Proportion of Major Coal Producing Countries in the World (1985)

Item	United States	The Former Soviet Union	Poland	Australia	Japan	Britain	China
Coal Output (10,000 t)	80985	72620	24938	17550	1644	9188	87228
Throughput (10,000 t)	33762	31133	12219.6	13338	1561.8	9188	14293.8
Percentage of Washing (%)	42	42.88	49	76	95	100	16.4

For protect environment and increase economic benefit of coal enterprises, we are vigorously organizing and actively raising funds so as to speed up the construction of coal washing plants, we also hope the U.N. and other countries to introduce new technology and products into China, welcome to China to invest for building washing plants.

About 10% of the raw coal produced in China contains more than 2% of sulphur, these high sulphur coal are mainly distributed in southwest and northwest regions of China.

Because of burning high sulphur coal, about 15 mt of SO_2 exhausted to the air in China in 1990. The acid rain caused by sulphur directly affects industrial and agricultural production and human health, thus the chinese government pays great attention to this problem.

The Nantong Coal Mining Administration in Chongqing, Sichuan province found a new approach on development and utilization of high sulphur coal. It washes the coal with 4% of high sulphur, produces clean coal with less than 1.5% of sulphur, pyrite contains 53% of sulphur extracted from middlings and refuse, the residual middlings and refuse for power generation, ash from power plant for making brick, cement and building materials (Fig 4).

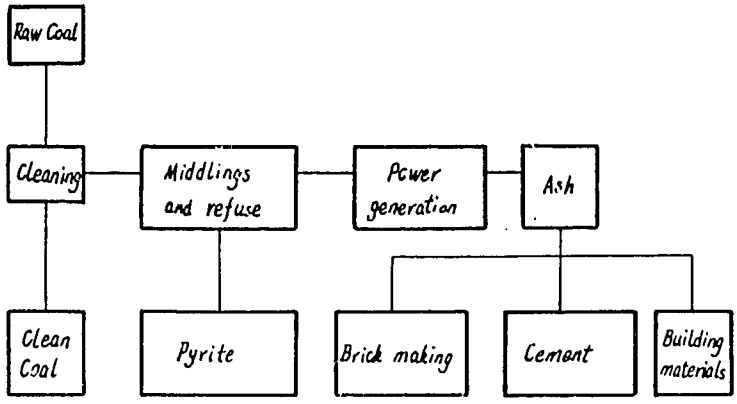

Fig 4. High sulphur coal utilization in Nantong Coal Mining Administration, Sichuan province

(2). Briquette

In China, 84% of coal burn directly, thus the utilization coefficient of coal is only about 22%. If use briquette, the heat efficiency of coal would be increased by 10-20% and pollutant exhaustion can be greatly reduced, see Table 6 and 7.

Table 6. Heat Efficiency of Different Coals

Fuel	Heat Efficiency, %	Coal Saving, %
Bulk Coal	16-18	0
Coal Blank	17-18	1-5
Wet Coal	18-20	5-10
Ovoid Briquette	24-26	28-33
Honeycomb Briquette	40-50	55-60

Table 7. Pollutant Exhaustion from Coal Burning Oven (g/kg)

Fuel	Contamination Factor (g/kg)				
	Coal Dust	SO_2	NO_x	CO	BaP
Bulk Coal	2.95	15.889	0.515	44.835	99.032
Coal Blank	1.681	5.005	o.491	42.279	30.616
Wet Coal	o.634	7.605	o.412	38.557	26.473
Ovoid Briquette	0.48	5.472	0.385	38.052	53.572
Honeycomb Briquette	a little	3.123	0.385	0.625	not found

According to the statistics, in China, heat efficiency of raw coal burning for different purposes are not same:

Industrial boiler	60%
Thermal power	31%
Industrial kiln	20-30%
Domestic stove	15-30%
Locomotive	5-8%

Briquettes produced in China include two categories: industrial and domestic briquettes(Table 8). According to 1990 statistics, production output of domestic briquette in China reached to 33 mt/y, accounted for 30% of the total domestic coal used in cities and towns; the industrial briquette was about 22 mt/y, China also has machining capacity of complete plants by which 5 mt/y of briquettes can be produced.

Table 8. Classification of Briquettes according to use

Briquette	Industrial Briquette	Briquette for industrial boiler, kiln and locomotive fuel
		Briquette for smelting and casting
		Briquette for making gas
	Domestic Briquette	Ordinary ovoid briquette and honeycomb briquette for cooking
		Honeycomb briquette and combined briquettes for large kitchen range, water boiler and heating
		Briquette for roast, chafing dish and handwarmer

In China, domestic briquette include the following categorias:

Domestic briquette
- Honeycomb briquette
- Ovoid briquette
- Stick briquette

The industrial briquette mainly are:

a. Briquette for industrial boiler and kiln

China has 400,000 grate firing industrial boilers and 140,000 kilns, so that research of industrial briquette is the direction of briquette development, a series of new techniques have been developed.

b. Briquette (briquette coke) for metallurgy

This is one of the best ways to effective use of non-coking coal, for example, add suitable binder into non-coking coal, then press to form briquette coke, the successful development of briquette coke is of benefit to energy saving and reducing cost, the result to see Table 9.

Table 9. Property of Metallurgical Briquette Coke and Furnace Coke

Coke Category	Ash (%)	Volatile Matter (%)	Sulphur (%)	Tumbler Test		Reactivity of Lump Coal		Grain Size (mm)	Furnace Capacity (m^3)
				M40 (%)	M10 (%)	Reactivity (%)	Strength after reaction (%)		
Briquette Coke-1	12.82	0.96	0.32	M20 95.3	4.0	31.0	54.4	41x32x27	
Briquette Coke-2	11.60	1.01	0.50	M20 92.7	6.6	32.0	49.4	41x32x27	
Briquette Coke-3	13.84	0.55	0.36	M20 92.7	6.0	31.9	49.7	41x32x27	
Briquette Coke-4	12.09	0.77	0.37	M20 92.3	7.0	32.8	46.7	41x32x27	
Furnace Coke for Meishan Steel Mill	14.3	1.24		78.6	7.6	36.1	49.9	>40	>1000
Furnace Coke for Anshan Steel Mill	14.1	1.15	0.61	73.8	9.0	33.9	45.7	>40	>2000
Furnace Coke for Wuhan Steel Mill	13.6	1.02	0.72	79.9	7.0	28.2	58.7	>40	>2000
Furnace Coke for Baoshan Steel Mill	11.68	0.98	0.37	87.3	6.4	39.1	53.2	>40	>4000

c. Briquette for making gas

We have developed gasify material for fertilizer industry — smokeless briquette, we also developed gasify briquette for making burning gas which will be used in glass mill and ceramics factory and also for producing domestic fuel gas by two-stage gas generator. For example, weakly coking coal from Datong mixed with fat coal from Kailuan, then add compound cementing agent, the characteristic of this briquette is suited to the coal requirement for gas generator and two-stage gas generator to produce gas.

In short, briquette will have bright future due to it's energy saving and environmental protection.

(3). Development of coal water mix technique

In 1988, China worked out a important energy policy-- use less oil and replaced by coal. Burning of coal water mix (CWM) is one of the effective and economic ways of techniques for high efficiency and cleanly use of coal. In China , the combustion efficiency and utilization coefficient are quite low, the total efficiency is about 25%. Furthermore, during long distant transportation, disperse storage, loading and offloading, 5-7% of coal will be further lost. All these clearly show the advantages of using coal water mix. The industrial demonstration shows that burning coal slurry, the combustion efficiency can be raised by 5-10% and energy consumption can be reduced by 20%, the result is very obvious.

China has developed a complete set of practical production techniques, China now has 6 coal water mix plants (include being constructed) with annual capacity of 1 mt, two additive factory with annual capacity of 500-2000 t/y and 3 coal water mix experiment and research centres.

The capacity of Beijing Coal Water Mix Plant is 250,000 t/y (Fig 5), the quality of it's product see Table 10.

Currently, coal slurry is applied in industrial boilers and kilns in various industries, it includes 6 industries, see Table 11.

In short, long experiment in some demonstration sites proved that 1.8-2.1 tons of coal slurry can replace 1 ton of heavy oil, it will have bright future because 30 mt of oil directly burned each year in China.

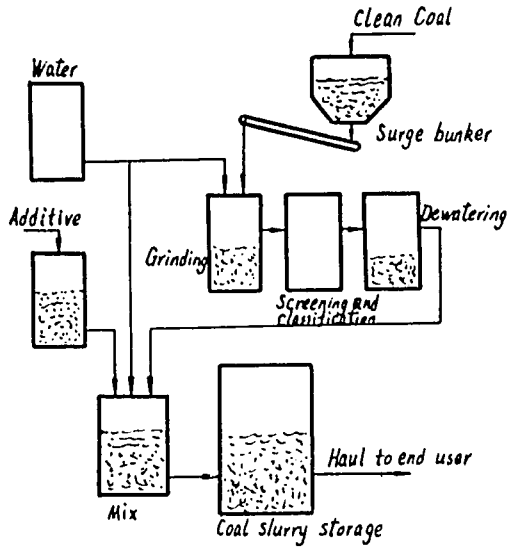

Fig 5. Demonstration flow sheet of Beijing Coal Water Mix Plant

Table 10. Quality of Product from Beijing Coal Water Mix Plant

Concentration (weight %)	65% dry coal weight
Viscosity	≤ 1000 cp
Heat Value	18.8-20.1
Maximum Grain Size	≤ 250 μm
K90	≤ 140 μm
Ash	≤ 7%

Table 11. Application of Coal Water Mix

Industrial Department	Boiler	Research Content
Light Industry	50 t/h industrial boiler for produce heat and electricity	Experiment and research production technique
Building Material Industry	Tunnel drying oven for drying coal water mix	Experiment and research production technique
Metallurgical Industry	Small steel rolling heating furnace	Production technique
Machining Industry	Large forging heating furnace	Production technique
Metallurgical Industry	Ore sintering furnace	Production technique
Textile Industry	15 t/h industrial boiler	Burning technique

(4). Coal gasification and liquefaction

Coal gasification is a important way for having clean coal, it can remove impurities and detrimental ingredients to the maximum, fully utilize heating value of coal.

According to 1989 statistics, there were 273 cities from 450 cities in China have gas burning installations, the popularization rate is only 18% (Table 12).

Four major oven type gasify technology currently adopted in China (Table 13), coke oven is better considering the economy, but carbide furnace and two-stage gas generator are more suited to middle and small cities

Table 12. Source of Gas in China's cities

Gas Category	Source or Gasify Equipment	Gas Heat Value (KJ/m^3)	Cities Use Gas
Natural Gas	Gas field in Luzhou, Baxian, Sichuan province	33488-35999	Chengdu, Chongqing, Beijing
Associated Gas in Oil Field	Dagang oil field	37674	Tianjin
Mine Gas	Longfeng, Laohutai, Shengli coal mine in Fushun	14651-16440	Fushun
Coke Oven Gas	Model 58 oven	15906-18837	Beijing, Shanghai, Nanjing, Shenyang, Taiyuan
	Model 61 oven	20092	Shanghai
	Model 66 oven	14651	Harbin, Changchun, Dalian, Tianjin
	"Red flag innovation" coke oven		Dalian
Vertical Box Oven Gas	Vertical box oven	5023	Beijing, Jinzhou, Hegang
Horizontal Oven Gas	Horizontal oven	13395	Changchun, Harbin
Wood Oven Gas	Continuous vertical carbide furnace	16325	Shanghai, Changchun, Dalian, Nanjing, Qingdao, Datong
Two-stage Generator Gas	Two-stage generator	12558	Fuxin
Water Gas	ϕ 2740 water gas oven	11092*1	Shanghai
	ϕ 2260 water gas oven	11720	Dalian
	ϕ 1980 water gas oven	11720	Dalian
Generator Gas	Model W-G generator, Model 3AII-13 generator	5232*2	Shanghai, Beijing, Dalian, Dandong
Lurgi Pressure Gasify Gas	Lurgi oven	16440*3	Kaiyuan Army Fertilizer Plant, domestic use in No. 1 Truck Factory
Liquefied Petroleum Gas	Catalytic cracker	92092	Beijing, Tianjin, Shanghai, Nanjing, Shenyang, Changchun, Harbin
	Three Tubular Heavy Oil Heat Accumulation Thermofor Catalytic Craking Oven	18837-20930	Xian, Lanzhou, Jinan, Shanghai, Shenyang

Remarks:

*1 Gas companies in Shanghai and Dalian use gas as mix material, directly for domestic use in Jincheng and Luan Coal Mining Administration.

*2 Gas companies in Shanghai and Beijing use gas for heating, domestic use in Xian(for example, Shaanxi Diesel Engine Factory).

*3 After built pressure gasify plant, it plans to change product due to low economic benefit.

Coal liquefaction includes two parts: indirect and direct liquefaction. Research of liquefaction technique in China has started in the recent years, research of direct liquefaction started from 1980. China Coal Science Institute has built liboratory with world advanced level which conducts coal liquefaction , processing of oil to improve quality, analysis and test.

Table 13. Comparision of Gas Coal for Different Ovens

Oven Type	Coke Oven	Carbide Furnace	Lurqi Oven	Two-stage Gas Generator
Main Product	Metallurgical coke	City gas	City gas or synthetic	City gas
By-products and economic benefit	Tar, benzene, ammonia and gas combined chemical production increase benefit	Coke, tar ammonia combined chemical production high benefit	No combined chemical production high cost of gas, low benefit	No combined chemical production, high cost of gas low benefit
Feed coal	clean coking coal with lean coal	Gas coal (Long flame coal)	Non-caking lump coal	Non-caking and weak caking fault coal
Moisture and Ash Content	ash 18-26%	ash 25-32%	moisture 20% ash 19%	moisture 15% ash 20-45%
Management condition	Stable production	Suites to adjust gas supply	Large scale production	Construction plant centrally or decentrally
Disadvantages	High investment, strict coal requirement, furnace coke hard to sale	High investment, quite strict coal requirement	High investment, high operating cost, serious pollution, hard to use remaining pressure, not suite to be gas plant for middle and small cities	Low heating value, high CO_2 content
Improvement	1. To be large scale 2. expand raw material coal types, adopt tamping coking	1. To be large scale 2. Gas coal briquetting 3. Adopt acceleration gasification system, increase carbide gas output	1. Improve gas quality 2. Improve separation result of gas from waste water, protect environment	1. enhance degestion and absorption 2. Seriation research 3. complete set of technique, for example, fine coal briquetting, break cohere technique, part of water gas become methane

In a word, the technology for coal cleaning and briquetting has been in certain level, technology of CWS is on the developing stage, but gasification, especially liquefaction is the project pending further developing.

3. According to development program, by 2000, China's coal output will be increased from current 1.11 billion tons to 1.4 billion tons, the washing capacity of raw coal of coal cleaning plants will be increased from current 250 mt/y to 500-550 mt/y, the coal throughput will be increased from current 210 mt to 380 mt. In order to achieve this goal, it plans to build 73 new cleaning plants with capacity of 200 mt, moreover, conducts technological transformation for existing 120 cleaning plants. Thus, coal mines remove 80 mt of refuse, save haulage capacity of 49.6 billion ton-kms. Due to improvement of coal quality, about 40 mt of coal saved each year, also reduce air pollution due to burning coal. At the same time, gasification will be achieved progressively in large and middle cities, most residents in small cities will burn briquette instead of bulk coal currently burnt.

It is estimated, by 2000, 40 new briquette plants will be set up with increasing capacity of 0.5 mt/y. Coal slurry plants will open up market further, it plans to build 4 coal slurry plants(Huainan, Pingdingshan, Yangquan, Jingyuan) with capacity of 1.4 mt/y, build new gas plants in many areas if the condition allowed, to supply gas to 1 million families.

4. We hope to supply to other countries the following:

(1). Complete plant and project contractor of coal cleaning plant, coal briquetting plant and coal slurry plant;

(2). Export service of treatment technology, equipment for mine water and slime water and flocculant for clarification.

We hope to have international cooperation on the following projects through U.N. support:

(1). Fire-fighting on spontaneous combustion of underground coal seam in Xinjiang. The fire lasts nearly 300 years. According to statistics, the combustion area reached to 200-300 km^2, about 100 mt of coal burnt each year, not only lost vast coal resources, but also seriously pollute the environment. We hope U.N. to organize experts to diagnose it and provide financial and technique support.

(2). China is a country with less water, fresh water resource is very limited, Currently, only 2800 billion tons, 2400 m^3 average per person,

only accounts for 1/4 of world water resource. During coal mining, large quantity of water should be drained, about 4 tons of water drained for per ton of coal produced, except some water reused, still 1.5 billion tons of water have to be drained. At the same time, many mining areas are seriously short of water, not only short of process water, the more serious problem is short of drinking water. If we have sufficient finances, we can recover and purify mine water(include slime water), if so, it is not only benefit future generations, but also beautify the environment.

(3). China has about 750 refuse heaps and will further increase with 100 mt of refuse every year. There are more than 100 refuse heaps with spontaneous combustion problem currently. They are not only occupy farm land, but also cause serious pollution, are badly in need of treatment. It is badly needs to solve the problem of fire fighting of refuse heaps, comprehensive utilization of refuse,reclamation and vegetation.

(4). China will devote major efforts to develop coal cleaning and clean coal technology, now, we actively make preparation for setting up a research and development centre of clean coal technique. We hope to receive the support from U.N. and have cooperation with various countries in the world to conduct research and development work jointly.

Finally, we would like to thank again the U.N. to give this opportunity to us to introduce China's condition at this congress. We welcome friends from various countries to visit China, jointly develop clean coal techniques and utilize coal more efficiently.

IEA Second International Conference on the Clean and Efficient Use of Coal and Lignite: Its Role in Energy, Environment and Life.

HONG KONG

30 November - 3 December, 1993

"THE LONG VIEW"

THE PERSPECTIVES OF COAL USERS AND SUPPLIERS

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"THE LONG VIEW"

THE PERSPECTIVES OF COAL USERS AND SUPPLIERS.

If there's one thing that both coal industry suppliers and users have in common, it's the need to take a long term view. Coal producers invest in mines whose production life is usually a minimum of 20 years and often much longer than that. Coal users install facilities which have lifetimes of over 30 years. Both are quite familiar with the idea that their investments are only worthwhile when looked at from a long term perspective. They are also used to dealing with the uncertainties that are an inevitable part of long-term planning processes. Hence the title of this talk - "The Long View".

The "Long View" that I am going to describe is a view which inevitably focuses on electricity. In essence, it's a rightly optimistic view. However, there are challenges which both suppliers and users must confront, and I will also discuss these in my speech.

One of the themes of this Conference is "Coal use : public perceptions of its role in energy, environment and life". All too often coal is described either as "an old fashioned fuel" or as "a fuel with no future". Not only is such talk incorrect, it is also misleading, perhaps even mischievous propaganda. But it does represent a perception held in society, probably rather more widely than if we in the coal industry - both as producers and consumers - had been more agile in selling the importance of coal in the past. Now more than ever, we do not want to run the risk of losing the argument by default. We must be prepared to put the case for coal ourselves; nobody else will do it for us. Therefore, the view I am about to share with you is aimed also at contributing in some way to the promotion of the coal industry.

You might imagine that coal suppliers and users would have differing views of the coal business. However it's my contention that, apart from the desire of the producer to generate positive margins so as to satisfy his shareholders in the long term and the user's desire to burn the most appropriate fuel, their respective views occupy much common ground. The main feature of this common ground is easy to identify.

Coal was the principal fuel behind the industrial revolution in Europe. It is still the main fuel for electricity - now the preferred energy source in most developed countries - and it will continue to be the driving force behind the industrial revolution in developing nations. The future of coal is inextricably bound to the future of electricity.

Let's examine this common ground in more detail by looking at the coal industry in general, and then by studying our own " Long View" of the future for electricity.

Some two thirds of global hard coal production comes from China, the USA and the former Soviet Union and, of this, only coal in the USA and a little in China was produced by private concerns until recently. But now eventual privatisation and deregulation in both Russia and China surely means that state controlled production will decline whilst private production will increase. Elsewhere in the world, coal is produced by both state organisations and private firms depending on the regime of the country concerned.

Who are coal's customers? Over half of all hard coal produced is used in the generation of electricity and over a quarter for raising steam or providing heat in industry. The balance is divided between steel making and the residential and transport sectors. But these proportions are not static.

Since 1945, coal's importance as a fuel in the transport, industrial and domestic sectors has declined in the face of cheap oil, followed by gas and clean, convenient electricity. However not all of coal's markets have been on an irreversible decline. One cheap, secure and reliable way of meeting the growing demand for electricity has been and still is through thermal power stations fuelled by coal, particularly after the oil price shocks of the 1970s when the price of oil went up by three and a half times in real terms.

A significant consequence of the first oil shock in 1973 has been the development of the seaborne trade in hard coal. Although still only around 10% of total production, its growth has been rapid particularly over the last decade. In energy equivalent terms, the seaborne thermal coal trade is almost twice the size of the much vaunted Liquefied Natural Gas business, although only around 10% of the total trade in oil. At this level, its contribution to the total trade in energy is, of course, highly significant. I shall return to trade matters again towards the end of this paper.

Now, let's turn to the electricity industry.

The best prospects for growth in coal consumption in the future lie with power generation. Nearly half of world electricity production comes from coal fired power stations.

Globally, consumption of electricity grew at an annual average rate of over 8% in the 60s, about 5.5% in the 70s and just under 4% in the 80s. It is projected to grow at 2-2.5% up to 2020. Even though the efficiency drives prompted by the 1973 oil shock have brought a reduction in overall energy intensity, that for electricity has increased. The most significant statistic is that the share of electricity in the world's final energy consumption package grew from under 10% in 1960 to about 15% in 1990 and is expected to be over 20% by 2020 - as such it is the fastest growing source of energy.

Electricity has been gaining share in all markets where it competes because it is convenient, clean and efficient at the point of use. Even though in some developed countries there are signs that this growth may be slowing down - electricity's most favoured markets [for instance industrial machinery and domestic appliances] can become saturated and gas and other fuels are occasionally better able to compete - electricity still holds sway as the fastest growing energy source. However, it is in the developing countries where the real scope for energy expansion now prevails, and here demand for electricity can be expected to grow the fastest. In the residential and commercial sectors of countries in this category, air conditioning applications are growing quickly as is broad household ownership of other appliances; electricity is also required for many expanding industrial operations.

Convenience and efficiency are not the only reasons for growth in electricity consumption. For all countries, electricity is the medium for consuming different sources of primary energy - coal, gas, nuclear, hydro. Through this, electricity is not only a way of converting energy to utility; it also contributes to energy security and diversity - both important factors in the wake of events like oil supply crises and the Gulf War.

As I have mentioned, Shell's scenarios for the future to 2020 predict electricity consumption growth world-wide at 2-2.5% p.a. However, there are significant regional differences. Growth in N. America may well be less than 1% p.a. - a good example of the way that growth in electricity consumption slows down as society moves towards the post industrial era. Whilst in Japan, the rest of the Far East and S. Asia combined, we foresee a rate of nearly 7% p.a. Obviously it is in this part of the world that there is also the greatest concentration of countries undergoing successful major industrialisation.

Electricity demand here is clearly higher per unit of economic growth than in developed countries. In addition, fuel for domestic use in developing countries is switching from wood, coke and kerosene to electricity. Thus, overall coal demand is shifting away from the household sector towards the power generating and industrial sectors, and it is increasing. In case you're not entirely convinced of the argument so far, let me just give one more example: China's share of global electricity consumption is expected to double from 5% in 1990 to 10% in 2020. Of course China is the country where the statistics are the most awe-inspiring. According to our scenarios, by 2020 China could be using more electricity than the USA did in 1980, and, with a population four times greater, there will be more growth to come.

What is coal's role in this impressive future for electricity?

In 1990 coal fuelled nearly 40% of the world's electricity consumption of 10,000 Twh - twice as much as any other fuel (gas was 14%, oil 12%, nuclear 17%, and hydro 19%).

Although coal's share as a fuel for power generation may well fall from this level to around 30% by 2020, annual consumption in absolute terms will rise from 1.9 billion tonnes/year to over 2.5 billion tonnes/year. What makes these figures even more impressive is that an increasing amount of coal will be consumed in new, more efficient power stations with more electricity being generated from less coal.

By 2030 virtually all today's coal fired power generating plants will have been replaced by new stations and a total of twice as much electricity as in 1990 will be generated from coal. But coal's growth is not without challenges: as before, there will be stiff competition on the economic front - the choice of fuel (factors such as cost, security and availability), and on the technological front - in essence efficiency and environmental.

I have already pointed out how crucial the power generation market is for the future of coal. But this is also true for the future of gas. So how do coal and gas fired power stations compare?

In simple terms, the economics of power generation depend on both the capital and operating cost of the plant and the cost of fuel. For the typical new plant in Japan and per unit of electricity, a gas plant is likely to have lower capital and operating costs than coal. These costs reflect the requirements to reduce sulphur dioxide emissions, and so include FGD installation in the capital cost for coal and oil. As far as the fuel costs are concerned, gas prices are still predominantly linked to oil prices, whilst coal prices are determined by a combination of production costs and supply/demand perceptions. In addition, fuel diversity and security of supply are both crucial factors in the strategy of fuel choice for a major public utility.

In recent years much attention, some of it adverse, has focused on the environmental impact of conventional coal fired plants. Most notable among the concerns are emissions of sulphur dioxides, nitrogen oxides - gases associated with acid rain - and carbon dioxide - linked with the enhanced greenhouse effect. Efficient clean coal burning technologies, many of which are now under commercial trials, represent a major advance in meeting these concerns and will help ensure the long-term future of coal fired power stations.

My own company has developed the Shell Coal Gasification Process, this is being incorporated in an integrated coal gasification combined cycle 250 megawatt demonstration power plant commissioning now in the Netherlands. The gasification process converts coal into a clean synthesis gas (carbon monoxide and hydrogen) and offers thermal efficiencies up to 45%. In due

course improvements in turbine technology will raise this figure to 50%, compared with about 38-45% in conventional plants.

This process can operate on a wide variety of coal types including high sulphur coal, lignites, coal fines and petroleum coke. It has a much reduced environmental impact, with the removal of 99% of the sulphur and with CO_2 emissions per unit of energy output up to 25% lower than when replacing existing conventional coal plant.

This is just one example of combined cycle technology. But coal gasification is not the only method of improving the performance of coal burning technologies for power generation. Combined cycle technologies can also be used with pressurised fluidised beds. In addition, improvements are being made to conventional technologies by way of super critical steam cycles, which also offer efficiencies up to 45%. A great deal of effort is being put behind all of these and success will be achieved. At the moment these processes involve relatively high capital costs but, as they mature, this should be offset by lower fuel costs per unit of electricity as higher fuel efficiencies are attained. Overall, therefore, reasons exist why coal promises to be highly competitive relative to gas and oil.

As I said at the beginning, suppliers and users have to take a long term view of their investments and they must have the confidence that economic conditions will allow each to make a satisfactory return. However, there are three important facets which all of us in the industry would prefer not to occur. Each of these could introduce uncertainty and volatility.

First - the issue of supply security. In the early days of the international coal trade, doing business was subject to term, and, often, escalating contracts. This gave supply security to the user and an assured market to the supplier. Over-supply in the early '80s generated its own security and hastened the growth of a spot market. The change has been marked. In the early 1980s only 10% of coal sold to European Community utilities from the international market was spot. Last year the EC utility import had nearly doubled and the proportion of spot sales had risen to 45%. The main reason for this change is the low cost of entry into coal production. With good geology and access to reasonable transport and loading facilities, coal projects can be brought into production at relatively low cost and sometimes without regard to the status of the marketplace. The new production then has to fight to place its volume with the classical consequences on market prices at large.

A coal producer needs to make a return on shareholders' investment and actions like reducing costs and selling to premium markets normally support this objective. The problem for coal suppliers, both export and domestic, is the over-supply trap. This results in squeezed margins, aggressive competition between suppliers, closure of high cost production capacity and - despite the immediate outlook - investment in new sources of supply with even lower costs.

This, along with the abundance of coal resources, would seem to enhance the security of supply for coal users but, with demand for internationally traded steam coal projected to grow by nearly 10% each year at least for this decade; this means over 100 million tonnes p.a. of new capacity must be developed by 1998. Supply may not always look so secure!

Second - suppliers' profitability. Internationally traded coal prices and cash costs of production have fallen by around 5% p.a. in real terms since 1982 although, in the last five years, the decline has ceased when measured in suppliers' local currencies; in other words the currency in which they pay their costs and dividends. Although the suppliers have suffered some pain, they have improved efficiencies, reduced costs, and by and large, survived since average prices have not

fallen below average cash costs in spite of many years of apparent over-supply. Although there may be scope for further real price reductions in the foreseeable future, we shall not see them coming down at the same rate as the 1980s.

For a coal supplier to invest in new capacity there must be the expectation of a reasonable return. However, it has long been only wise to test investments in substantial new production against prices that indeed reflect over-supply conditions. This implies that the financial justification of new production capacity will have to be much more rigorous and will act to moderate its introduction. The corollary is that, when major new production is committed, it will be capable of withstanding down-turns and will, of course, also pose strong competition to existing mines.

Also, suppliers must understand better the impacts of new investments from the points of view both of timing and how new capacity might affect future price movements. If nothing else, coal suppliers can rest assured that they are going to operate in a highly competitive intra and inter-fuel environment.

Finally, I want to touch on the issue of carbon tax. Let me emphasise, this is a concern not only for coal suppliers - who fear shrinking markets and falling margins - but also users - who emphatically recognise the value of coal as the best provider of energy security within their fuel supply portfolios.

There is a wide range of uncertainty about the effects which different levels of carbon tax would have in reducing carbon dioxide emissions. Studies by the IEA indicate that the imposition of a tax of $100 per tonne of carbon emitted (equivalent to $12/boe and significantly greater than the current price of internationally traded steam coal) would produce less than 10% reduction in emissions in OECD countries compared with the "reference" case representing "business as usual".

Enthusiasm for carbon taxes as a way of achieving environmental goals seems to be waning in many - but not all - countries. One can speculate on the reasons for this. The impact of coal burning on climate change remains uncertain, the threat to local economic advancement from carbon taxes levied on fossil fuels could be considerable - particularly in the developing world. And there are a host of practical considerations - not least, the difficulty of achieving consistent regional, let alone global application to what is clearly perceived as a global problem.

But there is also a more progressive side to this debate. Increasingly, alternatives to carbon taxes are emerging. For instance, voluntary actions between governments, suppliers and users are going to prove very significant. Examples include investment in more efficient plant (here I harp back to my previous point), a new push for combined heat and power projects, greater emphasis on conservation along the whole production-to-consumption chain, renewed consideration of recycling, development over the long-term of renewable energies, the protection of carbon sinks and possibly the encouragement of reforestation. But most important over the medium term is the benefit that must potentially accrue from technology transfer and co-operation with the developing world.

These measures all have the potential to be economically justified within a free market environment. But they are all areas that now deserve much more careful study to assess their respective contributions to environmental goals and, most important, their practicality in implementation. For me, the challenge for our industry is to shift emphasis to the vigorous study of alternatives to carbon taxes. I suspect that over a reasonable period we could be pleasantly

surprised that practical, workable and worthwhile alternatives will not have the adverse economic effects many have traditionally feared.

I started my talk by stating firmly that the one thing coal suppliers and users have in common is the need to take "The Long View". I hope that by now I have demonstrated that our view is indeed lucid and the landscape well defined. The plain facts are that economic development cannot take place without electricity and the electricity industry cannot manage without coal.

However, both suppliers and users in the coal industry each have important obligations. Suppliers must maintain coal's competitive position as a fuel by containing costs. And users must continue developing technologies that will allow coal to be burnt more cleanly and more efficiently. Finally, neither of these commitments will yield much at all unless all of us in the coal industry take the lead in making the case for coal to an often sceptical and sometimes uninformed public.

After all it is society at large - who also happen to be our end customers - who need to be assured that our "view" is both crystal clear and properly directed.

IEA SECOND INTERNATIONAL CONFERENCE
HONG KONG
30 NOVEMBER - 1 DECEMBER 1993

"THE REALITY OF COAL AND COAL TECHNOLOGY"

DR A C TOOHEY
CHIEF EXECUTIVE
WORLD COAL INSTITUTE

I welcome the opportunity of addressing you today on behalf of the World Coal Institute.

Our Institute, of some 32 coal producers in 14 countries, provides a coordinated voice for coal, disseminating the facts on coal. We work actively to:-

- promote the awareness of coal as a safe, secure and abundant source of energy for the world's electricity generation and industrial markets, emphasising the world's dependence on coal as energy demand rises;

- disseminate knowledge of current and new technologies available to improve efficiency and environmental performance in mining, transportation and utilisation of coal;

- coordinate the exchange of technology in both coal production and coal utilisation, while encouraging governments and international bodies to facilitate and support the transfer of technology, particularly to developing countries.

My address today is on "The Reality of Coal and Coal Technology".

The **REALITY** of coal commences with coal reserves - with estimates of coal reserves exceeding 220 years at current levels of consumption - some 4-5 times the equivalent reserves of oil and gas. However, it is not only the size, but the geographical diversity of the coal reserves that is the real attraction. More than 100 countries have viable coal reserves. Several countries are of course disproportionately well endowed with coal. China, the CIS and the USA together account for just over three quarters of the world's proven recoverable reserves of bituminous coal. However, the number of countries and players involved is enough to ensure dynamic, competitive growth - with no fear of a **COALPEC**!

The **REALITY** of supply diversity, and security via diversity, will have been evident from the preceding speech. Coal has of course been mined and burnt continuously for many thousands of years, since pre-historical times. The first organised mining industry was evident in Britain some 900 years ago, and of course the Industrial Revolution was based on coal - with the growth

in international commerce in the 19th century being based on the switch from sail power to steam.

The vitality of the international industry over recent years is shown dramatically by the manner in which the relative positions of major supply countries and customers have changed - and we now have more than 10 countries supplying substantial tonnages in the international market - which itself is just 10% of world production, thus offering scope for rapid growth.

The oil era, based on the international availability of cheap, convenient and apparently abundant supplies, only arrived after the Second World War. The need to balance the barrel, and coal supply problems, and of course straight economics, led to the rapid penetration of oil into the power generation market.

In 1955 coal accounted for 75% of total energy use in Europe (with petroleum just 23%). By 1972, coal's share had decreased to 22%, while oil had grown to 60% of total energy use. Over the last 20 years - the modern phase of the coal industry, and a period of increasing oil costs, the international coal market has been characterised by coal-to-coal competition throughout, and extended periods of over-supply. The commercial reality is that coal has displaced fuel oil from cement manufacture, and regained much of the power generation market from fuel oil.

We are now entering an era when methane gas (and LNG) will take a part share of the growth of the electricity market - apart from some doubtful economics in one or two cases, this can be seen as a complementary development. There is not enough gas available, technically or economically, and certainly not with sufficient supply security, to displace existing coal consumption on an international scale. It is a question of sharing the growing market - but when the gas runs out, coal will still be there!

I will not dwell on the nuclear power generation era, which had its heyday in the period 1960-1980. There have been too many accidents and incidents, reported and unreported - but most damaging has been the exposure, partly as a result of privatisation, of the true economics and security risks inherent in fuel reprocessing and in the final decommissioning of fuel reactors -the first of which are now ending their economic lives. The nuclear industry has the time it needs to solve its problems - the coal industry will welcome competition in 50 years when the oil and gas run out, provided we don't have to subsidise the high costs of nuclear electricity!

Other speakers will cover the rising aspirations of the third world, and the organisers are to be praised for the time devoted to the needs of developing nations at this Conference. Demographic considerations alone mean that an increasing percentage of the world's population will live in such areas, and no one can feel happy with a scenario which does not allow for improvements in per capita living standards. Over recent decades, any rapid growth in the third world has often been at the expense of the environment, but greater awareness of the transnational nature of pollution, and the relative cost effectiveness of investment in the

third world in solving global pollution problems, should mean more coordinated and

environmentally acceptable growth in coal mining and utilisation in these countries, in the future.

The reality of the growth in the use of coal lies in increased use in the third world. Developing countries currently account for about one third of world energy consumption but this will climb continuously, rising to more than half within 25 years. A lot of this growth will come from countries such as China, India, and Indonesia - countries having large indigenous coal reserves - and it is neither economically nor politically realistic to expect that the increased demand for electricity in these, and most other developing countries, will not be coal-based.

It should be recognised that the problems associated with combustion of coal in the developing world can be more severe than say, in Europe. It often makes most commercial sense to burn the lower rank or lower quality coals in the local market - those seams with the highest ash contents, or which cannot be beneficiated economically, as run-of-mine coal. This can pose problems - all of which have been solved before in Germany - or Queensland - or Southern Africa - or the American Mid-West.

There are of course those who would dictate to the third world the standards that they should apply in providing for their future energy needs. This can be as unhelpful as the attitude that the first world has an obligation to fund developments in the third world to compensate for pollution caused over the last century.

What is needed of course is a carefully coordinated programme - requiring a near super-human non-nationalistic approach to the search for global solutions. Thus far, the political agreements are perhaps running ahead of the true understanding of the problems. Indeed, most of the current environmental debates - and the regulations and taxation proposals flowing from them -are characterised by the reluctance to accept how little we know. There is an almost naive belief that improvements can be achieved at negligible cost, and that anything that involves recycling or reduction of pollutants is automatically sound.

It is also becoming clearer that even if the OECD countries were to achieve CO_2 stabilisation via taxation, the global impact would be minimal. What is needed is an economically strong first world, financially capable of helping the third world countries to develop their economies. It is certainly true that the higher the level of financial stability, the greater the ability to address the environmental issues.

I am sure that we will hear much on the difficulties associated with technology transfer and the funding of the investments needed to meet the energy needs of the future - and I would certainly commend simplification of the legal and fiscal regimes necessary to encourage joint ventures. It is obvious that participation with a major first world coal mining associate will bring exposure to the full process of technical and economic feasibility studies, with the associated environmental impact statements and project funding analyses - certainly true if you are dealing with one of the members of the World Coal Institute! My own experience of joint venture coal mines is also that, apart from the direct employment opportunities and staff training offered, there is a massive benefit in terms of the support of general educational and vocational training

facilities in the area. There are also endless commercial opportunities in support of the needs of the mine and its associated community; - all of them very real benefits, quite apart from the tax paid, and foreign earnings achieved in the case of export ventures.
Similar economic and political realities also dictate that the use of coal in first world countries will increase. The substantial role of coal in power generation in OECD countries over recent years, or equally in the European Community countries, comes as a surprise to many people. There is no doubt that unless the coal industry maintains these supplies, and takes its share of the growth in demand, the surprise would be even more real, and most unpleasant. I suppose one could claim that this lack of appreciation of the place of coal is an indication of just how cleanly coal is now mined, transported and burnt in these areas - but the truth is that the lack of appreciation of the facts concerning the true role of coal can lead to the development of economically damaging energy policies, offering so-called "solutions" to problems not yet properly defined.

It is now starting to emerge that the rush towards re-cycled paper needs review. Policies and public pressure were based on the unproven assumption that the use of re-cycled fibre was better for the environment - but more detailed life cycle analyses of a complex problem have led to the realisation that processes involved in extracting the wood fibre from the inks, clays and other fillers lead to significant volumes of sludge, while also producing more "acid rain" and "greenhouse" gas emissions. While every case is site specific, it appears that the most environmentally benign solution involves the use of virgin fibre from properly managed reforestation programmes. There is also the example of the arbitrary regulation concerning the collection 30% of plastic packaging waste in Germany. This was too much for re-cycling, so the excess was sold below cost - the other form of "dumping" - in neighbouring European countries, destroying the viability of their recycling industries - so the % is now being reduced, I believe. Also in Europe, one wonders whether the drive to ever lower sulphur contents of automotive fuels makes sense in terms of the energy expended, and the fact that some ten times as much CO_2 is emitted compared with the SO_2 eliminated.

Overall, we certainly expect to see world consumption of coal growing at some 1.5% per annum, and international trade growing at some 7% for the rest of this decade, and beyond.

Thus, one of the problems that all of us in the coal industry face is to improve the public awareness and perception of coal. Some of the WCI material - brochures and videos - is designed to assist at the scholar level. The size of the problem is evident from a recent survey in New South Wales, source of much of Australia's coal. 43% of those interviewed in a recent survey admitted that they knew hardly anything about the industry, more than half did not know that Australia relied on coal for electricity generation, and this in a country which generates more than 80% of its electricity from coal!

In some countries, in the early post war years, open pit coal mining operations were allowed to leave unsightly scars - the result of irresponsible operations and lack of regulatory controls. Over the last 15-20 years, such operations usually leave an area, after reclamation, which is better than before mining commenced. Regulations can of course go overboard - such as requiring land to

be restored as agricultural land, rather than an area of wildlife habitat or leisure parks - while farmers in the area are paid to take land out of agricultural use!

Not surprisingly, worldwide experience shows that there is a high correlation between knowledge of an industry and a more positive attitude towards it. This is the challenge we all face - any environmental debate needs to be an informed debate.

The industry almost seems to delight in perpetuating the "dark and dirty" image. Advertisements, brochures and reports have pictures of coal tips, coal mines and miners at the end of a shift - we should be extolling the benefits of electricity, and the fact that it can be and is produced cleanly from coal. The oil industry tend to advertise the leisure activities associated with automotive transport - not refineries and operators cleaning out distillation columns!

WCI's job is to reach the parts that national industry associations cannot reach; to speak for coal on a worldwide basis; and to ensure that the decision makers in the UN and other international organisations are fully briefed on the importance of coal worldwide.

The impact of coal utilisation is a subject of concern to all.

In the industrial market, combustion of coal in modern boilers and smaller fluidised bed units does much to alleviate the environmental problems of the past. But in this area, and even more so in the domestic heating and cooking sector, there is ample scope for conversion to electricity - bringing with it the wider spectrum of the benefits of civilisation, as well as a better environment. It is well said that after food, clothing and shelter, mankind needs electricity!

About half of the world's coal production is used in the generation of electric power - and conversely, just under half the world's electricity is derived from coal. Years ago, the prime environmental concern was with smoke and dust - but the ability to remove particulates by electrostatic precipitation and filtration, and improved combustion techniques, has led to the easy elimination of these problems in all modern power stations.

There are true stories from Sweden of the conversion of a major oil-fired power station, situated close to a residential area, with the local populace being unable to discern any difference despite their preconceptions of the problem of black smoke. What a pity that so many publications continue to feature pictures of power station cooling towers, with their plume of white water vapour taken in silhouette, and shown in black and white, with a "dark" plume take as evidence of the harmful emissions of fossil-fuel combustion!

Over more recent years, the pressure has switched to the removal of gaseous pollutants from stack gases - in particular, the oxides of sulphur and nitrogen, as their role in acid deposition became clear. Problems were often site specific - especially as many coals, and particularly internationally traded coals, had sulphur contents lower than the residual fuel oils they displaced from power generation, after the oil price rises of 1973 and 1978. Various technologies for the removal of sulphur are now well-refined, and flue gas desulphurisation techniques are well

established commercially - to the extent that few first world countries would permit new power stations without adequate controls of sulphur emissions. More difficult, throughout the world, is the problem of justifying FGD retrofits to existing plants - which can be a very expensive process. However, one can envisage solutions in which generators are encouraged to move towards the newer clean coal technologies, giving even greater levels of sulphur removal as well as increased efficiency, albeit at an increased capital cost. In third world countries, the replacement of aged equipment by current PF combustion technology with FGD can also find justification in terms of improved efficiency and improved quality of life.

Oxides of nitrogen can be controlled to acceptable levels via the use of specially designed burners, or through catalytic reduction.

Many examples of highly efficient, clean burning applications with well proven technologies now some 10 to 15 years old abound in Scandinavia, Holland, Germany and Japan - to name but a few. These are the designs which we should seek to promote in the rapidly industrialising economies of Eastern Europe and Asia, and of course, in the Third World.

The newer technologies, of which we will hear much in the next few days, are now reaching commercial reality - I include various designs of Pressurised and Circulating Fluidised Beds, and the IGCC Integrated Gasification Combined Cycle plants - in the latter case, the Dutch utilities are now commissioning the world's first commercial scale unit. These newer technologies offer substantially improved performance in terms of removal of pollutants (and even turning them into saleable by-products) - and also, of course, through higher efficiencies give a means of reducing the carbon dioxide production per unit of electricity generated. I would suggest that many improvements will be achieved during the first decade of implementation of these technologies, which will then be ready for worldwide dissemination.

One would like to see state subsidies or inducements diverted to encouraging commercialisation of such technologies - rather than subsidising uneconomic coal, or even worse, uneconomic nuclear! The switch to lead-free gasoline has been achieved via inducements - why not the switch to improved power generation? Some funding of Research and Development is available - but more is needed.

Research into improving these newer technologies, into improvement in turbine performance and into alternative technologies is ongoing - but obviously could do with financial and fiscal support to accelerate the commercial demonstration phases.

The reality is that clean coal technologies are now at the first step of commercialisation. Will the improvements in efficiency be enough to stabilise or reduce CO_2 levels? Not on their own - remember that CO_2 from coal-fired power generation is responsible for only about 10% of the manmade enhanced greenhouse effect.

What is most unfortunate at the present time is the swamping and near suppression of any voices querying the seriousness of global warming, or the supposed consequences of global warming.

So much depends on the modelling of climate behaviour, without having sufficient knowledge yet of the behaviour of sources and sinks. Unfortunately the chaos theory that describes the climate has pervaded the environmental debate.

There can be no doubt that the world needs to do more to husband scarce fossil fuel resources by using them efficiently. It is perhaps less certain that the imperative to reduce CO_2 emissions to levels below 1990 levels has been scientifically proven. Some of us remember the dire warnings of the sev nties concerning the imminent onset of the next ice age - and NASA scientific observations show no temperature rise over the last 15 years. Maybe the position will be clearer 15 years from now - but in the meantime lets avoid the certainty of the economic penalties that half-baked solutions such as carbon taxes would bring.

Although there has been some limited introduction of carbon or energy taxes, some signs of reality are also apparent. In the Netherlands, the latest National Environmental Outlook shows clearly that current measures (including a tax now equivalent to some $ 14/ton of coal) will be insufficient to stabilise, let alone reduce CO_2 emissions by the year 2000. The Japanese parliament has also, last month, backed off the imposition of taxes that would have caused even more harm to an economy already struggling to recover its momentum. The US administration has been required to replace more draconian measures with a call for voluntary restraint.

It is perhaps well to remind ourselves of the words of Article 4 in the Rio Convention on Climate Change:

> "The Parties shall, in accordance with Article 10, take into consideration in the implementation of the commitments of the Convention the situation of Parties, particularly developing country Parties, with economies that are vulnerable to the adverse effects of the implementation of measures to respond to climate change. This applies notably to Parties with economies that are highly dependent on income generated from the production, processing and export, and/or consumption of fossil fuels and associated energy-intensive products and/or the use of fossil fuels for which such parties have serious difficulties in switching to alternatives."

As the world struggles to climb out of recession, and as the most optimistic forecasts show the difficulties that the third world will face in funding the future, it is unreal to believe that international stability can be achieved and maintained without allowing the growing third world population to achieve a higher standard of living - and that means electricity, and that means **COAL**. It is unreal to believe that these countries can afford the more expensive, more capital intensive routes to electricity - even if alternative fuel supplies were available, the money and skilled resources are lacking. Certainly within the World Coal Institute, our members are committed to assisting in the development of projects throughout the world to deliver **REAL** supplies of the fuel on which the world has relied, **does** rely and can rely in the foreseeable future.

Let's help them burn it efficiently and cleanly!

The Technological Pathway for Coal

Remarks of Mr. Jack Siegel at the IEA International Conference on the Clean and Efficient Use of Coal and Lignite

Today I would like to share with you some observations as to where we have been, where we are and where we are going on the coal technology pathway. Twenty years ago the world was faced with an impending oil embargo crisis. This led to the realization that we would have to rely more heavily on coal as a source of energy. This reliance would have to be made within the environmental requirements established in the relatively new Clean Air Act. The coal technology community was now challenged with the following:

- Technologies must be developed to reduce dependency on imported oil through conversion of coal liquids or gases and to expand coal use in power generation and thus decrease our dependence on imported oil.

- Reliance would be placed on technologies that could achieve the environmental goals established in the Clean Air Act.

Industry and governments around the world marshalled their intellectual, financial, and management resources to meet the challenge. New coal utilization technologies, such as atmospheric fluidized-bed combustion, pursued in the 1970s would be commercially deployed in the 1980s at the industrial scale. The IEA would be established and would pursue a number of technology development efforts. One of these efforts was the cooperative effort among the United Kingdom, Federal Republic of Germany and the United States to develop pressurized fluidized bed combustion at Grimethorpe. Lime/limestone flue gas desulfurization would come into commercial use on utility and large industrial-sized boilers. Although reliability and operability were a source of concern and a major technical challenge, they were overcome in large measure by the work of the Electric Power Research Institute. A number of coal liquefaction processes would be pursued at the pilot plant scale. Major

demonstration projects would be initiated in the 1970s to ensure that supplies of transportation fuels would be secure from interruption. Technologies, such as coal/oil and coal water mixtures, which would allow coal to directly displace oil in boilers would be developed and in many instances successfully tested. Interest would be renewed in coal gasification technologies to produce a substitute natural gas and synthesis gas for production of liquid fuels and chemicals. Research and development efforts would be directed toward the environmentally benign coal-fired open and closed combined cycles. When we emerged from the 1970s, coal technologies were being pushed along a broad front and with many successes. The technology pathway for coal had indeed been charted.

As the 1980s dawned, a significant milepost along the pathway was represented by the passage of major legislation contributing new goals and programs. For example, the Energy Security Act of 1980 established goals for the production of synthetic fuels and provided $88 billion in incentives to establish a synthetic fuels industry in the United States. The goals were production of 500,000 barrels of oil equivalent per day of synthetic fuels by 1987 and, in a second phase, 2 billion barrels of oil equivalent by 1992. The Synthetic Fuels Corporation was established to manage the program. The use of the SFC to advance synthetic fuels technology was a departure from the traditional government acquisition approach to coal technology. The SFC was to be primarily a financier with the industrial participant maintaining ownership. The SFC had available a variety of financial incentives to stimulate construction and operation of new facilities by industry but used only loan and price guaranties. Only price guaranties proved to be effective. The SFC had some success in advancing coal technology along the pathway. Most notable were the Coolwater Integrated Gasification Combined Cycle Project and the Dow Syngas Project. Both of these projects provided the technical underpinnings for the highly efficient IGCC projects of the 1990s.

During the early 1980s, Federal support to coal R&D was limited to long-term, high-risk R&D that would not otherwise be pursued by industry. However, the mid-1980s saw a change in emphasis on coal technologies which included:

- Explicit recognition of "acid rain" concerns. Retrofit cleanup technologies received increased emphasis.

- Pursuit of technologies which would allow the clean use of high-sulfur coal in new and repowered facilities.

- Reduction in priorities given earlier to coal liquefaction because of the high cost of the product and reduced concern about the "liquids problem."

- Growing emphasis on technologies to assist in expanded use of coal in industry and other non-utility sectors.

- Recognition of electric utilities' interest in smaller, modular plants with improved efficiency and high environmental performance.

In 1984, funding for the SFC was rescinded by Congress. In light of falling energy prices, deficits and budget cuts, the Corporation was formally abolished in 1985. However, $750 million from the rescinded SFC funds were put into a special account, entitled "Clean Coal Technology Reserve." This account was dedicated to "conducting cost-shared clean coal technology projects for the construction and operation of facilities to demonstrate the feasibility of future commercial application of such technology." This began the Clean Coal Technology Demonstration Program, a highly significant milepost along the coal technology pathway. In the beginning, the program was to demonstrate those technologies which could lead to increased coal use in an environmentally acceptable manner. In 1987, the President initiated a major expansion of the program by supporting the recommendation of the U.S. and Canadian Joint Envoys on Acid Rain to demonstrate technologies capable of reducing precursors of acid rain. The program was expanded to a $5 billion joint industry/government cost-shared program where industry was required to assume at least 50 percent of the project cost. Since that time, the program has progressed through a series of five nation-wide competitive solicitations conducted over nine years. Each solicitation was associated with a specific level of funding and with a defined objective. At the end of the five originally

planned solicitations, 45 projects valued at more than $6.8 billion are moving forward. Government funding for the projects is about $2.75 billion. Private industry provides 66 percent of the projects' value. Today, three projects have been completed, 21 are operating and 21 are in design or construction.

We have fifteen advanced power generation system projects valued at more than $4.6 billion. These projects are characterized by high efficiency and low SO_2 and NO_x emissions integral to the combustion/conversion process. The high efficiency of these systems will allow reduction in CO_2 emission which is so important to the global climate change partnership being forged today. These technologies offer a high degree of fuel flexibility which enhances the use of domestic and international coals. The bulk of the advanced power generation system projects will produce technical, environmental and economic performance data in the latter half of the 1990s. This is compatible with most utility expansion plans. Sufficient information and data should be available to impact decisions to repower existing facilities to meet the Phase II emission requirements of the Clean Air Act Amendments.

Environmental control systems encompass the largest number of projects; 20 valued at more than $0.7 billion. General characteristics include high pollutant capture efficiency which contributes to reduced costs and the mitigation or elimination of solid waste management problems. Most of these projects will have their operating experience documented by 1995, with almost all of the NO_x control projects completed by the end of this year. Reports indicate that the SO_x emission reduction targets, established in Phase I of the Clean Air Act Amendments and to be implemented by January 1, 1995, will largely be met by fuel switching, emission credit trading and other non-technical solutions. The more stringent Phase II limits which will occur in 2000 will most likely require technology solutions. These solutions will utilize the SO_2 and combined SO_2/NO_x emissions control technologies demonstrated under the Program.

There are five projects in the coal processing for clean fuels application category. The project value is $0.4 billion. These technologies are characterized by the production of high energy dense solids, stable compliance fuels, and co-production of coal derived liquids that

can be used as chemical or transportation fuel feedstock. The schedules for the completion of these projects are varied but several will be commercially available for consideration in fuel switching scenarios for compliance in Phase I of the Clean Air Act Amendments.

The final applications category involves the industrial application of clean coal technology. This category contains 6 projects valued at over $0.6 billion. Included are 3 coke oven emission control projects, a highly successful coal-fired cement kiln application and two industrial-scale combustion projects.

The Clean Coal Technology Demonstration Program has seen a number of achievements to date including:

- A commercial replication of the atmospheric circulating fluidized-bed combustion technology at the 100 MWe scale. This is a direct consequence of demonstrating the technology at Colorado-Ute between 1988 and 1991.

- The first U.S. application of pressurized fluidized bubbling-bed combustion at utility-scale of 70 MWe has operated for over 5,000 hours. A circulating bed version nears construction so that an alternative approach can be evaluated.

- Five different approaches to the integrated gasification combined cycle systems are on the pathway to full-scale demonstration. These projects will cover a broad spectrum of gasifier types, coals, gas cleanup systems and operating conditions.

- Advanced power generation system options are being expanded through the demonstration of an externally fired combined cycle system, a coal-fired diesel and an integrated gasification combined cycle fuel cell.

- Two advanced hot flue gas desulfurization technologies are achieving 95% SO_2 capture and producing wallboard grade gypsum.

- Six NO_x control options covering the full range of boiler types are in the latter stages of operation. Three of these systems have been adopted for commercial use by the host utility. At least one commercial sale outside the host utility has been realized for one of the technologies.

I would now like to spend the remaining time to share my views on where the coal technology pathway will lead in the future. In 1992, the U.S. Department of Energy enhanced the prospects for success at both the R&D and demonstration phases of technology development by fostering the close integration of the Clean Coal R&D Program and the Clean Coal Technology Demonstration Program. The resulting Clean Coal Research, Development and Demonstration Program provides a continuous pathway from fundamental research through demonstration with a view toward commercial deployment.

Between now and the early 2000s we will complete the Clean Coal Technology Demonstration Program as originally conceived. In May 1994, we will complete an assessment of what needs to be done to assure successful completion of the program. This could involve a program to enhance the commercial potential of the technologies being demonstrated by identifying opportunities to improve the technical, environmental, economic or operational performance of the technology. Then, using the existing demonstration facility, we can embark upon an enhancement project to improve the commercial deployment potential of the technology.

There is broad recognition that the coal technology pathway leads to international markets. This was recognized in the export initiative contained in the Energy Policy Act of 1992. This initiative involves:

- DOE cost-sharing up to 50 percent of project definition activities. This includes efforts by U.S. industry to export U.S. technology, equipment, and/or services.

- DOE assisting the sponsor in working with financial institutions such as the Export/Import Bank to ensure financing is in place when needed.

- DOE cost-sharing demonstration of some high risk but potentially high pay-off technologies. These demonstrations would be in selected countries where opportunities exist for U.S. industry.

The Secretary of Energy recently announced that a high priority plan by the Department of Energy is to support a cost-shared demonstration in China of advanced technology to produce clean efficient electricity.

We have established definitive long range mileposts along the technology pathway. For example, by the year 2010, it is our goal to demonstrate advanced coal-fired power systems with more than 55 percent efficiency while controlling SO_2, NO_x and particulate emissions to less than one-tenth of the levels required by the Clean Air Act Amendments.

We understand the deep-seated environmental concerns about coal use which abound worldwide. We also are convinced that the coal technology pathway we have traveled and will be travelling will lead to a significantly enhanced environment. We also are convinced that our travel along the coal technology pathway will lead to a sustainable environment for future generations.

IEA SECOND INTERNATIONAL CONFERENCE ON THE CLEAN AND EFFICIENT USE OF COAL AND LIGNITE: ITS ROLE IN ENERGY, ENVIRONMENT AND LIFE

KEYNOTE SPEECH: *COAL IN THE 21st CENTURY*

RUSSELL HIGGINS

EXECUTIVE DIRECTOR, MINERALS AND FISHERIES GROUP, DEPARTMENT OF PRIMARY INDUSTRIES AND ENERGY, AUSTRALIA

This conference is addressing fundamental aspects of the most important issue we all face as we move through this decade: our future energy security and how we ensure it.

The conference takes on extra significance because of its location Asia; and, more specifically, here in Hong Kong - in the heart of Asia-Pacific, the region where energy growth into the next decade will be higher than in any other region of the world.

Australia has been particularly active in the Asia region - bilaterally with our regional trading partners, as well as in the International Energy Agency and the Asia Pacific Economic Cooperation forums - to build up a sound edifice of common energy security through assurance of energy supply.

Our close association with this conference, of which we are a co sponsor, is a reflection of our commitment to regional energy security.

There was a time when assurance of energy supply might have meant simply securing access to energy resources.

Today, it means much more. It includes the surety of political and public acceptance of the sources of energy supply - principally the means of electricity generation.

The focus of the conference is coal - the most abundant and readily accessible energy source of the region; but a source which is particularly vulnerable to environmental and public expectations.

We in this region - embracing Asia and the Pacific - need to work together and in cooperation with members of the International Energy Agency to ensure that our future energy is secured through the most economically efficient and environmentally acceptable use of energy sources - and, in particular, coal.

Coal has the potential to provide the bulk of our new energy requirements in a reliable, secure, and economically efficient way.

Asia-Pacific is particularly significant in terms of energy trade. Coal trade will be a vital key to the region's future economic growth. Between now and the year 2000, demand for black coal in the region is expected to increase by 1.1 billion tonnes to 3.4 billion tonnes.

In the year 2005, the region is expected to consume almost three-quarters of the world's black coal production.

Seaborne steaming coal trade within the region by that year will be 190 Mt per annum, or almost 50 percent of total world seaborne trade.

A focus on coal trade within Asia-Pacific is appropriate because the resources and production capacity of the region will be more than sufficient to meet even the high rates of demand growth forecast for the region. This underlines the need for us all to ensure the optimum conditions for growth in production.

1. Determining the destiny of coal

This conference is about change - the changes that are on the horizon for the coal industry, the challenges those changes impose on the industry, and the responses we might make.

How important coal will be in the international energy economy will be greatly influenced by the attitudes of today's energy decision-makers.

Coal is the most likely option for supplying the bulk of new electricity demand well into the next century.

Natural gas has an important role, of course, along with nuclear and, more importantly, improved efficiency from all sources. Renewables will be able to make only a relatively minor contribution.

With this in mind, I believe we must decide now that the industry has a positive growth outlook. And we must put in place commercial and government policies designed to bring about the future we want for coal.

To do so, will require cooperation between the parties along the whole length of the coal chain - exploration, project planning and development, mining, - through the chain to utilisation. These parties will need to have a common commitment to assisting each other to ensure coal remains an economic source of energy that progressively improves its environmental standing and acceptance.

This conference can and must contribute to the achievement of that goal.

2. Setting our Goals

I would like to propose a list of strategic actions necessary if we are to get the most out of coal in the next century. These actions are directed at responding to two key questions:

First: What sort of coal industry do we want in the next century?

Is it to be an industry characterised by growth, that is environmentally responsible and economically competitive; or will it be one that is environmentally constrained and subsidised and is, therefore, likely to decline?

Given the unquestionable role that coal has to play in the foreseeable future, it is not necessary to take sides, pro or anti coal, in order to understand that we have an obligation to utilise coal in the most economically efficient and environmentally responsible manner.

If this is to occur, then massive investment in production, transport infrastructure and utilisation will be required from private and public sources.

Investment on the scale required will simply not occur unless there is a prevailing expectation that coal is going to be a growth industry in the long-term, with levels of return to investors consistent with returns available elsewhere.

Secondly: What character and style of industry do we wish to create?

Is it to be an industry that has general community support; or will it be one that is viewed as a necessary evil?

The size and importance of the international coal industry are barely grasped by the general public, whose opinions, quite properly, drive so much of government policy - particularly environmental policy.

Policies for growth in the industry will be insufficient unless they win the political battle and establish coal as the leading energy material for the 21st century.

3. Strategies for Action

Achieving the ambitious goals I have proposed will require agreement on actions by individual countries and groups of countries, to maximise the benefits of coal.

A challenge for this conference is to formulate the mechanism by which such cooperation can be achieved.

I believe the actions required fall under four headings:

- technology;
- coal promotion, linked closely with research, development and demonstration;
- market reforms; and

- international cooperation.

I. Technology

Technologies for coal-fired power generation - the conventional, the new and advanced - will play a critical role in deciding the future for coal.

How critical this role might be will depend as much on the approach we take to its application, as on the technical performance standards of the technology.

Many factors come into the choice of technology appropriate to a particular application, including environmental standards, choice of site, plant capacity required, possible uses for waste material, other plants in the system, and so on.

Attention has focused, in particular, on environmental performance and relative economics.

The improvements that can, and are, being made in conventional technology, will need to be assessed next to the advantages offered by integrated, advanced systems.

Comparative performance

There is a pressing need for an improvement in the quality of information on the new technologies, and, in particular, a need for comparative economic analysis of all alternatives.

The cause of the new technologies will be best served if there is freely available, objectively based, information to determine their relative competitiveness.

A study of advanced power generation options by IEA Coal Research concluded that existing publications could not be relied on for comparative studies.[1]

The study suggested that such publications tend either to extol the virtues of particular schemes in isolation or else to evaluate a limited range of options in relation to requirements for a specific project. It considered that they seldom provide sufficient background detail, so that it is difficult to ensure that information taken from different sources is comparable.

Some of the literature seems to be comparing apples with oranges: hypothetical efficiency of the new technologies with the efficiency achieved to date in the day-to-day operation of conventional technology.

When there are only two or three percentage points difference in such comparisons, as there are in some cases, it becomes critical that the comparisons be soundly based.

The marginal cost of achieving these percentage points improvement appears primarily aimed at reducing carbon dioxide emissions.

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[1]IEA Coal Research: *Advanced Power Generation - A comparative study of design options for coal*, March 1993, page 72.

Caution is necessary if we are to avoid driving emission standards even higher by overstating the potential of new technologies for reducing emissions, particularly when less costly methods that do not require fundamental changes to the nature of our energy supply may be more readily available.

For example, more may be gained from raising the efficiency of conventional power plants already operating than through investment in new technology.

Raising the thermal efficiency of all pulverised coal plants in Asia and the Newly Independent States to, say, thirty five percent - achievable under standard operating conditions - could have a major impact on greenhouse gas emissions.

Quantifying the benefits and of measures such as this would be an appropriate task to place in a broader context consideration of new technology.

SOx and NOx control should also be compared, of course, and the merits of integrated technology objectively compared, in *economic* terms, with their control in conventional technology through add-on systems.

Coal requirements

Along with improved comparative information on performance characteristics, there is a continuing need to ensure the availability of information on coal characteristics. Such information is necessary to optimise performance.

Coal suppliers can assist in ensuring the right matching of competitively priced coal to the chosen technology, but they require open access to the results of research and demonstration projects to be in a position to continue to supply their customers in a freely competitive market.

Regardless of the preferred technology, the first and essential step in the clean coal chain is a competitive, reliable supply of coal that meets appropriate environmental standards.

Investment analysis

For new plants, comparative analyses of economic and environmental performance are essential. I do not think that there is yet any clear-cut technical route for new projects.

Consider, for example, the following mix of claims and expectations:

- Existing pulverised coal plants, operating at super critical pressures, can achieve thermal efficiencies around forty three percent, even after control of sulphur dioxide and nitrogen dioxides.[2]

- The demonstration Integrated Gasification Combined Cycle (IGCC) at the Buggenum plant in the Netherlands is designed to achieve the same level of efficiency as this.

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[2]Report to the IEA Committee on Energy Research and Technology, *Electric Power Technologies: Environmental Challenges and Opportunities.*

- Ultra super critical pulverised coal plants, operating at efficiencies in the range of forty five to forty seven percent, are expected to be commercial by the late 1990s.

- In the same time frame, IGCC plants are expected to achieve efficiencies of about forty six percent.

Thermal efficiency, however, is not the complete story so far as environmental benefits of the new technologies are concerned.

Nevertheless, whatever the environmental merits of the new technologies may be, they are not sufficient grounds, in themselves, for justifying the scale of investment required. It must be shown that they are the most economically efficient and technically feasible option for achieving environmental goals.

In the final analysis, utilities will make decisions about the technology appropriate to their needs on a hard-headed assessment of benefits and costs quantifiable in financial terms.

It will be of critical importance that early experience of the new technologies justifies the claims being made of them, if they are to have a long-term future as the established technology.

Failure to perform to expectations in commercial applications could be damaging to all our interests.

For these reasons, it is essential to maintain an even-handed approach to technology that reflects the most efficient and environmentally sound use of coal.

ii. Promotion and Research & Development

Community Attitudes

The Australian Coal Industry Council - a body of government, companies, and unions - recently published a report on community attitudes towards the coal industry[3].

The report reveals that knowledge of the coal industry is poor, even though coal is Australia's largest commodity export.

For example, when asked what coal is used for in Australia, electricity generation was specified by only forty five percent of those interviewed; and steel-making was specified by only fifteen percent.

In contrast, home heating or burning was specified by twenty four percent, despite the fact that the use of coal for home heating in Australia is negligible.

To appreciate the huge knowledge gap this information reveals, consider the reality: coal supplies forty percent of Australia's energy, far higher than in North America (twenty three percent) or for OECD countries in total (twenty one percent).

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[3] *Report on Community Attitude Survey*, prepared for the Australian Coal Industry Council by Corporate Impacts Pty Limited, February, 1993.

To appreciate the huge knowledge gap this information reveals, consider the reality: coal supplies forty percent of Australia's energy, far higher than in North America (twenty three percent) or for OECD countries in total (twenty one percent).

Coal is the dominant fuel for electricity generation in Australia, accounting for about eighty five percent of electricity generation. Electricity generation, in turn, consumes about eighty percent of domestically used coal in Australia. Most of the remainder is used in the steel industry.

Competitively priced coal underpins Australia's energy supply, our balance of payments, and, hence, the well-being of every Australian, yet the survey revealed that one in four considers coal will be an unimportant industry in thirty years time.

Similar results have been found elsewhere. Such findings have an important bearing on the future of the coal industry.

Public attitudes, no matter how misconceived, feed into political decision-making and policy. Political leaders are responsible and responsive to the electorate.

We would be doing a disservice to the public, however, if we did not try to raise the level of understanding about such critically important matters.

Coal promotion is misunderstood by some as a form of advertising, with the implication that the industry is seeking to mislead for short-term gain.

This is certainly not what I have in mind, but I do consider that there is a need for concerted action to provide easily read, accurate and balanced information on the role of coal in the international economy, its environmental impact, and its importance for individual countries.

The survey I mentioned earlier revealed a strong desire on the part of the general public for such information.

The IEA has made a useful contribution to the type of promotion material I have in mind. A good example of this is its publication, *Clean Coal Technology: Options for the future*, prepared by the Working Party on Fossil Fuels and published by the UK Department of Trade and Industry.

This seems a well balanced statement, with the right mix of technical information and readable style.

IEA Coal Research

Coal promotion should bring to a wider audience the results of current research. IEA Coal Research undertakes an important part of this role.

As most of you will know, IEA Coal Research is an organisation for information collation and dissemination.

Its publications provide independent and objective analyses of coal issues - from production to utilisation and waste disposal. IEA Coal Research has a distinctive

role because of its international character and its reputation for plain language reports on difficult subjects, based on exhaustive literature searches.

Australian Coal Research

Research is fundamental to technical progress in the industry into the next century.

Australia's coal research program is undertaken by a diverse range of institutions - public, private, academic and industry - and covers black and brown coal.

Our research programs are consciously focused on commercial gains, based on our national skills and interests in coal production and transport issues. We believe that these areas are the ones in which we can make the greatest contribution to ensuring coal remains competitive and environmentally acceptable.

Economic and environmental improvements in coal utilisation and longer-term work on coal conversion are of critical importance. We support work in all these areas, albeit at a lower level.

iii. Market Reforms

Restructuring

Australia's coal industry grew rapidly following the oil price rises of the 1970s; suffered a major contraction in the early 1980s, as the energy market re-adjusted; and has since been in a process of continuous restructuring.

Apart from assistance for retraining, there has been no government intervention in restructuring, despite numerous mine closures, employment losses and severe regional economic impacts.

Many - probably all - the Australian mines that have been forced to close are economically superior to some mines that continue to operate in other countries.

Generally speaking, the work force has accepted the need for restructuring and the need for work place reforms as the only means of achieving long-term survival in a competitive international market.

It is relevant to describe the manner in which Australia has gone about restructuring and our undaunted intention of continuing to do so, because we have a reputation for seeking similar hard decision-making from other nations.

We know from our own experience that there is a transitional economic cost, and, more importantly, a heavy social cost.

The prospect for the 21st century is nevertheless for a highly competitive international coal industry, with each nation gaining from enhanced industry efficiency, through competitive energy pricing.

There are parallels between this restructuring and changes now occurring in the Newly Independent States (NIS). The ultimate goal of any international action must be to bring the NIS into a free international economy.

The policy instruments used to reform the energy industries of the NIS should be designed for this goal, which may mean resisting short-term direct aid programs in favour of building up an internal entrepreneurial spirit capable of matching competition elsewhere.

As in our own countries, there should be no illusions about the difficulties of restructuring.

General Trade Reforms

The international coal industry has set the example for reform that is now possible for other industries if the GATT is successfully concluded this month.

Coal does not stand to gain directly from the GATT, but there is no doubt that a general freeing up of world trade will benefit world economic performance, contribute to growth, and hence energy demand.

The prospects for coal in the 21st century are thus very closely linked with general economic and trade reforms.

Discriminatory Energy Pricing

I have a lingering concern about the steady freeing up of world energy trade.

That is the possibility that price distortions may be introduced into world energy markets on environmental grounds.

Carbon taxes are one example of this mentality, but others are possible if arbitrary decisions are made about the environmental or social desirability of one form of energy over another.

The problem harks back to the issue of community attitudes I mentioned earlier. There may well be public pressure to introduce discriminatory policies on slender evidence.

Once in place, such measures, including carbon taxes, will be difficult to reform, as they find a place in the budget framework as revenue measures.

Security of Supply

A driving force behind maintaining expensive domestic sources of energy is energy security. Energy security is essential to economic well-being and social stability.

Unlike other energy sources, the very abundance and world-wide distribution of coal offers the best guarantee of energy security that could be given.

Australia alone has resources to meet its current level of production (and therefore exports) for over 300 years.

The threshold condition for continuity of supply through exploration and development of new resources is a satisfactory return on invested capital.

The corollary of assured supply is long-term commitment to producers and preparedness to pay prices reflecting this commitment.

We should not forget that market reforms and stimulating world economic growth underlie much of what will be discussed in this conference, whether it is finding funds for research programs, investment to ensure supply, or financing new power stations.

iv International Cooperation

There are clearly mutual benefits for us all if we can establish a sound basis for international collaboration in the area of promoting clean coal utilisation.

For our part, Australia meets regularly with several regional partners in bilateral discussions on energy issues. We are also closely involved in the Asia Pacific Economic Cooperation forum and Australia is the so-called shepherd of the APEC working group on regional energy cooperation. ASEAN is also an important forum for cooperation on these issues.

These bodies are not competitors with the IEA, and we look to the IEA to contribute to our regional efforts to assure our energy future.

One way in which this conference could progress us towards meeting some of the challenges I have outlined today, would be for it to formulate a mechanism for on-going cooperation that would ensure a positive role for coal in the 21st century.

There are already very close relationships within Asia-Pacific on energy. These include bilateral trade in energy resources, cooperation in energy development, R&D collaboration, and bilateral and multilateral consultations on a wide range of energy-related issues.

This conference could agree on establishing ways of further developing our efforts in these areas in a manner that ensured the region had access to information, resources, and technology.

Existing forums, such as the APEC energy working group, would be obvious starting points.

I believe there is scope to develop a cooperative venture for promoting coal in the Asia-Pacific region. There need not be a major commitment of resources to the task, but rather the bringing together of existing activities.

The roles I see for this new venture would be to:

- Analyse impediments to growth in coal utilisation in the region.
- Disseminate standardised, comparative information on technological developments.
- Encourage international collaboration on research and demonstration projects.

- Provide advice on appropriate technologies, feasibility assessments, etc for new projects.

- Encourage positive community attitudes to the utilisation of coal.

My objective is to put in place arrangements that will ensure that we, in this region, have ready access to whatever resources are needed to make optimal and practicable decisions about our future energy needs and to be able to carry through our energy planning into tangible results.

Only if that happens can we ensure our future growth.

None of us can afford to be denied the information and technology essential for energy growth.

None of us can afford to make the wrong decisions about our future energy needs.

The region has within it enormous energy potential and the prospect for rapid growth. Our resources, our information, our enterprise, our innovation, and the development of our technology can be complemented by the lessons learnt in other regions.

The challenge for all of us in the region is to work cooperatively to realise the potential of the region for the benefit of our societies.

COAL TECHNOLOGY OPTIONS; INTERNATIONAL COOPERATION AND PARTNERSHIP

By Minami Ichikawa
Director
Coal Mining Department
Agency of Natural
Resources and Energy

I. "Coal as a Savior of the Earth"

We, the mankind, can never sustain our stable economic society without using energy.

And coal is one of the energy forms which is second to none with a number of advantages such as its huge amount reserved on the earth, economy, the possible formation of an international competitive market to be participated by many supplier countries scattered all over the world, and relatively easy development for utilization. This form of energy is also important since it now occupies about 30 percent of the worldwide supply of energy.

According to the IEA data forecasts, this unshakable high-ranked position of coal will be maintained well into the 21st century. Toward the future, a particularly rapid growth in demand is likely in developing countries, justifying the expectation that the total demand may exceed 1.8 times the present level in 2005.

Among others, the Asian-Pacific region depends more largely on coal for as much as 60% of their total energy consumption. Under such circumstances, the region is positioned to use not only economical but also abundantly available coal as an indispensable means to achieve substantial economic development as well as to improve the consumers' level of life.

The region has continued a high economic growth in recent years and is further expected to remain as a promising sector of the world economy until and even after the coming century sets in. This may well bring an abruptly sharp increase in coal consumption sometime in the future.

The ASEAN countries as a whole actually intend to expand their coal thermal power

generation capacity 5.4 times from 4.3 million kilowatts to 23.3 million kilowatts in 10 years from 1990 to 2000. China also projects an increase in similar capacity 1.9 times from 80 million kilowatts to 150 million kilowatts in 10 years up to the year of 2000. All these indicate a likely substantial growth in future demand for coal mainly to produce electric power.

II. Exploitation of Coal and efforts To Solve Global Environmental Problems

Such rapid increase expected in the future exploitation of coal mainly in the Asian-Pacific region importantly requires appropriate response to the problems relating to global environment over which recent world people have become more and more concerned.

First of all, acid rain which is caused when such substances as SOx and NOx emitted from the burning coal dissolve into the clouds and raindrops is a grave problem to solve. In recent years, the Asian-Pacific region has invariably faced the same problem manifesting itself amid growing demand for energy, mainly for coal. This instigates our concern over, not to speak of the destruction of forest resources and damages to building structures, possible hazardous effects on the health of those living at and near the places where coal is consumed.

For instance, in the Asian-Pacific region, the emission of SOx increased 1.6 times from 18 million tons to 29 million tons in 12 years from 1975 to 1987. It is expected that such emission will further increase another 1.5 times to 44 million tons in the Asian region as a whole unless some effective measures are taken to protect environment.

In the second places, part of the growing concern over the global environmental problems is more strongly directed toward the issue of CO_2 emission which causes greenhouse effects. Coal has a problem as it, when burned, emits more CO_2 than other fossil fuels.

A tentative important measure to solve this problem is development and penetration of the technology which will enhance both wide-spread energy saving and more efficient combustion of fuels. Supposedly this is a field of great potential to be improved by most developing countries.

Nevertheless, it is considered that global environmental problems will eventually be a cause to slow the economic growth in every part of the world but undeniably offset such a torture with some benefit of more efficient economy possible with development of energy-saving and better fuel burning technologies. At any rate, an ultimate goal should be to tackle the important assignment for development of striking a tripartite balance among economic growth, environment, and energy.

III. Japanese Course Followed in the Battle with Global Environmental Problems

Well-balanced response to coal utilization and environmental problems is an issue rather long-familiar but in some sense unfamiliar to Japan.

Hence, a brief account is hereby given of Japanese policies toward the utilization of coal based on our previous efforts to protect environment.

Concerning the Japanese environmental protection efforts, to overcome the serious problems such as of air pollution due to soot and dust encountered in the course of rapid industrialization since the latter half of the 1960's, total mass emission control was enforced on the emission of sulfuric oxides in 1974 and of nitric oxides in 1982. As a result, large fossil-fuel burning facilities are now regulated to observe the limits of SOx emission at around 100 ppm and NOx emission at 200 ppm or less. The Japanese industry has successfully cleared these limits, well demonstrating its possession of the world-highest level of desulfurization and NOx-reduction technologies.

In Japan, the large-scale smoke and soot control facilities are spread fairly widely to achieve its environmental quality standards. In the electric power industry, for example, 78% of its coal boilers as a whole are equipped with desulfurization equipment and 56%, with NOx-reduction equipment to clear severe such standards. Meanwhile, as for coal burning, wide-spread use of low-pollution combustion technology is under promotion with such means as two-stage combustion, low-NOx burners, and built-in desulfurization fluidized bed boilers.

In addition, Japan has achieved its goal of more efficient use of energy (energy saving) by successfully improving energy consumption 36% on an original GNP unit basis in a period between 1973 and 1988 intervened by two waves of oil shock.

In terms of coal-related achievements, the electric power sectors, in an attempt to improve thermal efficiency such as by increasing the sizes of coal thermal power plants, has succeeded in achieving some 40% grid-terminal thermal efficiency of highest-advanced large (100kW-class) pulverized coal firing plants. This, combinedly with other achievements
including implemented introduction of consistent-process steel production technology and recovery of converter gas has greatly contributed to the improved energy situation.

IV. Development of Clean Coal Technology

With the recently growing worldwide concern over and international commitments to global environmental problems in mind, Japan has further conducted many R&D projects and related survey of technologies to produce and use cleaner coal (clean coal technologies) for secured exploitation of coal as an important mainstay of oil-substitute energy while paying everlasting attention to global environmental problems.

In the first place, a development effort is now exercised, through Center for Coal Utilization, Japan (CCUJ), an advanced technology development organization in charge of coal utilization in the private sector toward technically implemented practical use of such clean coal technology as is in expected to be developed more efficiently as well as preferably in short or medium terms. Concrete items currently under development include the art to reduce CO_2 emission through improvement of thermal efficiency using pressurized fluidized bed combustion (PFBC), fluidized bed cement calcination, and other techniques, methods of better handling coal such as Coal Water Mixture (CWM) and Coal Cartridge System (CCS) Processes and desulfurization/NOx-reduction technology including the partial coal combustion furnace process.

From a medium- and long-term viewpoint, development of advanced clean coal technologies is also under way mainly at the Clean Coal Technology Center established within the New Energy and Industrial Technology Development Organization (NEDO) toward well-prepared response to global environmental problems. More specifically, such research and development work is directed toward Coal Liquefaction Technology to produce fuel oil from coal, Integrated Coal Gasification Combined Cycle Power Generation Technology, which consists of technical arts (1) to further reduce CO_2 emission using such techniques as born coal in an environmentally friendly manner (including the topping combustion technique toward improvement of thermal efficiency by raising PFBC combined cycle gas turbine inlet temperatures and O_2/CO_2 burning techniques), (2) to more efficiently use clean coal for chemical materials and other purposes including coal pyrolysis (a technology to implement more flexible gas, liquid, and char production through mild gasification of coal), and (3) to help improve desulfurization effects more aggressively including advanced coal reform techniques (subject to pre-heated relatively high-advanced desulfurization and ash removal).

V. Clean Coal Technology Cooperation

From a more extensive global-scale point of view, promoted aggressive cooperation, with developing countries and relatively much coal utilization-weighted areas where energy is expected in increasing demand toward the future, in more efficient use of coal and implementation of environment-related technologies may well be said nothing other than vital not only in view of well-prepared response to global environmental problems but also because it will contribute to more constant and smoother international supply of coal implemented through efficient use.

As mentioned above, under such circumstances where a sharp increase is expected in future demand of coal, it is heard that claims have been raised in large numbers against industrial pollution such as due to SOx and NOx emission with soot and dust as a serious problem at and around the places of coal consumption.

It is now the very time for many countries to tackle the important but difficult assignment of harmonizing energy utilization with environmental preservation.

With these situations taken into consideration, various Asian countries have recently promoted efforts toward solution of environmental problems in compliance with people's growing interest in saving energy by taking some measures including enacted environmental standards for air quality and limits on exhaust gas emission. It is, however, also the fact that developing countries are not always in the position to easily introduce in earnest due to increasing energy production costs (including expenses for facility construction and operation).

As a first step to eliminate the above difficulties facing the Asian-Pacific region, Japan has proposed so-called Green Aid Plan, a program to assist China and ASEAN countries in overcoming in their self-help effort such energy- and environment-related difficulties. Such our proposal has already been partly accepted since concrete programs started with some of these countries last year. The programs contain (1) survey cooperation, (2) joint researches, (3) surveys for demonstration, and (4) model projects toward extensive solution of wide-range energy and environment-related problems.

Within the framework of this Green Aid Plan, coal utilization-related infrastructures are under improvement for wider penetration of clean coal technologies.

I would like to give a brief account of such projects in progress in a little more concrete manner.

(1) Development of a comprehensive program relating to supply-demand and utilization of coal (master planning for general affairs)
As part of survey cooperation, a master plan started to be prepared in cooperation with China's Ministry of Energy (present Ministry of Coal Industry) in 1992. In 1993, this cooperative master planning with China will be joined in by Indonesia whose Ministry of Mining and Energy is now approached by us through negotiations.

(2) Development of simple desulfurization equipment for coal boilers
One of cooperative researched is now conducted on simple desulfurization equipment for coal boilers in behalf of developing countries in cooperation with the Indonesian Government. The studies are under way for ready operation of the facility completed in July this year.

(3) Surveys for demonstration
A series of surveys for demonstration selected in 1992 Huangdao Power Plant in Chingtao City, China as the first facility for demonstration tests of desulfurization

technology. This test emphasizes the penetration within China itself using sulfurization equipment characteristically simpler and less expensive than that employed in Japan. In 1993, Taiyuan Power Plant in Taiyuan City, Shanhsi Province was just selected as the second facility for demonstration.

(4) Projects to assist introduction of environmentally friendly coal utilization systems

One of model projects is implemented substantial expansion in 1993 of the field of cooperation to clean coal technologies which will be added to the items so far studied. As a concrete measure, model projects have just been put in force for the intended penetration of environmentally friendly coal utilization systems including desulfurization equipment, fluidized bed boilers, biobriquette manufacturing facilities.

This measure places emphasis on desulfurization, setting its goal at firmly establishing technical capabilities so that each country will be able to carry out its own environmental measures as well as increased incentive to introduce anti-pollution equipment. Another important aim is to relieve their burden due to enforced environmental regulations by reducing costs for the installation of anti-pollution equipment.

As far as flue gas desulfurization facilities are concerned, the first attempt will be made to install locally suitable simple and multi-model plants jointly with China's Council of State. Agreements have presently been reached with China upon the scheduled installation of 2 units in Shantung Province and one in Liaoning Province.

Next, as for fluidized bed boilers, it has been agreed upon that demonstration tests will be carried out using different types; one installed in Shantung Province, another in Peking, and the other jointly with the Philippines' Ministry of Energy.

Concerning briquette manufacturing facilities, as agreed upon with China's Council of State and the Indonesian Ministry of Mining and Energy, one unit is to be installed for demonstration purposes in each of China and Indonesia where the presidential order was issued at the beginning of this year, encouraging the whole nation to introduce briquettes.

The Ministry of International Trade and Industry of Japan thus firmly believes that promoted Green Aid Plan will greatly contribute to economic growth compatible with environmental protection in every of the countries cooperatively promoting this plan. We also intend to continue aggressive efforts of cooperation relating to the utilization of coal mainly under this plan.

Other than through the Green Aid Plan so far mentioned, we are also cooperative enough to positively participate in many APEC activities as part of our policies toward joint development with Asian countries. And also Japan has just attended the clean coal seminar held in Chiang-main of Thailand in September this year under the sponsorship of APEC Experts' Group on Clean Coal Technologies. IEA's only recent activities included its Hong Kong Conference held with such great applause. Our Ministry's intention is to continue invariably aggressive assistance to support every aspect of such international activities financially as well as in terms of necessary human resources.

VI. Agency of Natural Resources and Energy Conclusion

Development and penetration of clean coal technologies are also quite essential for Japan in promoting the utilization of coal as an important oil-substitute form of energy while harmonizing it with global environmental problems. It is, however, more vital to encourage the use of cleaner coal on a broader scale of international cooperation with perception of this issue to be tackled by the entire people of the world.

This is why we think we will maintain close contact with IEA member nations and dialogues with those countries interested in joining our cooperative projects toward world-wide penetration of the achievements derived from developed clean coal technologies. With such efforts, we also intend to aggressively enlarge the sprawling waves of worldwide cooperation and partnership in the hope that we could make international contribution to further improved position of coal which is not only an ultimately reliable form of energy but also a true savior of the earth.

SESSION I

ASIA-PACIFIC COAL USE STRATEGIES: NEEDS, PLANS AND OPPORTUNITIES

Development and Demonstration of Clean Coal Technologies

Akira Kunito and Masaki Takahashi, EPDC

Abstract

Clean and efficient use of coal and lignite is the most important issue in the energy and environmental policy in Asian countries. Since they are the world economic growth center, it is not only an issue for themselves, but also an issue of worldwide in terms of energy security and global environment. The paper presents the development and demonstration of Clean Coal Technology in Japan and how the technology be transferred. The financial, regulatory and technical barriers and challenges will be addressed. Technology options and experiences of clean coal technology transfer will be introduced. Understanding the technical and financial need of Asian developing countries will be the first step. Developing cost effective technology, regulatory and financial schemes which could be accepted by the developing countries are the next step. Understanding different approaches to this issue from the developed countries and seeking coordination of these approaches are also important.

1. Asian Energy, Coal and Electricity Overview

Asia is the world economic growth center. Fig. 1-1 shows change in GDP per Capita 1960 - 85, and we can find most of major Asian countries in the top twenties. World Energy Council's study shows the largest GDP in Pacific region in its reference case. (Fig. 1-2)

Table 1-1 show the coal's role in the primary energy consumption in Asian countries. China and India are the biggest coal consuming countries and show also high dependence on coal (77% and 57% respectively.) Tables 1-2 and 1-3 show projections of coal production and consumption in Asia respectively. China and India will remain the biggest producers and consumers. Australia will remain the third biggest producer and the Indonesia will increase its production drastically. South Korea and Japan will reduce their production, but they will remain as major consumers of coal as well as Australia and North Korea. Taiwan, Indonesia, Philippines and Thailand will increase their coal consumption drastically in the next decades.

Table 1-4 shows the projections of coal-fired power plant capacity. China again will play a major role here and double its capacity by 2000 with the increase of 70 GW in eleven years. Japan triples its capacity with the increase of 25 GW. Korea, Taiwan and Indonesia will increase their capacity 12 GW, 7 GW and 10 GW respectively.

2. Modern Power Stations

2.1 Unit Size Increase

Unit size of coal fired power plant has been increased to seek economy of scale. Usually the bigger the plant size, the smaller the capital cost per generating capacity ($/kW, most commonly used in Jpana is a power factor of 0.75) and therefore the cost of electricity ($/kWh). Largest size of coal fired power plant in Japan is 1000 MW and this size or bigger size units are prefered for the new capacity addition in Japan. Fig. 2-1 shows the history of unit size increase in Japan.

2.2 Steam Conditions Improvement

Supercritical and Ultra-supercritical steam conditions

Supercritical plant have been built in industrialized countries for a long time and well accepted technology. Although some old plant experience in the US with low availability made some US utilities hesitated to apply this technology, it has been well accepted in Japan and Europe, and will be commercially available to the developing countries. Figs. 2-2 and 2-3 show the history of steam pressure and temperature change and the improvement of plant efficiency. Figs. 2-4, 2-5 and 2-6 show the pictures of plant, wet scrubber, electrostatic precipitator and the denitrification (Selective Catalytic Reduction, SCR) plant at the newest coal fired plant of EPDC, Matsuura #1 unit, 1000 MW commissioned in 1991.

Ultra-supercritical steam conditions technology has been developed in Japan and Step I steam conditions (310 bar, 593°C double reheat) are ready for commercial application. Since it is a conventional steam cycle, operation capability, reliability and availability are expected to be the same or higher than the conventional sub-critical plants. Matsuura #2 unit, 1000 MW to be commissioned in 1997 will apply USC steam temperature (593°C, Fig 2-7).

In China and India where the big grid capacity is expected, large size (500 MW or larger) unit will be chosen. Supercritical or Ultra-supercritical steam conditions will best fit to such countries.

These steam conditions could be combined with fluidized bed combustion, both at atmospheric and pressurized. When the grid size is not so big and intermediate or smaller size (350 MW or less) unit is preferred, atmospheric fluidized bed combustion with SC or USC will best fit to the needs.

2.3 Environmental Control Technologies

i) SOx control technologies

Fluidized Bed Combustion
FBC is suitable to burn low quality coal or waste. It does not require add-on deSOx facility. It eliminates pulverizer which usually require the largest portion of maintenance in the PC plant. The capital and generating cost is modest. It is well accepted to the industries at the unit size of 50 to 200 MW, and now 350 MW AFBC is under construction at Takehara in Japan. The plant is expected to be commissioned in 1995. (Fig. 2-8)

Wet Scrubber
This is the most widely applied deSOx facility in the world. it has high deSOx efficiency with low Ca/S molar ratio. However it uses much water and has high capital and operating cost. Reduction of cost is the first priority for this technology to apply to the developing countries.
(Figs. 3-4 and 3-5)

Spray Dryer

Spray Dryer is categorized in the semi-wet desulfurization. It does not use so much water as wet scrubber. For low sulfur coal, deSOx efficiency could be expected over 90%, however for high sulfur coal deSOx efficiency will not be expected so high, because the erosion will be getting serious when the sulfur content is getting higher. It has over 50 units applications in the United States and Europe. It has not been applied in Japan because of the constrains of solid waste disposal.
(Figs. 3-4 and 3-5)

In the high sulfur desulfurization test in China described later, a study shows that the spray dryer type will be more economical in levelized annual cost if the plant is smalller than 200 MW while the simplified wet scrubber will be more economical if the plant is bigger than 200 MW.
(Fig. 3-6)

ii) NOx control technologies

Combustion modification including two Stage combustion (TSC) and low NOx burner should be the first step to reduce NOx since it has lower capital and generating cost than the add-on de-NOx system such as SCR. (See fig. 3-6). However , when stricter NOx control is required like in urban area with serious air pollution, SCR will be the option. SCR is well accepted in Japan and Germany and many application have shown satisfactory operating data.

2.4 Combined Cycle Technologies

PFBC

Pressurized fluidized bed combustion (PFBC) plants are now in the demonstration stage in Sweden, Spain, US and Japan, at the unit size of 70 MW. It will be applied to the commercial plant (350 MW) before the turn of the century. The plant could be prefabricated in the factory and transported to the plant site. The plant efficiency is expected to be 10% higher in relative value. In situ desulfurization in the pressurized boiler can eliminate the need of add-on DeSOx plant. It could use low quality coal and actually in Spain they uses very low quality (high ash and high sulfur) black lignite. It has rather low gas turbine inlet temperature (around 850°C) to eliminate alkaline metal problems and achieve better desulfurizing performance. It has modest capital and generating cost, and the plant area requirement is small and plant building height is not tall. Therefore, once it is demonstrated in the industrialized countries, it will be best fit to the developing county which requires medium size unit (50 MW - 350 MW) and high efficiency.

Figs. 2-9 to 2-10 show the pictures taken at the construction site of Wakamatsu 71 MW PFBC demonstration plant. It has started its test operation and the three years demonstration test will start next year.

IGCC

The IGCC is also in the demonstration stage in Europe and in the United States. It has a rather high gas inlet temperature (1100°C or higher), to achieve high efficiency. It is a high efficiency and clean technology in terms of SOx and NOx emission, however, the capital and electricity generation cost is rather high. Therefore it will be still difficult to apply this technology to the developing countries at this moment.

2.5 Advanced technology - cost and performance

Fig 2-12 show the capital cost learning curve, which every technology must go through this process. At the initial estimate with incomplete data the cost tend to be low and increase with its development and detailed studies. When the first commercial plant starts the service the cost is the highest and the decrease the cost at the second, third and fourth. The Matured plant cost will be applied at around the fifth commercial plant. PFBC, IGCC and some other advanced clean coal technologies are just at or before the peak of the curve. Sometimes we need governmental support to go through this process. However when we go through this process we can expect better performance in plant efficiency and emissions as shown in Table 2-1.

3. What are the needs of Asian Countries? - Identifying barriers to and challenges for the technology transfer.

Table 3-1 shows energy need/ population growth, technology, and financing are the important issues and no concern of climate change in the developing regions, while the latter is of concern and the former is no concern in most of the industrialized regions. Efficiency and conservation are the common important issues in all regions.

In some urban and newly developed rural areas, environmental damages caused by the development have been reported. It is not only for air pollution but also water and/or food contaminants, safety issues in working and residential areas. There are not categorical survey in this aspect, but environmental issues is becoming social problems in the developing countries. One example is reported in the recent newspaper article regarding Chinese environmental situation.

"Chinese environment has been worsened according to the Chinese environmental protection agency. SO2 emissions from coal firing in 1992 was 16.85 million ton, increased 7.7% from 1989. This is because China heavily depends on coal-firing electric power generation. The level of SO2 emissions are almost the same as that of the United States which decreased drastically in recent years.

Forty-five thousand tons of fish caught last year have been contaminated, and it caused fishermen 400 million Yuan damage. According to the China-Japan environmental researchers, mining waste water which include contaminants such as zinc flows into river without treatment, and many factories have been built in rural areas. They causes serious pollution in water quality.

A Chinese environmental protection agency's official said, 'Chinese environmental protection has becoming difficult. However, after getting rich enough economically and financially, fund for environmental protection will be available.' as a Chinese dilemma." (Asahi, 8/22/93, p.1)

3.1 Finance

Incentives to Direct Investments

Developing countries in Asia have accepted several tax incentives to promote direct investments, however, there are still some remaining barriers such as overseas investment ratio limitations and local contents requirements. Such barriers have been discussed as violation of GATT in Uruguay Round. The new international rules should eliminate the

barriers. The developing countries must understand that the rule will be beneficial to themselves in the long run by keeping the smooth trade flow.

Environmental Guidelines

If there is a competition in the industrial country side, consultants will not voluntarily put the environmental control equipment because the cost of their estimate increases and loses contracts in the completion. If there are not legitimate regulation on the environment by the developing countries' government, then financial agency should give guideline concerning environment as the aid or loan conditions. For example, SOx and/or NOx emissions standard should be given by the financial agencies according to the site conditions: whether the plant is located in the urban area and environmental capacity reaches the limit, or whether there are endangered species in surrounding area. In the industrial countries such guidelines are given by the central or local government, however, in the developing countries where there are no such laws or regulations, financial agencies should give such guidelines for them.

For example OECF set its environmental guideline as the lending agency, as well as JICA is setting environmental guideline as the international cooperate agency.

3.2 Organizational and Institutional Issues

Privatization

National enterprise have been acting significant role in promoting heavy industries, however lack of management capability caused serious fiscal deficit of governments. Investment from overseas tend to give higher priority to the national entities and causes shortage of currency flow at private sectors.
Therefore privatization of the national enterprise should be made in accordance with the economic and political status of each country.

Market incentives

Free market price mechanism is essential to ensure the market economy. Controlled price by the government cannot respond flexibly enough to reflect supply and demand balance, and thus it will be a barrier to the smooth economic activities. Transferring from the control price to the free market price must be done with carefully avoiding monopoly or oligopoly.

Legal schemes

Freedom of contract and legal stableness should be guaranteed. Legal schemes such as civil laws and commercial laws should be established to ensure economic activities' stableness.

Industry policy

In the transition period to the free market economy, while the private sectors are still immature stage, adequate industrial policy will take a complementary role to the market economy.

Human resources

Management training including sophisticated marketing technologies, quality control, and personal management as well as engineer and technician training is needed. To maintain self-sustained development, developing countries must hold their own experts who can plan development strategies. In the industrialized country side, number of staffs are too small to satisfy the needs to make development plan and executing the plan is not enough and need to be increased.

Property rights

To allow industrial countries to release information and know how their property rights must be protected properly. How the property rights are protected or not protected are summarized in the Table 3-3.

Organizational problems

In some countries it is not clear to which department is responsible to the legal matters to proceed the project. Both in developing and industrialized countries, it is important to smooth process of the project to have one representative contact who has a overall responsibility.

3.3 Technology Options

Fig. 3-1 show the improvement of SO2 emissions in the industrialized countries, while Fig 3-2 and Fig 3-3 show the trends of SOx and NOx emissions in Asian countries respectively.

Figs. 3-4 and 3-5 show the SO2 control technology cost for low sulfur case and high sulfur case respectively. Fig. 3-6 shows the performance of NOx control technologies. Fig. 3-7 shows the capital cost of environmental control systems. Around 20% of the total capital cost is required for the environmental control systems.

Example of Technology Transfer

Fig. 3-8 shows an example of technology transfer from Japan to China: High sulfur desulfurization demonstration test in China.

Cooperative initiatives for the technology transfer of Heat Rate Improvement and Clean Coal Technologies

Developing cost effective technology, regulatory and financial schemes which could be accepted by the developing countries in cooperation of industrialized countries will be essential. Understanding different approaches to this issue from the developed countries and seeking coordination of these approaches are important. We are trying to initiate the cooperative initiatives for the technology transfer of heat rate improvement and clean coal technologies which will be covered by other papers in this conference.

Conclusions

Economic growth rate of Asian countries are high and affect world energy demand and supply balance much. Consequently CO2 emissions from these countries will contribute large portion of global emission. However, global warming will not be a large incentive to reduce fossil fuel consumption for developing countries (and for most of the industrialized countries.)

Local environment important such as Water quality, air pollution in urban area which affect human life and health will be more acute and important.

The major barriers to clean coal technology transfer is consist of financial, legal and institutional, and technical issues. How to get finance and how to give incentives to invest on environmental equipment within the limited resources.

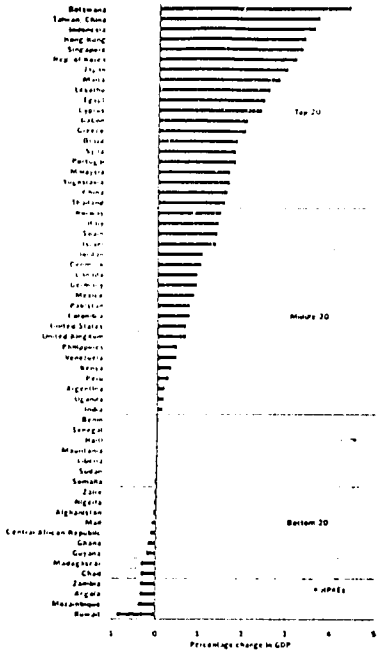
To get direct investment from industrialized country, eliminating limitation to the overseas investment, and protecting property right so that investors form industrialized country will not give up getting involved in such investment. It will also be necessary to use new schemes such as BOT, BOO.

Developing countries are not willing to invest on environmental protection facilities will not produce products nor generate electricity. Industrialized countries give some environmental guideline for each developing country, and ensure the minimum required environmental protection should be made at least.

Preparing legal and institutional background especially privatization, appropriate energy price, human resource development including management capability will be required.

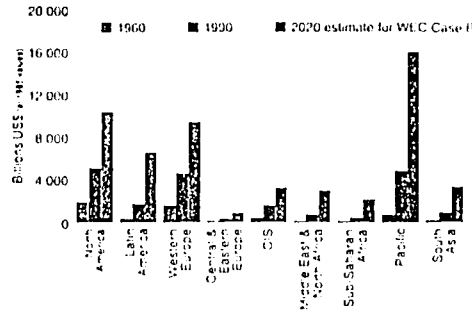
Widening technology options to develop cost effective technology, and technology which increases productivity such as efficiency improvement is important. To make information relating technology options easily accessible is also important. Finally, establishing technology assessment guide so that developing countries could choose right technology depending on its developing stage is required.

Fig. 1-1 Change in GDP per Capita, 1960-85



Source : The World Bank

Fig. 1-2 GDP 1960 to 2020 by Geographic Region



Source : WEC

Table 1-1 Share of Coal Consumption, 1992

(Million tonnes oil equivalent)

Country	Coal	Total	Share(%)
Australia	39.9	87.7	45
China	527.1	680.4	77
India	111.5	195.5	57
Indonesia	4.5	48.8	9
Japan	77.9	451	17
Malaysia	1.6	25.5	6
New Zealand	0.8	12.4	6
Philippines	1	15	7
Singapore		21	0
South Korea	23.3	114.1	20
Taiwan	16.5	56.6	29
Thailand	4.8	36.2	13
Other Asia	53.9	111.4	48
Total Asia & Australia	862.8	1855.6	46
Total World	2164.2	7794.2	28

Total Total primary energy consumed by each country

BP STATISTICAL REVIEW OF WORLD ENERGY

Table 1-2 COAL PRODUCTION IN ASIA[1] (EXCLUDING LIGNITE): 1990-2010

(Million metric tons)

Economy	1990	2000	2010	Change 1990-2010
China	1,080	1,400	1,700	620
India	201	345	555	354
Australia	163	216	285	122
Korea (North)	49	60	70	21
Korea (South)	21	13	7	-14
Indonesia	11	50	75	64
Japan	8	1	1	-7
Vietnam	5	12	24	19
Other	6	13	20	14
Philippines	1	4	5	4
Total	1,545	2,114	2,742	+1,197

1 Asia includes the SW Pacific but excludes Russia

EWC Coal Project projections, 1992

Source : APEC

Table 1-3 COAL CONSUMPTION IN ASIA[1] (EXCLUDING LIGNITE): 1990-2010

(Million metric tons)

Economy	1990	2000	2010	Increase 1990-2010
China	1,063	1,365	1,655	592
India	205	360	575	370
Japan	113	142	151	38
Australia	57	66	85	28
Korea (North)	52	65	75	23
Korea (South)	43	56	60	17
Taiwan	19	35	57	38
Hong Kong	10	13	16	6
Indonesia	7	25	45	38
Vietnam	4	8	17	13
Philippines	3	13	22	19
Thailand	1	6	25	24
Other	11	17	24	13
Total	1,588	2,171	2,807	1,219

1 Asia includes the SW Pacific but excludes the Russia. 1990 figures do not exclude stock adjustments. EWC Coal Project projections, 1992

Source : APEC

Table 1-4 Projections of Coal Fired Power Plant Capacity

(Thousands 10^6 kw)

Countries and Regions	1990(a)	2000(a)	2010(a)	(b)/(a)
Japan	1 467 (as of March 31, 1991)	6 025(c) (as of March 31, 2000)		2.7
[illegible]	1 [illegible]	1 [illegible]		[illegible]
Korea	[illegible]	[illegible]		[illegible]
Taiwan	[illegible]	[illegible]		[illegible]
Hong Kong	[illegible]	[illegible]		[illegible]
[illegible]	[illegible]	[illegible]		[illegible]
Thailand	[illegible]	[illegible]		[illegible]
Malaysia	[illegible]	[illegible]		[illegible]
Philippines	[illegible]	[illegible]		[illegible]
[illegible]	[illegible]	[illegible]		[illegible]
Indonesia	[illegible]	[illegible]		[illegible]

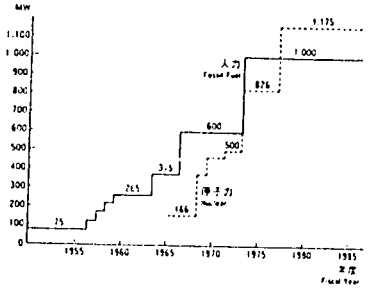
(c) based on 1991 [illegible] power facilities plan

Source : Okamoto

Fig. 2-1

ユニット最大容量の推移

Improvements in Maximum Unit Capacity

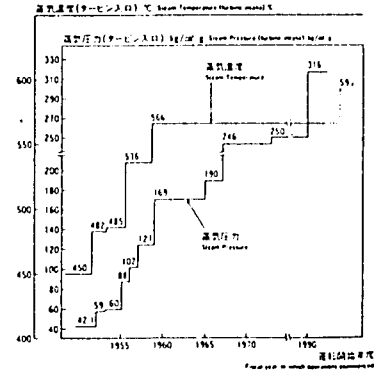


Source : The Federation of Electric Power Companies

Fig. 2-2

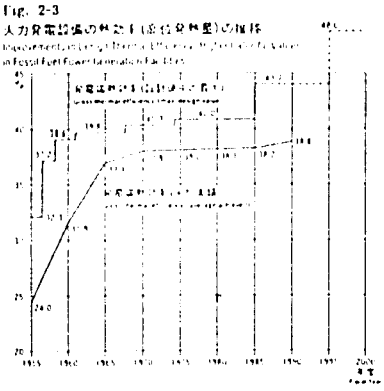
火力発電設備の蒸気圧および蒸気温度の変遷

Improvements in Steam Temperature and Pressure in Fossil Fuel Power Generation Facilities



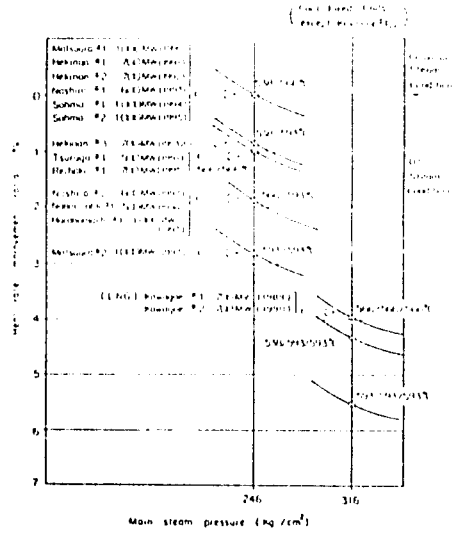
Source : The Federation of Electric Power Companies

Fig. 2-3



Source : The Federation of Electric Power Companies

Fig. 2-7 USC Steam Conditioned Units



Source : Nakabayashi

Fig. 2-4 Matsuura Power Station

Fig. 2-5 Wet Scrubber at Matsuura

Fig. 2-6 Electrostatic Precipitator and Selective Catalytic Reduction systems at Matsuura

Fig. 2-8 Takehara II Power Station

Fig. 2-10 Installing PTIC at Nakamatsu

Fig. 2-9 Unloading PTIC at Nakamatsu

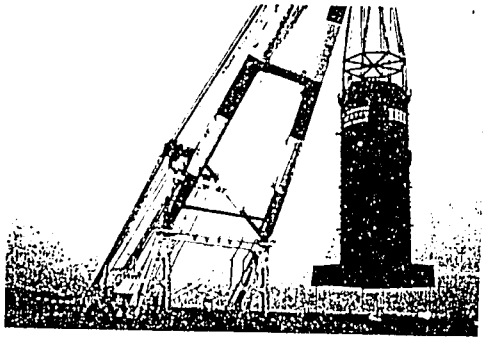


Fig. 2-11 Land Transportation of Ceramic Filter at Nakamatsu

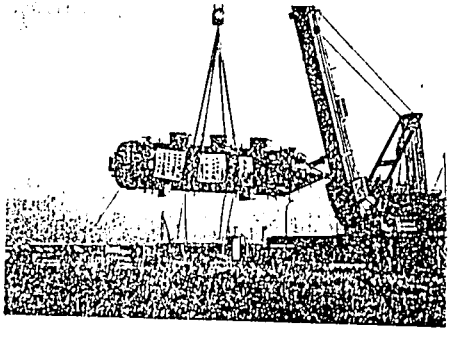
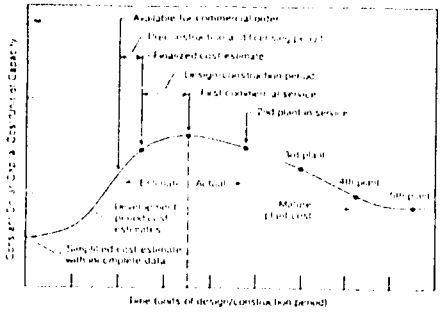


Fig. 2-12 Capital Cost Learning Curve



Source : EPRI

Table 2-1 Performance Improvement of Advanced Coal-Fired Plant Syste

Types of the power systems	Plant efficiency (percentage)	Emission Levels		
		SO_2 mg/kwh (percentage)	NO_x mg/kwh (percentage)	Particulate mg/kwh (percentage)
Pulverized coal fired systemet.	38.8	310	440	28
	(100)	(100)	(100)	(100)
AFBC	38.8	310	290	28
	(100)	(100)	(66)	(100)
USC	41.0	290	410	26
	(106)	(94)	(93)	(93)
PFBC	42.0	190	200	13
	(108)	(61)	(45)	(46)
IGCC	43.5	180	190	12
	(112)	(58)	(43)	(43)

Data: Electric Power Developement Co., LT

AFBC, Atmospheric Fluidized Bed Combustion
USC, Ultra Super Critical Steam Power Generation Technology
PFBC, Pressurized Fluidized Bed Combustion
IGCC, Integrated Coal Gasification Combined Cycle Power Generation

Table 3-1 Regional Key Issues and Priorities

	Energy Need & Population Growth	Technology	Financing	Insitutional Deficiencies	Efficiency & Conservation	Climate Change
North America	4	4	4	3	3	3
Latin America	1	1	1	2	1	3
Western Europe	4	3	4	3	1	2
Central & Eastern Eur/CIS	4	2	1	1	1	4
Middle East & North Africa	1	1	1	1	1	4
Sub-Saharan Africa	1	1	1	2	2	4
South Asia/ Pacific	1	2	1	1	2	4
of which China	1	1	1	2	2	4

1: very important 2: important 3: of concern 4: no concern

Source : WEC

Table 3-2

Financial and Organizational & Institutional Issues

Financial Issues

Incentives to Direct Investment

Environmental guidelines

Organizational & Institutional Issues

Privatization

Market Incentives

Legal Schemes

Industry Policy

Human Resources

Property rights

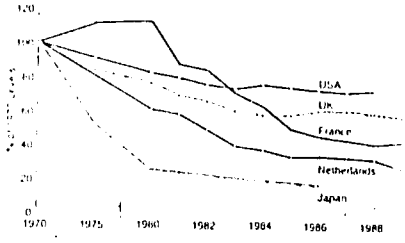
Organizational Problems

Table 3-3 Situation on Intellectual Property Rights in Major Developing Countries in Asia

Country / Item	Korea (First-to-file system)	Thailand (First-to-file system)	Philippines (First-to-invent system)	Indonesia (First-to-file system)	China (First-to-file system)
Expiration of patent	15 years from publication (not exceeding 20 years from the application date)	15 years from [illegible]	17 years from patent date	14 years from application	15 years for invention and 5 years for utility model and design from application date
Place of Examination	Member country	Member country	Member country	Member country	Member country
Management of patent information	Computerized, which is progressing to be completed on '93	Computer management being performed	Computer management being performed	Computerized and not progressing	Also, [illegible] on progressing with the installation of computers [illegible]
Number of patent examiners (April, 1989)	145	15	[illegible]	8	[illegible]
Number of patent applications	23,307 applications (89) (14,0[illegible] foreign applications)	1,945 applications (90) (1,867 foreign applications)	1,843 applications (89) (1,772 foreign applications)	774 applications (89) (661 foreign applications)	Also 13,550 applications (89)
Current basic law	Patent Law (January 13, 1990) (Law No 4207) Enforcement Ordinance of Patent Law (August 29 1990)	Patent Law (March 11, 1979) (D.E. No 2522)	Patent Law (June 20 1947) (Republic law No. 165)	Patent Law (1989) (Law No. 0, enforced on August 1, 1991)	Patent Law (April, 1985) Enforcement Ordinance of Patent Law (April 1985)

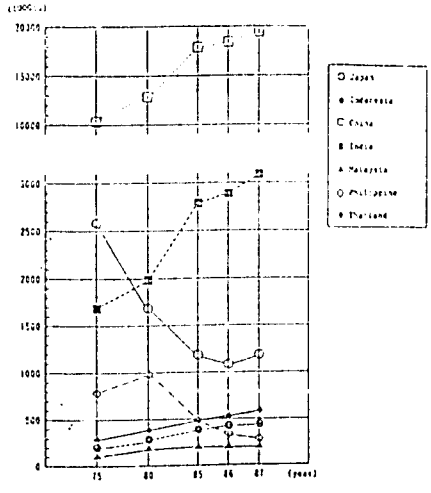
Source : MITI

Fig. 3-1 SOx emissions in Industrialized Countries



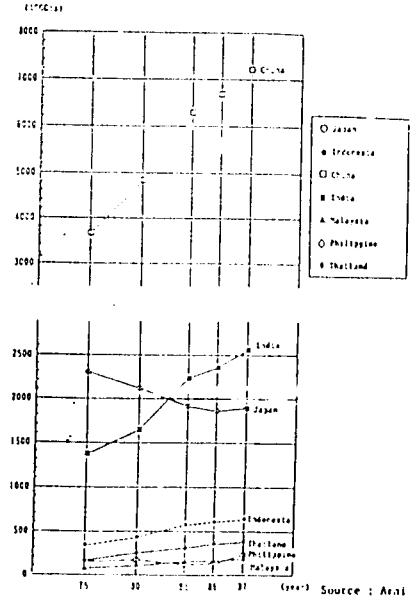
Source : WEC

Fig. 3-2 SOx emissions in Asia



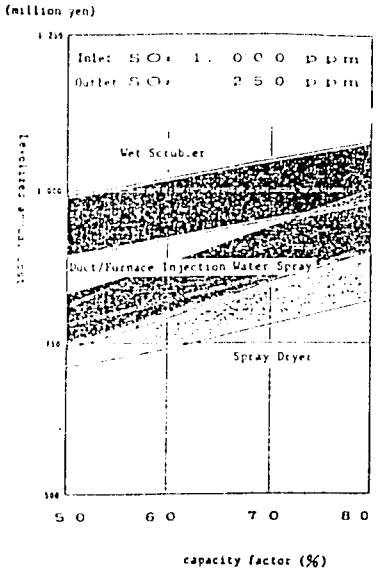
Source : Arai

Fig. 3-3 NOx emissions in Asia

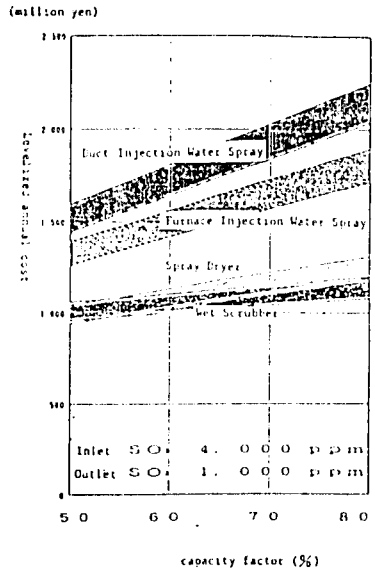


Source : Arai

Fig. 3-4 SOx control (Low Sulfur)



Sorce: Arai



Source ; Arai, Chemical Engineering Association, Autumn Conference

Fig. 3-6 Cost of Wet Scrubber

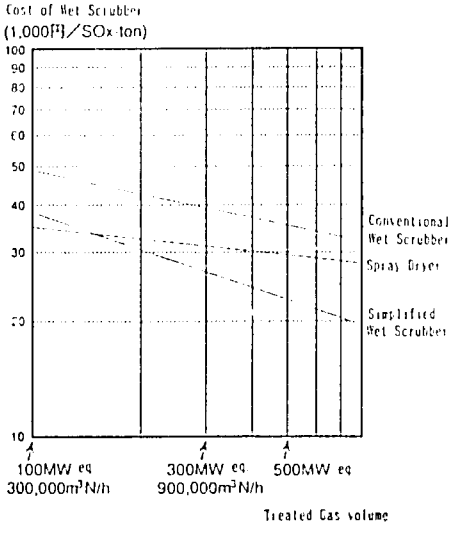


Fig. 3-7 NOx Abatement Technology Development for Coal-Fired Power Plant

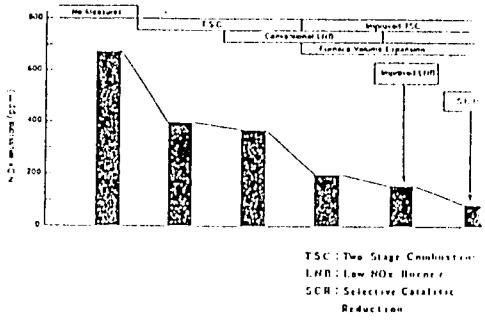


Fig. 3-8 Cost of Air Pollution Control

	Project cost
FGD system	10
SCR system	3
CONBUTION MOD.	1
WASTE WATER TREATMENT SYSTEM	2
ESP system	3
SUB total	19
main PLANT	81
total PLANT	100

Fig. 3-9 DeSOx Demonstration Project in China

System 1

Site : Huang Dao Power Station,
Type : Spray Dryer
Capacity : 100MWeg.
out of 210MW unit capacity
Period : 1992 - 2000

System 2

Site : Tai Yuang Power Station,
Type : Simplified Wet Scrubber
Capacity : 200MWeg.
out of 300MW unit capagity
Period : 1995 - 2000

Fig. 3-10 CCT for Developing Countries

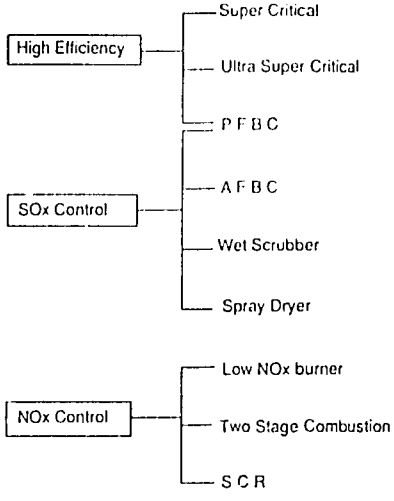


Fig. 3-11

Corporative Initiatives on Heat Rate Improvement and CCT Transfer

Asian Heat Rate Improvement Awareness Group (AHRIAG)

Heat Rate Survey
Reliability, Availability Survey
Technology Options Optimization

Asian Clean Coal Technology Awareness Group (ACCTAG)

Installation Survey
Environmental Requirement Survey
Technology Options Optimization

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PERUSAHAAN UMUM LISTRIK NEGARA (PLN)
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INTEGRATING IMPROVED COAL TECHNOLOGIES INTO THE ENERGY SYSTEM (INDONESIAN CASE)

A paper for the IEA Second International Conference
on The Clean and Efficient Use of Coal and Lignite :
Its Role In Energy, Environment and Life

Hongkong, 30 November - 3 December 1993

Presented by :
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Head of PLN Engineering Service Centre

ABSTRACT

TO FUEL THE NATIONAL ECONOMIC GROWTH, THE DEMAND AND SUPPLY OF ELECTRICITY IN INDONESIA HAVE BEEN DOUBLING IN EVERY FIVE YEARS FOR THE LAST TWENTY FIVE YEARS, AND THE SUPPLY HAS BEEN VERY STRONGLY OIL BASED.

TO REDUCE THE DEPENDENCE ON OIL, THE GOVERNMENT OF INDONESIA IN 1970'S MADE A VERY IMPORTANT DECISION TO ADOPT THE POLICY FOR THE DIVERSIFICATION OF PRIMARY ENERGY RESOURCES.

COAL WAS ONE OF THE PRIORITY CHOICES, AND IN 1984 PLN COMMISSIONED ITS FIRST COAL FIRED STEAM POWER PLANT OF 1600 MW CAPACITY.

THE SHARE OF COAL IN PLN'S ELECTRIC POWER PRODUCTION HAS SINCE INCREASED TO ABOUT 30% IN 1992/1993 AND IS PROJECTED TO ABOUT 80% IN 2003/2004.

COAL IS HOWEVER KNOWN AS POTENTIALLY SIGNIFICANT POLLUTER TO THE ENVIRONMENT.
AND IT WAS REALISED THAT STRONG MEASURES HAD TO BE TAKEN TO CONTROL THE IMPACT OF THE USE OF COAL.

HENCE THE LAW NO. 4/1982 ON THE MANAGEMENT OF THE LIVING ENVIRONMENT WAS INTRODUCED. SUBSEQUENT IMPLEMENTATION RULES AND REGULATIONS WHICH SET VERY STRINGENT ENVIRONMENTAL STANDARDS PROVED THE STRONG NATIONAL COMMITMENT TO ENFORCE THE DECISSION.

HENCE IMPROVED TECHNOLOGIES RELEVANT TO THE ENVIRONMENTAL CONSERVATION PRINCIPLES HAVE TO BE EMPLOYED IN THE UTILIZATION OF COAL FOR THE DEVELOPMENT OF THE INDUSTRIAL SECTOR, IN PARTICULAR THE ELECTRICAL POWER SECTOR.

- THE ENERGY DEMAND IN INDONESIA HAS BEEN CHARACTERIZED BY VERY HIGH GROWTH

- IN THE ELECTRICAL SECTOR (PLN) = ABOUT 15 % P.A DOUBLING EVERY FIVE YEARS

INSTALLED CAPACITY - MEGAWATTS

Type Of Generation	End of FYP I 1973/74	End of FYP II 1978/79	End of FYP III 1983/84	End of FYP IV 1988/89	4th Year of FYP V (1992/93)
Hydro	273.77	349.67	536.44	1,969.57	2,178.00
Steam	225.00	556.25	1,556.25	3,416.95	3,941.00
Gas Turbine	42.00	882.07	1,027.92	1,233.68	1,223.00
Diesel	230.31	500.40	784.39	1,769.02	2,060.00
C. Cycle	-	-	-	-	1,312.00
Geothermal	-	-	30	140.00	140.00
Total	776.08	2,288.39	3,935.00	8,529.22	10,854

Note: FYP = Five Year Development Plan
1973/1974 = Fiscal year from 1 April 1973 till 31 March 1974

ENERGY PRODUCTION - GWH

Type of Generation	End of FYP I 1973/74	End of FYP II 1978/79	End of FYP III 1983/84	End of FYP IV 1988/89	4th Year of FYP V (1992/93)
Hydro	1,029.58	1,384.28	1,816.27	5,226.86	8,788.00
Steam	713.45	1,523.10	7,365.49	14,218.38	24,341.00
Gas Turbine	158.32	1,156.73	1,065.60	1,581.98	2,508.00
Diesel	467.90	845.53	1,654.13	2,900.87	3,978.00
C. Cycle	-	-	-	-	181.00
Geothermal	-	-	1,011.98	1,011.96	1,084.00
Purchased	636.73	813.18	1,281.02	682.71	1,058.00
Total	3,005.98	5,722.82	13,391.82	25,622.76	41,938.00

ENERGY SOLD - GWH

Type of Consumer	End of FYP I 1973/74	End of FYP II 1978/79	End of FYP III 1983/84	End of FYP IV 1988/89	4th Year of FYP V (1992/93)
Residential	1,077.30	1,962.20	4,291.50	7,274.63	11,671.00
Industrial	596.00	1,443.40	3,435.90	9,052.24	17,047.00
Commercial	220.90	430.90	1,002.50	1,740.14	3,185.00
Others	320.80	450.40	1,269.80	1,925.83	2,353.00
Total	2,215.00	4,286.90	9,999.70	19,992.84	34,256.00

THE NATIONAL ENERGY POLICY COMPRISES THE FOLLOWING PRINCIPLES :

* INTENSIFICATION AND EXPANSION OF EXPLORATION ACTIVITIES FOR INDIGENOUS NATURAL ENERGY RESOURCES,

* DIVERSIFICATION OF THE USE OF ENERGY RESOURCES ESPECIALLY TO REDUCE DEPENDENCE ON PETROLEUM,

* CONSERVATION OF RESOURCES TO ECONOMISE AND TO IMPROVE THE EFFICIENCY OF RESOURCE UTILISATION

PRIORITIES OF ENERGY RESOURCES :

* HYDRO POWER
* GEOTHERMAL
* C O A L
* NATURAL GAS
* O I L

DEVELOPMENT PLANNING CRITERION :

* LEAST COST SOLUTION

- ONE PRIORITY CHOICE OF PRIMARY RESOURCE IS C O A L

- DISADVANTAGE OF COAL :
  * POTENTIAL POLLUTION TO THE ENVIRONMENT

CHARACTERISTICS OF AVERAGE INDONESIAN COAL :

* LOW SULPHUR CONTENT

  LESS THAN 1 % BY WEIGHT

DEMAND FORECAST - GWH

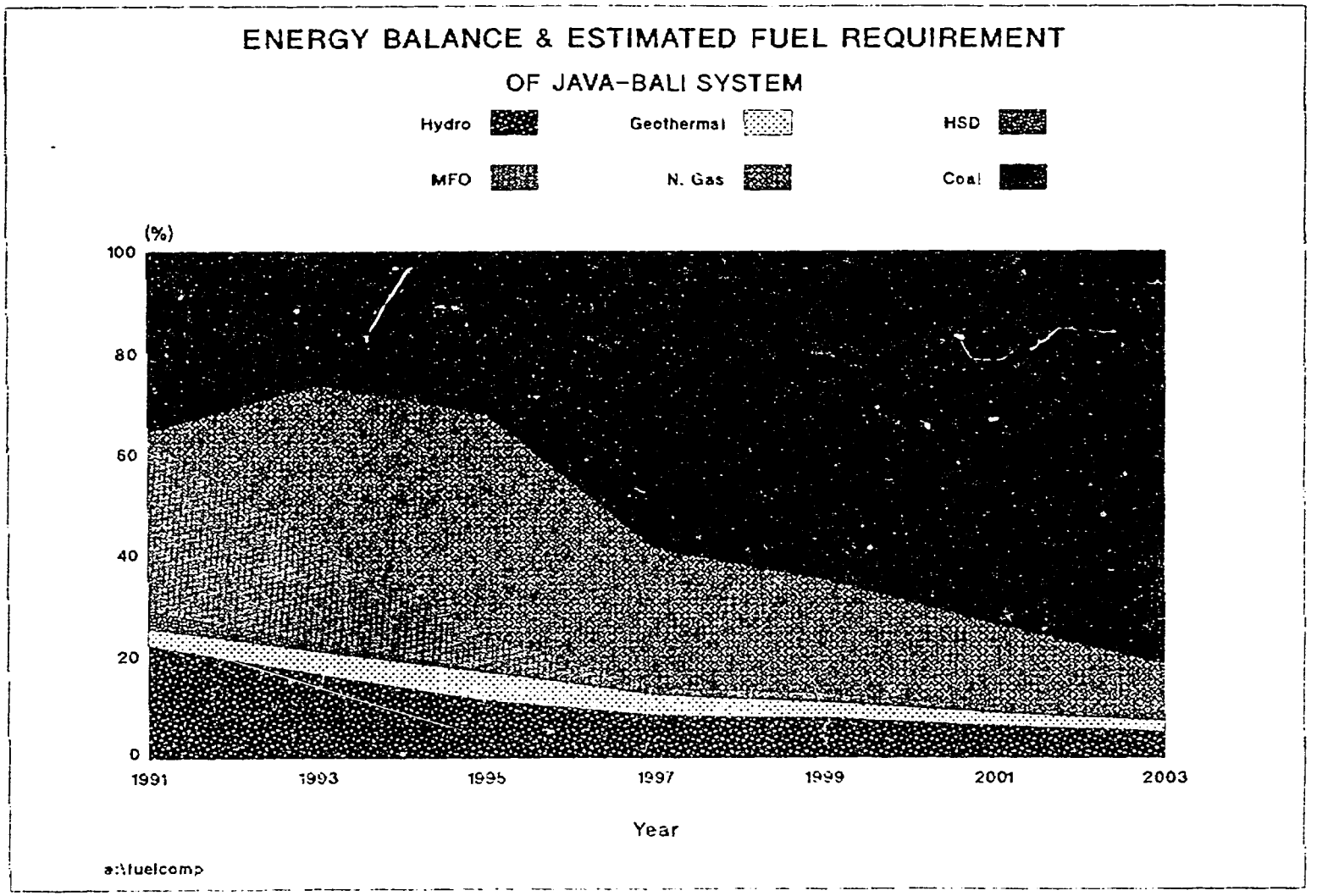
	End of FYP V (1993/94)	End of FYP VI (1998/99)	End of FYP VII (2003/04)
Energy Sales			
- Residential	15,469.3	27,766.0	42,602.9
- Industrial	28,180.2	55,330.6	83,083.0
- Commercial	4,202.6	8,185.2	13,601.8
- Others	3,152.4	5,972.4	9,708.5
Total	51,004.4	97,254.3	148,996.2
Energy production	81,287.6	116,534.9	178,503.1

FUTURE DEVELOPMENT PLAN - MEGAWATT

TOTAL INSTALLED GENERATING CAPACITY	END OF FYP V (1993/94)	END OF FYP VI (1998/99)	END OF FYP VII (2003/04)
PLN			
JAVA	9,716.00	15,408.00	18,833.00
OUTSIDE JAVA	3,258.90	5,487.50	9,024.20
SUB TOTAL	12,974.90	20,895.50	27,857.20
NON PLN			
JAVA	-	2,735.00	6,935.00
OUTSIDE JAVA	-	210.00	590.00
SUB TOTAL	-	2,945.00	7,525.00
GRAND TOTAL	12,974.90	23,840.50	35,382.20

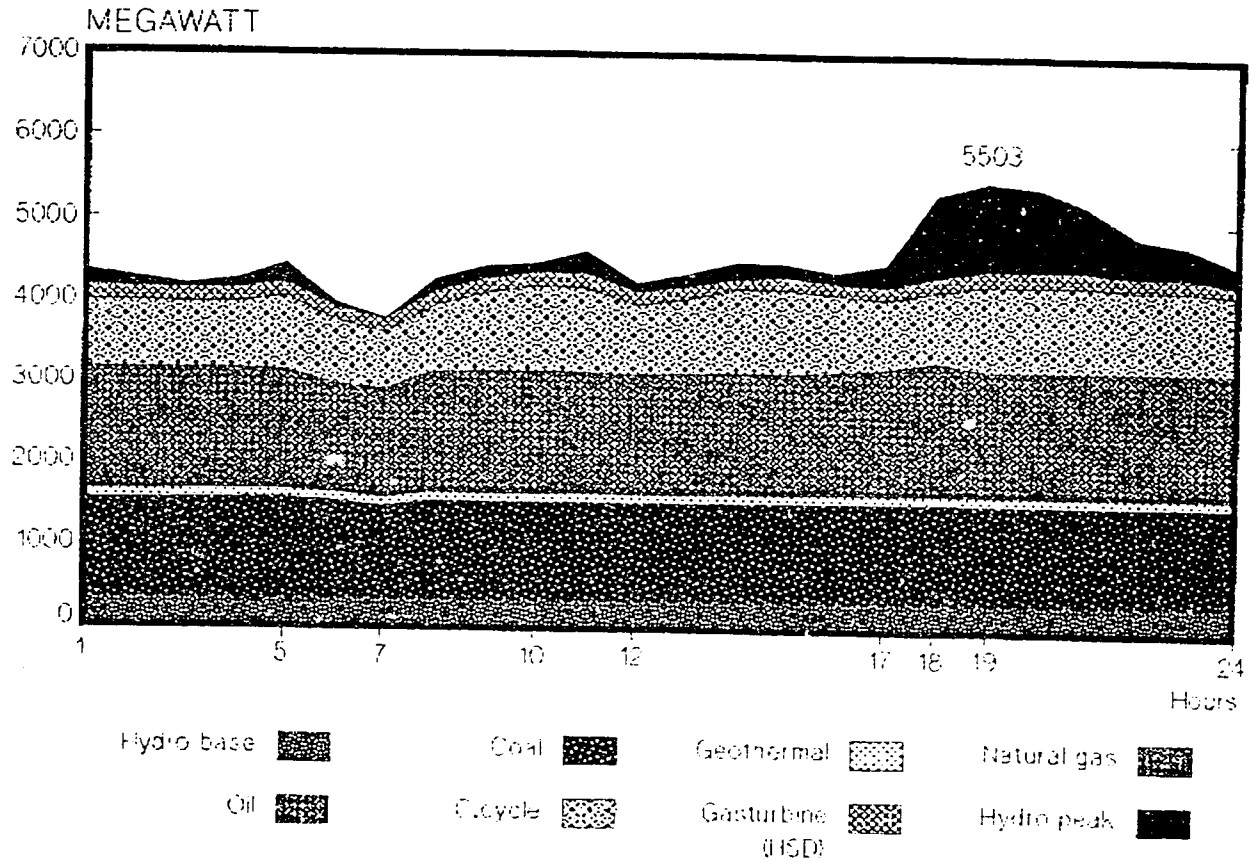
ENERGY BALANCE AND ESTIMATED FUEL REQUIREMENT OF JAVA-BALI SYSTEM - GWH

FUEL/ENERGY SOURCE	1993	1995	1997	1999	2001	2003
HYDRO	6,819	6,917	6,917	8,326	8,326	8,326
COAL	10,837	19,224	47,953	67,900	94,400	127,905
OIL :						
-HSD	693	159	6	221	239	302
-MFO	8,300	4,244	1,113	1,571	1,134	411
NATURAL GAS	12,880	26,667	22,425	23,436	20,886	16,674
GEOTHERMAL	1,818	3,161	3,161	3,161	3,161	3,161
TOTAL	41,347	60,372	81,575	104,615	128,146	156,779


ENERGY BALANCE & ESTIMATED FUEL REQUIREMENT
OF JAVA-BALI SYSTEM
Hydro
Geothermal
HSD
MFO
N. Gas
Coal
(%)
100
80
60
40
20
0
1991
1993
1995
1997
1999
2001
2003
Year
a:\fuelcomp

DAILY LOAD CURVE

24 August 1993



INDONESIA HAS ADOPTED VERY STRINGENT ENVIRONMENTAL QUALITY STANDARD

ENVIRONMENTAL REGULATIONS

1. LAW No. 4/1982 ON "PRINCIPAL REGULATION OF ENVIRONMENTAL MANAGEMENT".
2. LAW No. 5/1984 ON "INDUSTRIAL SECTOR"
3. LAW No. 9/1985 ON "FISHERIES"
4. LAW No. 20/1990 ON "WATER POLLUTION CONTROL"
5. GOVERNMENT REGULATION No. 29/1986 ON "ENVIRONMENTAL IMPACT ANALYSIS.
6. GOVERNMENT REGULATION No. 20/1990 ON "WATER POLLUTION CONTROL"
7. DECREE OF THE MINISTER OF POPULATION AND ENVIRONMENT :

   a. No. : KEP-49/MENKLH/6/1987
      "GUIDLINES ON IMPORTANT ENVIRONMENTAL IMPACT
   b. No. : KEP-50/MENKLH/6/1988
      "GUIDLINES ON ENVIRONMENTAL IMPACT ANALYSIS
   c. No. : KEP-51/MENKLH/6/1988
      "GUIDLINES ON ENVIRONMENTAL ASSESMENT STUDY
   d. No. : KEP-02/MENKLH/1988
      "AMBIENT QUALITY STANDARDS
   e. No. : KEP-03/MENKLH/1991
      "QUALITY STANDARDS OF LIQUID WASTES FOR THE OPERATION OF INSTALLATION"

Existing National Ambient Air Quality
Standards for Indonesia

Parameters	Measuring Time	Existing Standards KEPMEN/1988
Sulfur dioxide (SO_2)	1 hour 24 hours 1 year	- 260 $\mu g/m^3$ (0.10 ppm) -
Carbon monoxide (CO)	1 hour 8 hours	- 22,600 $\mu g/m^3$ (20 ppm)
Nitrogen dioxide (NO_2)	1 hour 24 hours 1 year	- 92.5 $\mu g/m^3$ (0.05 ppm) -
Oxidant as ozone (O_3)	1 hour	200 $\mu g/m^3$ (0.10 ppm)
Suspended particles (TSP)	24 hours 1 year	260 $\mu g/m^3$ -
Lead (Pb)	1 year 24 hours	- 6.0 $\mu g/m^3$
Hydrocarbon (HC)	3 hours	160 $\mu g/m^3$ (0.24 ppm)
Hydrogen Sulphide (H_2S)	30 minutes	42 $\mu g/m^3$ (0.003 ppm)
Ammonia (NH_3)	24 hours	1,360 $\mu g/m^3$ (2 ppm)

COMPARISON OF AVERAGE AMBIENT QUALITY STANDARDS

STATE	SO2 (ppm)			NOx (ppm)			Dust(ug/m3)		
	1 Hour	24 Hours	1 Year	1 Hour	24 Hours	1 Year	1 Hour	24 Hours	1 Year
Japan	0,10	0,04			0,04 - 0,06		200	100	
U S A		0,14	0,03		0,08	0,05		260	75
Germany		0,14	0,05		0,15	0,05	400		200
Canada		0,06			0,10			120	
Sweden		0,25							
Finland					0,10			150	
Italy		0,15							
France								350	
Korea		0,15	0,05						
W H O		0,06	0,01		0,05				
Netherland		0,04			0,08				
Switzerland		0,04	0,01		0,04				
Philippines		0,14			0,10				
Malaysia		0,08			0,09				
Australia		0,14	0,02						
World Bank		0,19						500	
Indonesia		0,10				0,05		260	

SO2 : 0.10 ppm = 260 ug/m3
NO2 : 0.05 ppm = 92.5 ug/m3

emisi2.wk1

COMPARISON OF EMISSION STANDARDS

STATE	SO2		NOx		Dust
	ppm	mg/Nm3	ppm	mg/Nm3	mg/Nm3
Japan	100 - 550	286 - 1571	190 - 400	390 - 820	50 - 150
U S A	310 - 630	900 - 1800	370 - 520	760 - 1060	45 - 250
Germany	700	2000	390	800	50
Sweden	270	770	160 - 310	320 - 640	48
Korea	1800	5143			
Taiwan	1000	2860			
Australia	480	1400			
Indonesia	200 - 300*	570 - 866*	83 - 224	170 - 460	400 - 600

*) In SO3

WASTE WATER QUALITY STANDARD

slide-10

	PARAMETER		UNITS	STANDARD QUALITY CATAGORY I	II	III	IV
	PHYSICS						
1	Temperature		oC	35	38	40	45
2	Suspendel matter		mg/L	1500	2000	4000	5000
3	Sedimen		mg/L	100	200	400	500
	CHEMICALS						
1	pH			6-9	6-9	6-9	6-9
2	Iron	(Fe)	mg/L	1	5	10	20
3	Mangan	(Mn)	mg/L	0,5	2	5	10
4	Barium	(Ba)	mg/L	1	2	3	5
5	Cuprum	(Cu)	mg/L	1	2	3	5
6	Zink	(Zn)	mg/L	2	5	10	15
7	Chrom	(Cr6+)	mg/L	0,05	0,1	0,5	1
8	Total Crom	(Cr)	mg/L	0,1	0,5	1	2
9	Cadmium	(Cd)	mg/L	0,01	0,05	0,1	0,5
10	Mercury	(Hg)	mg/L	0,001	0,002	0,005	0,01
11	Clad	(Pb)	mg/L	0,03	0,1	1	2
12	Stanum	(Sn)	mg/L	1,00	2	3	5
13	Arsenicum	(As)	mg/L	0,05	0,1	0,5	1
14	Selenium	(Se)	mg/L	0,01	0,05	0,5	1
15	Nickel	(Ni)	mg/L	0,1	0,2	0,5	1
16	Cobalt	(Co)	mg/L	0,2	0,4	0,6	1
17	Cyanida	(CN)	mg/L	0,02	0,05	0,5	1
18	Sulphida	(H2S)	mg/L	0,01	0,05	0,1	1
19	Fluor	(F)	mg/L	1,5	2	3	5
20	Clorin	(Cl2)	mg/L	0,5	1	2	5
21	Amoniac	(NH3-N)	mg/L	0,02	1	5	20
22	Nitrate	(NO3-N)	mg/L	10	20	30	20
23	Nitrit	(NO2-N)	mg/L	0,06	1	3	5
24	BOD5			20	50	150	300
25	COD			40	100	300	600
26	Active Metyline Blue			0,5	5	10	15
27	Phenol			0,01	0,5	1	2
28	Vegetable Oil			1	5	10	20
29	Mineral Oil			1	10	50	100
30	Radioactive						
31	Pesticide (include PCB)						

- APPLICATION OF CLEAN COAL TECHNOLOGY :

*	NOx	LOW
*	SOx	POST COMBUSTION FGD
*	PARTICULATE	ELECTROSTATIC PRECIPITATOR

COAL CONSUMPTION AND ASH PRODUCTION
OF VARIOUS TECHNOLOGY

TECHNOLOGY	MW	COAL CONSUMPTION	ASH PRODUCTION	CO2 EMISSION
1. PULVERIZED COAL COMBUSTION :				
- WET FGD	150	1700 (BITUMINOUS) + 250 LIMESTONE	600	3740
- DRY FGD	150	1700 (SUBBITUMINOUS) + 145 LIMESTONE		3400
2. AFBC (ATMOSPHERIC FLUIDIZED BED COMBUSTION)	150	1700	880	3740
3. PFBC (PRESSURIZED FLUIDIZED BED COMBUSTION)	150	1500	900	3300
4. IGCC (INTEGRATED GASIFICATION COMBINED CYCLE)	200	2200 (BITUMINOUS)	400	4840
		2700 (SUBBITUMINOUS)	190	5400

LIST OF % SOx AND NOx REMOVAL

TECHNOLOGY	% SOx REMOVAL	% NOx REMOVAL
1. PULVERIZED COAL COMBUSTION :		
- WET FGD	90 - 95	-
- DRY FGD	80 - 90	-
2. AFBC (ATMOSPHERIC FLUIDIZED BED COMBUSTION)	90	60 - 80
3. PFBC (PRESSURIZED FLUIDIZED BED COMBUSTION)	90 - 95	60 - 80
4. IGCC (INTEGRATED GASIFICATION COMBINED CYCLE)	99	80 - 95

TO MEET THE STRINGENT ENVIRONMENTAL STANDARD IT IS NECESSARY TO INTEGRATE THE BEST SELECTION OF COAL TECHNOLOGY FOR THE ENERGY SUPPLY SYSTEM

ASIA PACIFIC COAL USE STRATEGIES: Needs, Plans, and Opportunities

Plenary Session 1

"INTERNATIONAL COLLABORATION AND PARTNERING FOR EFFECTIVE SELECTION, DEMONSTRATION AND ON-GOING USE OF CLEAN COAL TECHNOLOGIES"

Albert M. Ferrer
Vice President and Corporate Executive
Fossil Power Industry

December 1, 1993
2:15 to 4:00 pm

THE CHALLENGE :

Over the past ten years, the number of countries requiring strict environmental compliance has increased significantly. With the collapse of the Soviet Union and the trend toward privatization in many regions of the world, many countries are looking at their indigenous coal or lignite reserves as potential major energy suppliers for their fast growing economies. At the same time, global environmental concerns have increased environmental awareness in many of the developing nations. This scenario is resulting in a significant search for ways to use clean coal technologies to allow them to utilize their lignite and coal reserves in an environmentally acceptable manner. Other countries fearing dependency on a single fuel source and type are also looking at ways of utilizing indigenous or regionally available coal or lignite while meeting stricter environmental standards.

In many instances, these countries have existing energy facilities which, by their technological nature and age, do not conform to the new environmental requirements being promulgated in these countries. In almost every case, these nations are in the process of expanding their electrical generation and delivery systems to fulfill the demands of their expanding economies with the subsequent increase in their per capita standard of living. Generally, they are experiencing 5-10% electric load growth per year, with their economies expanding at about the same rate.

Due to the very nature of their economic development, most of the government resources are focused on the infrastructure required to support their economic growth. Few resources are left to nurture private investment in their countries.

Under these circumstances, there is relatively little time or resources to spend on the development of clean coal technologies. The result is that most of these developing countries are dependent on the importation of such technologies to make their coal or lignite utilization viable under stricter environmental requirements. The available clean coal technologies recently developed in industrialized countries address specific environmental requirements, and are generally protected by patents and licenses controlled by technology suppliers or manufacturers. Some of these clean coal technologies may be economically applicable to developing countries and some may not be. The end result is that these developing countries with a desire for "appropriate" clean coal technologies have generally limited access to them.

There are various avenues for collaboration and information exchange which help provide access to technology. Among these are:

- Educational exchange programs which expose and train developing country personnel to new technologies.
- Governmental assistance programs which promote use of indigenous clean coal technologies.
- Technical literature (paper copy and computerized information networks.)
- Sales personnel for manufacturers/vendors and technology suppliers inform through presentations or brochures, qualifications data, proposals, etc..
- Consulting arrangements -- case-by-case.
- Other avenues including international conferences (IEA, EPRI, etc.)

Most of the above information exchange tends to concentrate on the "latest and greatest state-of-the-art" as it is applied in the industrialized country where the technology was developed without enough emphasis on the practical and economic application of the technology in a developing nation. There is a need for engineering, construction and operations experience in order to properly assess their appropriateness for use in the developing nations.

We also must realize that we are dealing with a myriad of technologies. Some involve pre-combustion (coal clean up and preparation such as Custom Coals of Pittsburgh, Pennsylvania), others involve combustion technologies (such as CFB combustion, or TRW's in slagging combustion, and coal gasification, special burner designs, etc.) and others involve post-combustion technologies (baghouse, induct lime injection, wet limestone scrubbing, dry scrubbers, amine scrubbing, etc.). We can see how difficult it is for a decision maker in a developing nation to identify and decide which technologies are best economically suited for the country's needs as retrofits to existing plants or to be included in new generation facilities.

It is important to point out that in some instances (e.g. wet limestone scrubbing), a few of these technologies require supporting activities (such as limestone supply and processing or gypsum utilization or disposal) which need to be taken into account as part of the overall "appropriate application/evaluation" of these technologies. Another important aspect is that the application of these clean coal technologies also requires the proper education and training of management, technical and non-technical personnel to adequately operate and maintain of these technologies over their 20-30 year service life. The investment of time, people and money can be substantial.

WHAT IS NEEDED?

The knowledge gap we discussed earlier has been narrowed by the availability of information/databases (available through IEA, USDOE, EPRI, etc.) and through the case-by-case evaluations that many of these developing nations have conducted throughout the past five years... but it may not be enough!

We need mechanisms which not only provide access to various technologies to be evaluated, but which are able to match the most appropriate technologies to the scenario in a developing country. Almost all the countries in Southeastern Asia are proceeding at a fast pace towards higher levels of economic development with significant improvements in the standard of living for their people. To burden them now with expensive end-of-life (EOL) technologies could hamper or slow their economic development. One way which could be more economical is to provide a staged or stepped implementation of clean coal technologies as an "appropriate" approach to take for a specific country scenario. This staged concept would consist of examining the existing power generation infrastructure and applying economically viable technologies to improve environmental performance of power plants without significant retrofits at first, followed by application of other technologies in a phased basis. In parallel, the country's Integrated Power Generation Resource Planning could be examined to incorporate environmental requirements and the application of advanced technologies over a period of time. From this effort, a planned utilization of these technologies in new power plant facilities to be built can be derived, including, the technical and non-technical resources required These and other steps are discussed in one of the workshop papers "Systematic Coal Utilization/Technology Options Evaluation Process" (December 2 - Workshop A2).

However, to best achieve this match between approximate technology application and national needs, there should be a more intimate relationship between the organization possessing the broad technology knowledge base (with no economic self interest in any one of the technologies) and the recipient organizations in these developing countries with the need to use these technologies. To effect this intimate knowledge exchange which leads to the "appropriate" match, various management approaches have been attempted in industry. One, which we believe is the most successful involved the application of total quality management principles to the relationship and it is referred to as **Partnering**.

PARTNERING :

The U. S. electricity sector has functioned for many years as a joint effort between the utilities, equipment suppliers, engineering and construction firms and a wide range of other specialty or consultant services including a variety of utility management services. For many years the relationship of these parties was dominated by that of client and supplier. And, different utilities chose to embody into their own organizations greater or lesser degrees of the services capabilities available form private firms. However, the drive for reduced costs, greater efficiency and increased competition which has for some time prevailed in the U.S. electricity supply sector has driven all parties to seek out innovative ways to maintain their high quality of service while reducing costs. One of the effective concepts that has emerged is shared responsibilities under a "partnering" concept with these existing private service suppliers. It offers the prospect of a "win-win" situation for the partners in that is creates a capability of which the whole is greater than what each could do individually.

Partnering is a long-term commitment between two or more organizations for achieving specific business objectives by maximizing the effectiveness of each participants resources. To achieve its goals the partnering relationship must involve:

- Trust between the parties.
- Dedication to common goals, i.e. - a team endeavor.
- Understanding of each others individual expectations and values.
- Fully shared responsibility for work performance and quality of produce.
- The ability to adjust the sharing of responsibilities as the capabilities of the team members evolve over time.

Some of the key features of the Partnering Concept are:

- **Long-Term Commitment:**

  To be able to develop the close working relationship required and reap the benefits of it, we believe a partnering arrangement needs at least a 2-4 year life.

- **Achieving Jointly Set Business Objectives:**

  Partnering is not a loose or casual working relationship. It must be carefully defined in its scope and designed to meet specific objectives set by the parties. It's charter, scope and end-product must be clearly and mutually defined and understood.

- **Pro-active Participation of the Parties:**

  It involves shared responsibility -- individual team members do not succeed or fail, the team succeeds or fails. All involved play a key and active role in making things happen.

- **Sharing of Responsibility:**

  Sharing of responsibility makes maximum use of each parties knowledge strengths and resources. When one party's resources are marginal, strength from the other can be mobilized and applied to the requirement. The end-product (be it policy or system planning counsel, technical evaluations, project designs, etc.) can be used with confidence that it is well founded and objectively directed toward the jointly agreed purposes and goals.

In summary, the basic premise of partnering consists of two or more organizations that share similar values, have common goals, and possess complementary knowledge/know-how, joining forces to pursue a specific objective. This management concept promotes a relationship between parties based on trust, openness, ability to assemble resources possessing synergistic expertise, and includes appropriate incentives to develop a win-win situation among the parties involved. Ultimately, the partnering relationship develops into a whole entity which each part individually could not fully accomplish without substantial investment of resources and time.

Generally, this partnering concept would commence with "interface" sessions among the resources to be integrated into a partnering team to identify common goals, complementary resources to be shared, potential differences which could act as stumbling blocks in achieving these common goals and their resolution, potential incentives, values and value systems with emphasis on commonality among team members. Ultimately, a partnering team "culture" develops which results in each party seeing its key contributions to achieve goals while benefitting from the incentives and nurturing mechanisms. Each party contributes its knowledge and expertise about an issue while all team members "buy into" and commit to the actions required to resolve it or meet the agreed upon goals. It is at this step that the benefits of partnering are shown. We now have a team of complementary resources committing from both personal and organizational levels to achieve common objectives with the necessary their incentives to allow these resources to perform to established goals.

Applying this management concept to the scenario presented earlier, we see that power generation entities in developing countries bring to the partnering relation the detailed knowledge of local conditions, environmental requirements, capability of indigenous resources, organizational infrastructure, political and legal systems, realistic assessment of funding available and other factors essential to have the clean coal technology fit the need. Engineering-construction firms from industrialized countries such as Stone & Webster, bring the detailed knowledge of not just one clean coal technology but of all of them, and their applicability to specific situations. Since firms like Stone & Webster do not have an ownership (proprietary, license, etc.) position in these

technologies, we are better able to objectively evaluate them and choose the most cost effective one for a particular application.

With the detailed knowledge of the requirements to implement these technologies integrated with the detailed knowledge of available local/indigenous resources an "appropriate" methodology can realistically be developed which best meets the country's environmental requirements while providing the incentives to the implementing organization to meet these goals in a timely and cost effective manner.

Using the above example, other types of partnering relationships could be developed:

- Government-to-government partnership -- which can provide for a general relationship to promote the development of broad based revenues in the developing country to implement clean coal technologies.

- Manufacturer to local manufacturer -- to provide for longer term support in-country for the support of equipment involved in these technologies.

- Electricity Board to U.S. utility utilizing a particular clean coal technology which provides the developing country's electricity board with the operating and maintenance know-how for it to benefit from prior long-term experience with these technologies.

To make this "partnering" concept work requires:

- dedicated effort,

- mutual agreement and commitment among the parties,

- in-depth planning and training,

- openness in thinking - avoid paradigms,

- open and frank communication,

- involvement of the organization.

While Partnering does require effort and commitment, it has many rewards; among them:

- It enables you to expand your organization's ability to conduct analysis, evaluation, system planning and project evaluation preparation activities which exceed the capability of your in-house staff yet have that staff be an integral part of those expanded activities. By that staff participation, it increases their future capabilities, experience and knowledge base.

- It avoids the waste of resources, cost and time at the beginning of major projects to bring a new support contractor up-to-speed. It also saves the effort of multiple self-standing contractor procurement actions.

- It provides quick feedback and benefit to on-going efforts from the lessons learned from prior projects, analyses, and evaluations.

- It can provide both formal and on-the-job training of your staff leading to future expansion of your capability to effectively and efficiently plan and manage your operations.

CONCLUSIONS :

Our world is in a state of transition -- or possible better stated, several transitions. Those transitions present those of us working in the electricity supply sector with several difficult challenges.

Addressing these challenges requires dedication of talent and resources which frequently exceed those normally available. So, you must reach out beyond your in-house capabilities. We in the electric supply sector of the U.S. have extensive technology, and capabilities and experience in the use of those technologies to help you respond to those multiple challenges. And, we are prepared and anxious to provide a helping hand. It is in *your* best interest *and ours* that the support you need is provided in an effective, efficient, and cost-competitive manner. And, that as time proceeds, you increase both your in-house capabilities and that of your nations private service sector. In this context, we believe the proven attributes of the partnering concept merit your serious consideration. It is not a simple off-the-shelf product neatly wrapped and ready for delivery. It will take dedicated effort to define and put into place that arrangement which is best suited to your needs. But we believe the benefits which could result are large in terms of improving your capability to properly respond to the challenges you face.

Engineer-constructors such as Stone & Webster have many years of experience with partnering team concepts. These concepts have been used successfully in process, industrial and power industries in the U.S. and applied to small and large complex projects or ventures. We feel that it best matches the needs of the developing world with the capabilities available. By having the potential end user of the technology (e.g. local electricity board) team in a partnership with the right organization possessing the knowledge of the technologies available, while not possessing a self-interest in promoting any one of them, we have the opportunity for the optimum clean coal technologies to be applied in a cost-effective basis "appropriate" to the needs of the developing country.

SESSION II

ASIA-PACIFIC COAL USE STRATEGIES: AN INTEGRATED APPROACH

IEA Second International Conference on the
Clean and Efficient Use of Coal and Lignite

Plenary Address

ENVIRONMENTALLY SOUND TECHNOLOGIES FOR SUSTAINABLE DEVELOPMENT

by

Dr. Samuel Schweitzer
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U.S. Agency for International Development

December 2, 1993
Hong Kong

IEA Second International Conference on the
Clean and Efficient Use of Coal and Lignite

Environmentally Sound Technologies for Sustainable Development

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1. INTRODUCTION

The successful implementation of clean coal technology projects overseas depends not only on sound technological solutions, but also on the presence of sound strategies for long term, environmentally sustainable development. Clean coal technology will not succeed without the presence of this supportive developmental framework.

I will begin by establishing the vital link between energy and sustainable economic development. Next, I will acknowledge the substantial danger of continuing to use coal in the often inefficient and highly polluting manner of the past. I will then present USAID's outlook on how foreign assistance programs will be governed by the need to support sustainable development, incorporating environmental protection as a goal equal to economic development. Donors and multilateral development banks lack the resources to help developing countries make this transition, thus, private sector resources must be tapped.

I close with a brief discussion of how USAID -- using its experience in promoting public/private energy partnerships -- can assist to bring about the more rapid deployment of clean coal technology to support sustainable development.

2. ENERGY SHORTAGES: A CONSTRAINT ON SUSTAINABLE DEVELOPMENT

A fundamental problem facing developing countries is the need for more capital for the development of their electric power systems than their public sector utilities can supply. The demand for electric power is increasing at an average of seven percent annually in developing countries around the world. With a moderate economic growth in the future, developing countries will need over 1,500 GWs of new generating capacity by the year 2008, necessitating a capital investment of US $2.5 trillion.

An adequate and reliable supply of electricity is essential for social and economic development. The industrial, commercial and service sectors of the economies are highly interdependent on this form of energy. Therefore, it is not surprising that the demand for

energy in developing countries has been growing at rates of over 5.5 percent per year during the past 15 years.

Although access to electricity is essential for sustainable growth, developing countries, on the average, can afford only 500 kWh of electricity per capita per year compared to over 10,500 kWh per capita in the United States and 6,000 kWh per capita in Europe and Japan. Over 75 percent of the world's population consume only 18 percent of total electricity.

As developing countries seek to expand their economies, many now experience significant power shortages of over 10 percent of their generation capability. In Pakistan, for example, during the past 5 years, power shortages have been over 25 percent of the demand, in India, over 10 percent, in the Dominican Republic over 15 percent, and similar situations exist in many other countries. The negative economic impact of these shortages on developing countries has been tremendous.

Private industry in developing countries is perhaps hardest hit by power shortages. Various studies have revealed that power outages alone can cause economic losses of approximately US $1 per kWh not supplied. In Pakistan, for example, load shedding to the industrial sector alone has led to a 1.8 percent decrease in GDP and a 4.2 percent decrease in the country's foreign exchange earning. For India, the cost of unreliability in electricity supply to the industrial sector has been estimated at 1.5% of GNP. These estimates, however, do not include the value of future investments foregone due to unavailable or unreliable electric power.

Looking to the future, the problem becomes even worse. In a recent report, titled Power Shortages in Developing Countries, USAID projected that if the current trend in electricity supply expansion in developing countries continues under the modest economic growth rate of 4.5 percent per year between until the year 2008, developing countries will need additional power generation capacity of over 1,500 GWs, compared to current installed capacity of some 450 GWs. Future expansion requirements will demand an annual investment of about $125 billion per year, compared to current expenditures of about $50 billion, necessitating a total capital investment of US $2.5 trillion.

Even with dramatic supply and end use efficiency improvements and strict conservation, the need for substantial additional generation capacity can only be cut in half to some 700+ GWs during the 1988-2008 period. Also, there is a growing consensus that publicly controlled utilities -- because of an inability to secure financing, political influence, lack of spare parts, and inefficient operations -- will not be able to achieve this conservation scenario.

Even if conservation and efficiency improvements are successfully implemented, this "least cost" strategy will require investments on the order of $70 billion per year for new generating capacity. This portends a capital gap of about $300 billion during the next 20 years.

The environmental impact of coal use are significant and will continue to be so. Currently, electric power generation accounts for 30 percent of all fossil fuel consumption and 50 percent of all coal consumption worldwide. According to World Bank estimates, if the anticipated growth in fossil fuel-fired power plants without wide deployment pollution abatement technologies, pollutant emission would increase more than fourfold over the next twenty years and tenfold fold in the next forty.

Therefore, the cleaner use of the world's coal resources is essential to improving the environment. Clean coal technology improvements are needed in three areas:

1. reduction of harmful contaminants of coal fuels and switching to clean coals or other fuels,
2. more efficient conversion of coal to electricity, and
3. enhanced abatement of harmful emissions and waste products.

The application of proven clean coal technologies can substantially reduce the adverse environmental impacts of using coal. These approaches include technologies for coal cleaning, advanced boiler systems, particulate removal and flue gas desulfurization equipment, fluidized bed combustion systems, and integrated coal gasification combined-cycle technologies. Based on World Bank, OECD and Asian Development Bank analyses, these technologies can reduce particulates, sulphur dioxides and nitrogen oxides by over 90 percent, while also improving the thermal efficiencies of power plants.

Consequently, when most developing countries begin to address the needs of their energy sectors, they are confronted with a devastating "triple bind" that seriously constrains them from achieving sustainable economic and social development:

- Local, regional and global environmental degradation from energy use;
- Inadequate energy policy and institutional frameworks; and
- Insufficient capital for investments needed to expand energy capacity.

As a development organization, USAID can be most effective by focusing its limited resources on these areas. And, wherever possible, we prefer to act in partnership with the multilateral development banks, other donors, and host country governments and institutions.

3. CONSIDERING CLEAN COAL TECHNOLOGY WITHIN THE CONTEXT OF SUSTAINABLE DEVELOPMENT STRATEGY

The term "sustainable development" has its root in the 1987 report of the World Commission on Environment and Development titled Our Common Future. It is defined as, "meeting the needs of the present generation without compromising the needs of future generations."

USAID believes that sustainable development must be characterized by economic and social growth that does not exhaust the resources of a host country; that does not damage the economic, cultural, or natural environment; that creates many incomes and chains of enterprises; and that builds indigenous institutions that involve and empower the citizenry. Development is "sustainable" when it permanently enhances the capacity of a society to improve the quality of life.

In far too many nations, slash-and-burn approaches are still the norm -- not only in agriculture, but in energy development and in every other phase of development. In these countries, growth, by definition, consumes things: energy sources, forests, water, soil, even people. Additionally, sustainable development, whether in environmental protection, energy production or economic growth, must be based on the enhancement of indigenous capacity. Consequently, we are very committed to long-term institutional improvements through information and technology transfer and through training programs.

Under the Clinton Administration, the U.S. foreign assistance program, administered by USAID, has adopted four basic goals to guide its activities. These goals are:

- Encouraging broad-based, sustainable economic growth,
- Protecting the environment,
- Stabilizing world population growth and protecting human health, and
- Building democracy.

The first two of these relate directly to how USAID will support clean coal technology development projects in the future.

First, USAID is committed to encouraging broad-based, sustainable economic growth. The keys to economic growth are: an appropriate policy environment, good governance, adequate investment and savings, and the availability of appropriate productive technologies.

USAID aims at helping the people of developing nations to become participants in their economies by supporting policy reforms in such key sectors as energy and environment, encouraging the effective functioning of markets, by investing in human resources (especially education and training) and by aiding projects designed to promote environmentally sustainable economic growth.

Second, USAID programs and projects must serve to protect the natural and human environment. This will involve taking steps to reduce the long-term threats to the global environment, particularly the loss of biodiversity and climate change -- the latter being of central importance in any discussions over the future use of coal. Additionally, USAID will address environmental practices that impede sustainable development, such as threats to human health due to air, water, and soil contamination; unsustainable exploitation of forests, wetlands and other ecosystems; degradation of water resources; inefficient and

environmentally sound energy projection and use; and regulatory, statutory, enforcement and policy issues.

Regarding the relationship of USAID's goals to clean coal technology, the Agency sees a significant need to reduce the use of fuels and technologies that endanger the global and local ecosystem. Nevertheless, the more efficient use of coal, its conversion to less polluting energy forms, such as gas, and the environmental retrofit and upgrade of existing fossil fueled facilities will receive major attention.

4. PARTNERSHIPS: AN ESSENTIAL APPROACH

Fundamental to USAID's approach to implementing environmentally sound approaches and technologies is the creation of partnerships. We begin with collaboration between donors, multilateral development banks and host nations. We recognize that development, in every sense, depends on the developing country itself. USAID, other donors and the multilateral development banks can assist. We can help, facilitate, even accelerate, but the major task must be carried out by the host nation, not the donors.

Donors must reinforce each other and coordinate at every stage of the development process. USAID can improve its own effectiveness by cooperating with other donors in:

- the joint assessment of development problems and the threats they represent,
- cooperative planning and division of responsibility,
- allocation of resources to reinforce other development efforts,
- pooling of financial resources where possible and appropriate, and
- the sharing technical resources and expertise,
- the rapid transfer of information about methods and results, and
- the collaboration and communication in the field with host governments and local private sector institutions.

Given USAID's limited resources, partnership also involves leveraging. In its purest sense, leveraging involves the pursuit of matching funds. Where appropriate, this is an effective way to increase resources, and much of our leveraging work will continue to be done in coordination with multilateral development banks.

USAID will provide assistance where local country strategies exist that take into account the totality of the development problems confronting recipients. USAID will consider how social, economic, political, and cultural factors combine to impede development and identify root causes and remedies that will address them. Any assistance for energy development, including clean coal technology, must be consistent with these country strategies.

5. LIMITATIONS ON DONORS

As I noted at the beginning of this presentation, the funds of USAID, other donors and multilateral development banks are insufficient to finance all needed infrastructure, especially capital-intensive energy projects; such as clean coal technologies.

For many of the developing countries -- especially the lower income countries -- the amount of capital needed for the "clean" part of clean coal technology may be beyond the capacity of both the multilateral banks, host countries or bilateral donors. There have been some efforts, such as the Global Environment Facility of the World Bank and others to subsidize the additional cost of "clean" technology, but efforts such as this are woefully inadequate to meet the need for environmentally clean energy production technology.

However, even if all the funds required were available, they could not solve the problems without a sound policy and institutional framework for rationally absorbing them. Establishing this framework is the role of the donor nations. This is why USAID sees an increasing need for cooperative action by donors and multilateral development banks and by the private sectors from developed and developing countries.

USAID, like other donors, also recognizes that for the least developed countries the realities of personal survival have taken precedence over the need for environmental protection. We recognize the need for these weaker economies to rise to a level where the people and their leaders can appreciate the value of a clean environment and the necessity of paying the price to achieve it.

Major economic restructuring may be necessary in many countries before the resources of the private sector -- both internal and foreign -- can be attracted to invest heavily in resolving energy and environmental problems overseas. This restructuring is a long and difficult process.

In the short term, private sector participation and investment in new, cleaner and more efficient energy technologies may only occur in a select number of countries, while other countries work on setting in place the appropriate pre-conditions.

Donors cannot impose costly clean technologies upon developing nations which are unable to pay the costs of such equipment. The challenge we see for the clean coal technology industry is to develop innovative, lower cost technologies -- ones which are more competitive with older, less efficient technologies.

6. ROLE OF PRIVATE PARTICIPATION IN THE POWER SECTOR

A central premise of this paper is that, for many developed and developing countries, private participation in the electric power sector can assist in resolving the recurring problems of

insufficient financing and inefficient operations. Private participation can come in many forms: independent generation plants, industrial cogeneration and self-generation with sales to the public grid, privatization of utility ownership through partial or whole sale of assets, privatization of distinct utility services such as generation, distribution, or transmission functions through management contracting and leasing. Needless to say, no one approach is best suited for all countries.

Private sector participation can bring forth significant benefits:

- First, encouraging private participation in the energy/power sectors will raise additional investment capital from private sources thus reducing public borrowing.

- Second, private sector participation can also result in increased efficiency in management, operation and construction. From the environmental viewpoint, the private sector power plants -- more so than publicly owned facilities -- must remain in compliance with environmental standards and requirements, generally resulting in less environmental degradation during plant operation.

- Third, private participation can foster the adoption of more innovative, environmentally sound technologies and system operating methods.

Allow me to expand a little on the subject of innovation, especially since the introduction of clean coal technology overseas is such a good example. In the United States and other developed countries, the private sector, rather than the public sector, has been the source of most technological and system management innovation in the power sector. With its focus on efficient operations and enhancing its rate of return, private sector firms have invested heavily in technological and system management innovation, such as clean coal technologies.

Private utilities are constantly seeking new measures to improve plant performance, such as more efficient boiler configurations, exhaust heat recovery, combined cycle gas turbines, fluidized bed combustion systems, and modular design. Private sector innovation has additionally led to the installation of cost effective pollution control technologies and the design of more environmentally benign generation facilities.

Let me add a cautionary note. To be sustainable, clean coal technologies must be proven commercially available at costs that developing countries can afford. USAID cannot be in the position of urging these nations to accept technology that is experimental or untested. Also, we must caution the clean coal technology industry to transfer technology that is affordable, even if it is not "state of the art". Substantial gains in environmental improvement can be achieved by introducing what in the United States might be considered conventional clean coal technologies.

7. ROLE OF USAID

Despite the obvious role for the private sector to play in supplying the infrastructure for sustainable development, USAID recognizes that numerous barriers still exist in many countries -- barriers that USAID, other donors and the multilateral development banks can help overcome.

Private businesses need more and better information about overseas markets and investment conditions. They need stable political and economic environments to ensure their investments. Through their explicit policies, laws and regulations, developing countries who want clean coal technology must provide a clear and rationale playing field for foreign investors. And, ultimately, the users of energy must be willing and able to pay the true costs of its provision, i.e., cross-subsidizes for low cost energy must end.

Donors, such as USAID, understand that one of their roles is to assist in establishing the pre-conditions that are essential tor clean coal technology project implementation. Also, donors can act as a broker between hesitant and cautious host country governments and the private sector firms that are seeking investment opportunities. We can help breakdown the barriers and even distrust that commonly exists between developing country governments and their utilities and foreign investors. In our role as advisors to governments, we can thereby help open energy markets to private capital and move these nations closer to free market economies.

USAID can assist the implementation of environmentally sound technologies by helping establish the pre-conditions necessary for project implementation. These include:

- helping create a common base of information and understanding through information transfer and technology cooperation about available clean coal technologies, market opportunities and the requirements of foreign investors,

- assisting developing countries to fashion appropriate policy, fiscal and regulatory reform,

- fostering institutional capacity building in host country governments, electric utilities and other public and private entities so that they can plan for and integrate clean coal technology and private investment,

- working with multilateral development banks, host countries and project developers to achieve financial framework strengthening to assist in the difficult process of arranging equity and debt investment and security guarantees for specific energy projects, and

- assisting project developers with project identification and implementation by supporting the preparation of pre-investment analyses, and by working with the

local utility and government officials to overcome specific development problems.

In an effort to open up opportunities for clean coal technology and private investment in the energy sectors of developing countries, USAID -- in cooperation with other donors and multilateral development banks -- has provided a wide variety of assistance to developing countries.

- Brokering between host countries and project sponsors
- Information sharing- seminars, trade missions, technology options, and market assessments
- Policy and regulatory advisors - energy development and privatization
- Training courses & study tours
- Technical assistance - technology options and cost analyses
- Feasibility study support
- Financial packaging advice

In our presentations tomorrow, my colleagues and I will provide you further information about specific activities that we have supported in India, the Dominican Republic, Armenia and the Philippines.

8. CONCLUSION

Despite the difficulties facing the clean coal technology industry and its expansion in some developing countries, we at USAID are extremely positive about the future. The world -- especially the developing world -- will, and must, use more coal to provide the energy upon which modern economies are built. Yet, every effort must be made to minimize the adverse environmental and economic impacts of this trend.

Development agencies such as ours can help establish the necessary pre-conditions for investment in clean coal technology, but only the industry and its investors can provide the technology to do the job.

I would like to challenge the clean coal technology industry. Initially, it appears that clean coal technology may be most applicable to the upper income tier of developing countries, especially those where electricity prices are reflective of the real costs. For other, less well off countries, the clean coal technology industry will need to seek and propose innovative and lower cost clean coal technological alternatives. Within our resources, USAID stands ready

to assist wherever necessary to foster the rapid dissemination of clean coal technology among the developing nations.

IEA Second International Conference on the Clean and Efficient Use of Coal and Lignite

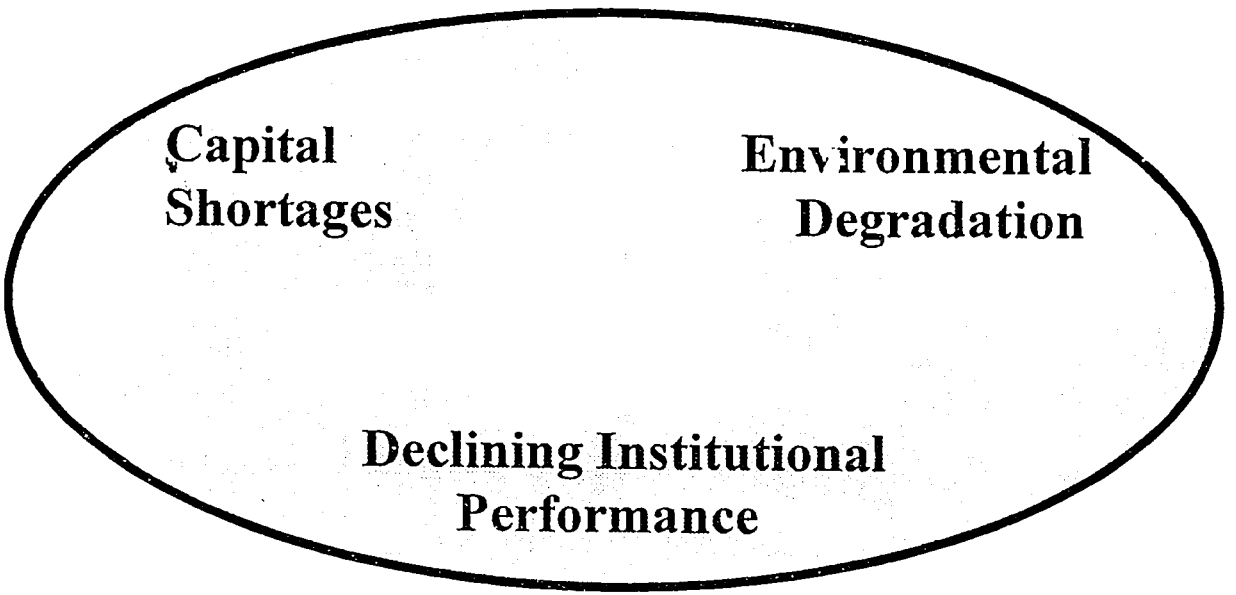
Plenary Address

Environmentally Sound Technologies For Sustainable Development

Dr. Samuel Schweitzer, Chief
Energy Innovation and Private Sector Division
Office of Energy and Infrastructure
U.S. Agency for International Development

Hong Kong
December 2, 1993

The Triple Bind



USAID Office of Energy and Infrastructure

USAID Goals

- Encouraging Broad-based, Sustainable Economic Growth;
- Protecting the Environment;
- Stabilizing World Population Growth and Protecting Human Health; and
- Building Democracy.

USAID Office of Energy and Infrastructure

Advantages of Private Sector Participation

- Access to Private Investment Capital
- Efficiencies in Construction and Operation
- Innovation Technology, e.g. CCT

USAID Office of Energy and Infrastructure

Pre-conditions for Clean Coal Technology Project Implementation & the Role of USAID

Information Transfer & Technology Cooperation

↓

Policy, Fiscal & Regulatory Reform

↓

Public/Private Institutional Capacity Building

↓

Financial Framework Strengthening

↓

Project Identification and Implementation

USAID Office of Energy and Infrastructure

Pre-conditions for Clean Coal Technology Project Implementation & The Role of USAID

	INFORMATION TRANSFER & TECHNOLOGY COOPERATION	POLICY, FISCAL & REGULATORY REFORM	PUBLIC/PRIVATE INSTITUTIONAL CAPACITY BUILDING	FINANCIAL FRAMEWORK STRENGTHENING	PROJECT IDENTIFICATION & IMPLEMENTATION
Key Participants	Host Country Public & Private Sectors U.S. Public & Private Sectors	Host Country Government Entities Host Country Priv. Sector Entities Multilateral Orgs. & Bilateral Donors	Host Country Government Entities Host Country Private Sector Entities	Host Country Entities Project Sponsors Investors & Lenders	Host Country Government Entities Project Sponsors Investors & Lenders
USAID Tools	Info Transfer & Technology Coop. Seminars Market Assessments Technology Options & Cost Analyses Study Tours Trade Missions	National Planning Assistance Legal/Policy Assist. Regulatory Assist. Privatization Assist. Training & Internships Document Prep.	Financial Advisor Technical Assistance Training & Internships Study Tours Conferences	Financial Advisor Cooperation with Multilateral Lenders Guidance to Private Investors Information-Sharing Seminars	Brokering with Host Country Gov't. Entities Feasibility Study Support Guidance to Project Sponsors

Continuous Support for Public-Private Partnerships

· USAID Office of Energy and Infrastructure

IEA Second International Conference on the Clean and Efficient Use of Coal and Lignite:
Its Role in Energy, Environment and Life
December 2, 1993

IMPROVED COAL TECHNOLOGIES FOR THE ASIA PACIFIC 21ST CENTURY ECONOMIC DEVELOPMENT

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Current state-of-the-art and future advances in coal utilization technology will play an important role in economic development in the Asia Pacific region in the coming decades. Coal and coal-using technologies thus will contribute to global social progress. The coal technologies that can be expected to have the most impact - state-of-the-art pulverized coal power plants, coal upgrading, fluidized bed combustion, and coal gasification - are described, and perspectives are offered regarding their applicability.

THE GLOBAL PROMISE OF ELECTRICITY

The theme of this conference, "Clean and Efficient Use of Coal and Lignite: Its Role in Energy, Environment and Life," effectively conveys a global perspective on why we are here. Population and poverty are the paramount long-term issues faced by our global village. In electric power engineering terminology, we can say that population and poverty are the root cause issues. The enduring solutions are global education and electrification. The means to achieve these solutions is technology innovation and application.

Energy Efficiency and Electrification. An advanced stage of human development and quality of life does not inevitably require or imply high energy consumption. In fact, the past three decades of experience in the United States, Japan, and the highly developed European countries show that increasing sophistication in industrial progress leads to decreased intensity of energy consumption. For example for the past several years growth in U.S. energy consumption has been less rapid than growth in U.S. gross domestic product (GDP). Specifically, energy consumption per unit of GDP decreases as electricity accounts for a greater fraction of ultimate energy use.

The implication of this relationship for energy policy planning is profound, given that in most Asian economies the growth rates of both electricity consumption and GDP are two to three times the corresponding growth rates for the world as a whole: Increased electrification is a key mechanism for accomplishing economic development while using energy resources effectively, equitably, and environmentally responsibly.

THE ROLE OF COAL RESOURCES AND COAL TECHNOLOGY

Coal in Asia. Coal is the most abundant fossil fuel, accounting for 80% of the world's fossil reserves. The geographical diversity of its resource locations, low extraction costs, low transportation costs and production capacity in excess of world requirements keep the delivered price of coal at the low end of the fossil fuel spectrum. Most projections show that worldwide coal consumption will at least double in the next 30 years.

Nearly half of Asia's primary energy requirements are met by coal, and this dependence is likely to continue for several reasons, many of them founded in the overriding goal of economic development. Two of the key contributing factors are:

- Coal is abundant in Asia, and is the single most abundant energy resource in several of its countries.

- Central planning in most Asian governments drives energy decisions toward indigenous resource development and other long-term internal benefits.

EPRI's Role. The Electric Power Research Institute is a non-profit tax-exempt voluntary membership collaborative R&D organization - the largest private energy R&D organization in the U.S. EPRI's mission is to discover, develop, and deliver advances in science and technology for the benefit of our members, their customers, and society. We develop and manage a broad research program aimed at all aspects of electricity production, delivery, and utilization; in 1993 this program will amount to over $550 million.

Almost one-third of EPRI's funded research objectives are aimed at technology advances to make coal a better energy source for electrification; these objectives include enhancing the productivity of existing coal-fired power plants and new state-of-the-art designs; controlling coal-fired power plant air, water, and solid emissions; upgrading coal supplies; and developing and demonstrating cleaner and more efficient coal-fired electric generating technologies.

Coal Technologies' Role. The purpose of the coal technology summaries below is to highlight important lessons learned from U.S. research, development, demonstration and deployment experience with technologies that may be applicable in the Asia Pacific in the next 30 years. Some perspective is also offered on the technological and financial infrastructure required to implement and support each of these technologies in Asia.

STATE OF THE ART IN PULVERIZED COAL FIRED ELECTRIC POWER

The goal of a pulverized coal (PC) power plant with near zero wastes and thermal efficiency approaching 50% is technically possible within the first decade of the 21st century. PC-fired electricity generation will remain the technology choice for many U.S. utilities and should be attractive for Asia Pacific development for several reasons:

- The PC power plant is proven technology for small or large capacity increments up to 1300 MW using a single-shaft steam turbine.

- The supercritical steam cycle technology used in new power plants being installed now has the capability for over 40% thermal efficiency even with full environmental controls. By early next decade a PC-fired combined cycle with topping turbine could achieve 47% thermal efficiency in a plant with full environmental controls.

- Current technology allows reliable and effective control of sulfur and nitrogen oxides. The experience base in the U.S. and elsewhere is growing steadily. For example, by year 2000, 60 GW of U.S. PC-fired generating capacity will be equipped with SO_2 scrubbers.

Technology is available from world-wide suppliers to build new state-of-the-art power plants (SOAPP) incorporating the following features, reflecting the results of decades of operating experience and development progress by EPRI, U.S. and international utility organizations, equipment manufacturers and engineering firms.

- "Ultra supercritical" steam conditions of 31 MPa (4500 psig), 870 K (600°C, 1100°F), double reheat.

- All-ferritic alloy boiler and turbine materials.

- On/off cycling capability; operable as low as 10% load; 40% thermal efficiency down to 50% load.

- Modular (replicated and highly shop-fabricated) construction; 24-month construction time from first concrete pour.

Efficiency Improvement and Environmental Performance. Earlier I made the point that electrification is a path to improving overall primary energy utilization. Recent advances in coal-fired power technology offer opportunities for improving the efficiency of the conversion step from primary energy to electric energy.

- Most new coal-fired plants built in the industrially developed countries will employ supercritical or ultra supercritical steam cycles and advanced plant control systems to optimize thermal efficiency at any required load.

- Thermal efficiency can be improved at least 3-5% in most existing large fossil power plants by installing heat rate and monitoring instrumentation and implementing formal heat rate improvement programs with rapid economic payback in recovered generating capacity and/or fuel saved. Such thermal efficiency improvements naturally result in 3-5% or greater reduction in particulate, SO_2 and NO_x emissions for the same electric output. Thermal efficiency advances reported at recent EPRI conferences and other international forums include (1) computer software to model boiler cleanliness, heat balance, and gas duct dynamics; (2) new instruments and systems for testing thermal

performance, monitoring heat rate, measuring circulating water flow and measuring low-pressure steam turbine efficiency; and (3) auxiliary equipment improvements such as condensing heat exchangers, macro biofouling control techniques, condenser air leakage control, air heater monitoring and feedwater heater control.

The state of the art in environmental control technology can enable significant particulate, SO_2, NO_x, water, and solid waste emission reductions from new PC fired plants to be built in the Asia Pacific region, compared to plants built in the industrially developed countries at comparable stages in their economic development history. These technologies are well developed and commercially available, including, for example:

- Electrostatic precipitator design advances for increased particulate control under varying load conditions and with a broader range of coals - advances such as wider plate spacing, intermittent energization and low-cost flue gas conditioning.

- Shake/deflate fabric filters, pulse jet fabric filters, and improved fabrics for lower cost particulate control.

- Lime or limestone slurry spray scrubbing.

- Forced oxidation limestone slurry SO_2 control, notably Chiyoda's CT-121 process.

- Lime slurry spray-dry SO_2 scrubbing.

- Combustion burner design NO_x reduction.

- Postcombustion NO_x catalytic or non-catalytic reduction by ammonia or urea.

- Fly ash and bottom ash utilization in road construction, building materials and machinery.

Accelerated technology transfer, development assistance and multinational investment programs coupled with a "global emissions trading" protocol all might have roles to play in resolving tradeoffs between global environmental protection and the urgency of economic development in many countries of this region.

Improving the Use of Existing Plants. Where an installed base of coal-fired electric generating capacity already exists, improving operation and maintenance along with implementing moderate-cost efficiency and environmental upgrades can be the most cost-effective near-term as well as long-term approach to generating capacity planning. This means that for existing plants also, recent technology advances offer numerous opportunities for application in the Asia Pacific region. Some examples are described briefly below.

- **Identify and permanently solve failure mechanisms.** Many PC fired plant shutdowns are caused by component failures whose root causes are now understood and preventable through relatively inexpensive operating changes, plant monitoring, or

component modifications. Examples of the current state of knowledge are EPRI's Boiler Tube Failure Reduction guidelines, training curriculum, and the computerized Boiler Maintenance Workstation.

- **Restore or improve thermal efficiency through performance monitoring.** Performance monitoring is the on-line detection of deteriorating thermal efficiency and its root causes. EPRI and the Potomac Electric Power Co. (PEPCO) have been developing improved sensors and instrumentation systems since 1982 at PEPCO's Morgantown Station. The computerized Performance Monitoring Workstation compares measured and target performance, looks for effects of operating changes on plant performance, and pinpoints component degradation. Several other U.S. utilities have installed or are planning to install the Performance Monitoring Workstation at existing power plants.

- **Implement diagnostic monitoring and predictive maintenance.** Present technology in continuous and intermittent diagnostic monitoring allows a maintenance philosophy called predictive maintenance that is based on knowing the condition of each plant component - rather than on a maintenance calendar (preventive maintenance) that can sometimes result in costly and unnecessary replacement of components. Predictive maintenance is being demonstrated by EPRI and Philadelphia Electric Co. at the Eddystone plant in Philadelphia.

- **Retrofit modern control systems.** Most PC plants operating today were designed with analog or pneumatic control systems that are 15-20 years old or more. Modern digital distributed control systems offer the potential for intelligent automation and integration with plant monitoring data.

- **Train operators using low-cost plant simulators.** The power of the modern microprocessor allows desktop workstation simulators to be designed and built for a fraction of the cost of the few full replica simulators that were built in the past for fossil power plants. Such simulators can be used to test operational changes and optimize startup and shutdown sequences as well as for new and refresher training of plant operators.

- **Upgrade deteriorated or obsolete plant hardware components.** Examples of modern components commercially available are:

  - retrofit burners for low NO_x and low load operation
  - super 9Cr steel alloy for longer-life, higher-temperature thick-wall components such as headers and steam lines
  - improved water chemistry instrumentation
  - titanium alloy low-pressure turbine blading
  - super clean steel alloys for low turbine rotors
  - erosion-resistant coatings for high pressure turbine blades and valves
  - improved generator stator insulation
  - inherently stable feed pump designs

- heat pipe air heaters
- adjustable speed drives

U.S. design, engineering, and operating experience is already available for many of these upgrades.

COAL UPGRADING

The coal upgrading approach most likely to be feasible in the Asia Pacific is physical cleaning to remove inorganic (ash forming) constituents and pyritic sulfur. There is an extensive base of U.S. experience with coal cleaning in more than 400 operating coal cleaning plants, most of them at the coal mine. The economic incentives - and effectiveness measures - for coal cleaning are:

- Reduce transportation volume and weight with minimal loss of the fuel's energy content.

- Reduce the impact of ash constituents on the power plant's coal handling equipment, pulverizers (erosion), boiler tubes (slagging, corrosion-erosion), particulate control and solid waste handling systems - all of which affect operating and maintenance costs and thermal efficiency.

- Reduce sulfur content to avoid or reduce the cost of SO_2 control and solid waste disposal systems.

- Improve the homogeneity of the fuel as delivered to the plant's boiler.

The Coal Cleaning Cost Model is an EPRI developed model in workbook format for estimating capital and operating costs of conventional coal cleaning processes to ±20% accuracy.

Even for lower rank (lower value) subbituminous coals and lignites, for specific situations a comprehensive analysis of the true fuel cost - i.e. including impacts on the plant - may show a payoff for coal cleaning that could not be justified based only on delivered fuel price per energy content. EPRI's Coal Quality Impact Model, available commercially, and the more comprehensive Coal Quality Expert being developed by CQ, Inc. under EPRI and U.S. Department of Energy funding, are tools for evaluating the economic tradeoffs in coal selection and coal upgrading decisions.

FLUIDIZED BED COMBUSTION

Fluidized bed combustion (FBC) has several attractive features for application in the Asia Pacific region.

- It offers broad flexibility of coal feed stocks, compared to pulverized coal or gasification plants.

- It has inherent SO_2 and NO_x reduction - SO_2 by *in situ* absorption by limestone fed into the fluid bed, NO_x due to significantly lower combustion temperatures relative to a PC boiler.

- It is cost-competitive with PC-fired plants, especially at the smaller sizes that may be most practical for bringing electricity generating capacity to medium-size growing urban load centers.

- There is an extensive experience base, especially in the smaller sizes found in several decades of U.S. industrial application.

AFBC. There are over 150 atmospheric FBC (AFBC) units operating for power generation in the U.S., and ten vendors of FBC boilers, four of whom offer units as large as 250 MW.

Large-scale bubbling bed (most of the solids stay in the bed) AFBC units are operating successfully at Tennessee Valley Authority's Shawnee station in Kentucky (160 MW) and Northern States Power's Black Dog plant in Minnesota (133 MW). The focus of AFBC in the U.S. is now on circulating fluid beds (CFBC - most of the solids continually circulate and are returned to the bed). The repowering project at Nucla station in Colorado (currently Tri State Generating & Transmission Assn. Inc.) successfully demonstrated CFBC technology at 110 MW scale. Texas New Mexico Power Co. built the largest CFBC units in the world - 2x150 MW lignite-fired, with reheat - and started them up in 1990. Commercial plants in planning have reached the 250 MW size in the U.S. and 350 MW in Japan.

EPRI evaluated early operating experience on four second-generation AFBC boilers (including the two Texas New Mexico units) to compare their availability with 27 PC boilers, 150-800 MW in size, all with flue gas SO_2 scrubbing systems. The average availability of the four AFBC units was only two percentage points less than the 27 PC units (86% versus 88%) - indicative of an advanced stage along the learning curve for the first large-scale applications of this technology.

Most U.S. AFBC units today are being installed in the 50-100 MW size range by independent power producers. Fuel feedstocks include not only coal and lignite, but also petroleum coke, anthracite culm, forest wastes, and tires.

PFBC. Compared to AFBC, pressurized fluidized bed combustion (PFBC) has the advantages of smaller size and thus lower capital cost, lower fluidization velocity (less erosion), added fuel flexibility, more opportunity for shop-fabricated modular construction and the potential for thermal efficiency over 40%.

The operating experience base is more limited for PFBC. Large-scale U.S. experience resides in American Electric Power Co.'s Tidd station 70 MW repowering demonstration under Round 1 of the U.S. DOE's Clean Coal Technology program. Other operating experience is being acquired from 2x80 MW bubbling bed PFBC units at Stockholm Energi's Vartan station in Sweden and from Endesa's Escatron 80 MW unit in Spain. The Stockholm units are providing district heating as well as power. The Escatron unit fires a lower-rank "black

lignite" with high ash, high sulfur and high moisture content. All four of these units have demonstrated environmental performance better than expected.

Other PFBC projects include Electric Power Development Co.'s 70 MW demonstration in startup at Wakamatsu, Japan; Midwest Power's planned 70 MW circulating PFBC repowering under Round 3 of the DOE Clean Coal Technology program; and American Electric Power's deferred 320 MW unit under Round 2 of the CCT program.

Recent EPRI studies suggest that the cost of electricity from a bubbling PFBC plant burning high-sulfur coal is competitive with other advanced fossil technologies and may have significantly lower cost than the other options when low-sulfur coal is burned.

Circulating PFBC is in the initial development stages, as is advanced PFBC, described briefly later.

ADVANCED COAL TECHNOLOGIES

The technologies described above are based on the Rankine steam thermodynamic cycle and (except for FBC) rely on postcombustion cleanup of environmental pollutants. These technologies can probably meet current or near future economic, efficiency, and environmental requirements in the Asia Pacific. However, a longer economic and environmental perspective for the region requires attention to higher efficiency, inherently cleaner technologies. Moreover, some of these advanced technologies - notably coal gasification in a combined cycle configuration - are already competitive with state-of-the-art PC-fired electric generation in some applications.

The leading near-term candidate is integrated coal gasification combined cycle (IGCC) of which several plants are in demonstration. In the future, significant efficiency improvements can be expected from combining coal gasification and pressurized fluidized bed combustion technology - termed advanced pressurized fluidized bed combustion or APFBC; and ultimately the integration of coal gasification and molten carbonate fuel cells - "integrated gasification/fuel cell" (IGFC). APFBC is being pursued by several developers and will be demonstrated at pilot scale in a joint project of the U.S. DOE, the Southern Company, and EPRI in Alabama. As for IGFC, the first fuel cell operation on coal gas occurred in September in an EPRI-sponsored test at Destec's Plaquemine, Louisiana gasifier. The challenge for these latter technologies - which have the potential for thermal efficiencies approaching 60% - is to reduce their complexity and capital costs to keep them "in the running" in the competition with more conventional technologies that are also continuing to evolve.

The U.S. Department of Energy's Clean Coal Technology program, initiated in 1986, has been essential to the demonstration, and indirectly the continued development, of advanced coal technology in the U.S. during an era when the availability of natural gas and the relatively low capital cost and risk of combustion turbine capacity additions has temporarily damped enthusiasm for new coal-based generation. The DOE-cosponsored demonstrations include not only the application of advanced high performance emission control systems to

existing PC plants, but also first-of-a-kind advanced power generation systems such as PFBC and IGCC. DOE has also built links from advanced coal-based development programs into its Advanced Turbine Systems program aimed at commercialization of 60% thermal-efficient (lower heating value) gas turbine cycles.

Coal Gasification. Coal gasification technology has a long history in providing the industrialized world with fuel gas, illuminating gas, chemicals, liquid fuels, and transportation fuels. The application of coal gasification to central station electric power generation is more recent. Large-scale demonstrations are summarized in the table below.

Name/location	Process	Size (MW)	Operation
Cool Water Daggett, CA	Texaco	100	1984-1989
Destec Plaquemine, LA	Destec	160	1987-
SEP Buggenum, Netherlands	Shell	253	1993-

These plants fuel combustion turbines operating at combustor outlet temperatures about 1370 K (1100°C, 2000°F) and have overall thermal efficiencies about 41% based on higher heating value. Acid gases are removed before the gas turbine using cold gas cleanup technology already commercial in the petrochemical industry.

Higher thermal efficiency (about 2% higher) will be achievable by using hot gas cleanup technology and the currently available 1560 K (1290°C, 2350°F) combustion turbines. Planned large scale demonstrations of this generation of IGCC are summarized below.

Name/location	Process	Size (MW)	Operation
RWE Germany	HT Winkler	300	1996
Endesa Spain	Prenflo	330	1996
Tampa Electric Polk County, FL	Texaco	260	1996
PSI Energy Wabash River, IN	Destec	268	1995
MITI Japan	not selected	370	2000
Sierra Pacific Piñon Pine (Reno), NV	KRW	95	1996

PERSPECTIVES

Technologies' Relative Potential for the Asia Pacific. The table below summarizes advantages and disadvantages of the technologies relative to each other for application to Asia Pacific economic development.

Technology	Advantages	Disadvantages
State-of-the-art PC-fired	• Opportunity for efficiency, environmental and cost improvements on an extensive base of indigenous engineering and operating experience • Opportunity for both intra-regional and external technology transfer partnerships • Economy of scale	• Economically uncompetitive at small scale • Efficiency constrained by Rankine cycle
Coal upgrading	• Modest capital requirements • Central government strategic planning can trade off economics of coal processing cost, power plant capital cost and siting, coal transportation cost, transmission line capital cost. • Straightforward technology transfer	• Limited environmental benefit
Fluidized bed combustion	• SO_2/NO_x control without add-ons • Cost competitive at small scale • Best for low quality fuels • Good experience base, some indigenous to region	• Efficiency constrained by Rankine cycle • Environmental performance could be challenged in future
Coal gasification	• Best environmental performance • Potentially highest thermal efficiency, and suitable for combining with advanced thermodynamic cycles • Potential upgrade from gas-fired combustion turbine plant • Best potential for future cost reductions	• Most sophisticated technology requirements; only relevant experience is in highly industrialized countries • Not cost competitive for some Asia Pacific situations • Must operate at high capacity factor or in energy/chemicals complex

Capital Intensity of Technologies. Capital requirements, financing capabilities and financial infrastructure will heavily influence technology choices and timing in the respective countries of the Asia Pacific region. Significant capital investment requirement is a characteristic of most of the coal technologies suitable for accelerating Asia Pacific economic progress. This suggests that development of financing mechanisms is likely to be a pacing issue for the implementation of coal technologies in the region.

Prospects for Advanced Coal Technologies. Electric power production in much of the Asia Pacific today is highly dependent on inefficient coal-fired plants with minimal environmental controls. Major expansion in the region's coal-fired electric generation can be expected in the next 20 years, but in that time frame most - well over half and probably two-thirds - of the added capacity will be pulverized coal-fired and fluidized bed combustion plants. Deployment of advanced environmental control technologies, PFBC and coal gasification combined cycle will be limited in the next 20 years to the developed economies that can afford to take a longer-term perspective on energy efficiency and environmental management, and can participate as technical and financial partners in completing the commercial demonstration and deployment of these technologies in the remainder of this century.

Technology Implementation Roles. Countries of the Asia Pacific region cover a wide spectrum of technological capabilities, industrial and economic development and robustness of financial infrastructure. The following observations are overly general but are intended to illustrate the different roles that the countries may play in implementing the major technologies (Ref. 3).

- **High income, highly developed economy and technology.** Japan, for example, will be most interested, for domestic application, in advanced technologies that can make best use of imported coals from diverse sources as well as limited domestic reserves. Sophisticated central government long-term energy policy and electric capacity planning and a well-established financial infrastructure enable Japan to implement advanced coal technologies (ultra supercritical PC, advanced PFBC, IGCC) selectively and on a strategic basis. The same capabilities will enable Japan to be a provider and partner in implementing the more conventional technologies (state-of-the-art pulverized coal, AFBC) in other countries in the region.

- **Middle income, emerging economy and technology.** Hong Kong, South Korea, Taiwan and Thailand, for example, can exploit their expanding economies and indigenous technical capabilities to implement the state of the art in commercially available technologies, e.g. state-of-the-art pulverized coal-fired plants with SO_2 and NO_x control, and IGCC in a few situations. With these technologies they are likely to attract technical and financial partners from within the region rather than outside (e.g. U.S. and Europe), because outsiders are at a geographic and cultural disadvantage and have less technically to offer these countries compared to others in the region.

- **Low income, early developing economy and/or technology.** China, India, Indonesia and the Philippines, for example, have huge indigenous coal resources and sound technical foundations and a tremendous potential for technology implementation. The

already commercially established coal technologies (PC firing of indigenous low sulfur coal, CFBC) will account for the bulk of their capacity expansion in the near term. The technology selection criteria will be construction time, cost and thermal efficiency; in other words, contribution of the chosen technology to rapid economic growth is paramount. Thermal efficiency will be important from the beginning of such countries' expansions because speed and cost are critical, and four 35% efficient plants can produce the same output as five 28% efficient plants.

As these countries develop economically and technologically, deployment of the more advanced coal technologies will become more feasible and attractive. Thermal efficiency will continue as a prime criterion, but initial capital cost may decline in importance, and environmental protection, fuel flexibility and integration of power plants with other industry segments will gain in importance.

Distributed Generation. Rapid build-up of central station generating capacity is not the only technology need in the Asia Pacific. Away from densely populated urban areas and for transmission and distribution system stability and flexibility, coal-fired units in the 100-350 MW range may be preferred. AFBC and PFBC are likely to compete favorably with PC fired plants in such situations.

For many urban areas capacity is needed in amounts and in places where building or upgrading transmission and distribution capacity is prohibitively expensive. In these situations distributed generation options such as diesel generator sets, small combustion turbines and gas-fired fuel cells will be attractive, especially since the urbanized economies that need this kind of generation can also support it technologically.

In rural areas of developing countries where initial demand is only a few hundred watts per person, the most cost-effective approach to electrification may be small localized generation such as low-head hydroelectric or photovoltaic solar power (Ref. 4).

Cogeneration and District Heating. An attractive application of state-of-the-art pulverized coal or AFFC technology in the Asia Pacific is cogeneration of electricity and steam with the potential for overall energy utilization of 70% or more. Cogeneration in the U.S. generally means co-production of medium or low-energy content steam for industrial process use. In Europe the concept of combined heat and power (CHP) is more common - even encouraged by policy in several countries - and includes home and business district heating and cooling.

CONCLUSION

- Global electrification is part of the long-term solution to population and poverty.
- Increased electrification is a key mechanism for accomplishing Asia Pacific economic development.
- Current state-of-the-art and advanced coal technologies will play an important role in Asia Pacific economic development both near and long-term.

- In the near term, the most important criteria for coal technology selection in the Asia Pacific will be short construction time, low cost, and high efficiency.

- For the longer term, the top technology selection criteria will be high efficiency, environmental performance, and integration of electricity generation with other industries.

- Modern optimized-efficiency pulverized coal-fired generation will be most attractive in the near-term for rapid expansion of capacity, exploiting an extensive base of indigenous and external engineering and operating experience.

- Fluidized bed combustion will be cost effective at small to medium scale and is especially attractive for low and variable quality indigenous coals.

- Coal gasification is a longer-term option that will increase in importance as technological sophistication and environmental priorities increase in the region.

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Integrating Coal Use into Korean Energy Systems

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1. Introduction

In Korea, as its economy continues to grow steadily, the primary energy consumption has been doubled every 10 years and its total amounted to 103.6 million TOE (Tons of Crude Oil Equivalent) in 1991. Nevertheless, per capita energy consumption was 2.39 TOE in 1991, which was estimated to be 30~67% of those of major developed countries. This relatively low figure indicates that the energy consumption in Korea will increase steadily in coming decade.

As energy consumption increases, the dependence of foreign energy has become burdensome to Korean economy. Since the available domestic energy source like anthracite is very limited, Korea is heavily dependent on the import in securing the most of primary energy sources, such as oil, natural gas, bituminous coal and uranium. The import share has increased continuously from 73.5% in 1980 to 91.3% in 1991.

Table 1. Major Energy and Economic Indicators

	1970	1980	1985	1990	1991	1992
G N P (10^{12} won)	25.0	52.3	78.1	130.7	141.6	148.3
Primary Energy Consumption (million TOE)	19.6	43.9	56.3	93.2	103.6	115.9
Per Capita Energy Consumption (TOE)	0.61	1.15	1.38	2.17	2.39	2.65
Foreign Dependence of Primary Energy (%)	47.5	73.5	76.2	87.9	91.3	93.7

In 1970's, Korea's energy consumption structure was primarily based on crude oil and anthracite. Around the end of 1970's, thanks to the energy resources diversification policy just after the 2nd oil crisis, nuclear power, bituminous coal, and natural gas was used more widely and oil consumption reduced drastically in the early 1980's. The oil consumption, however, began to increase again due to rapid economic growth and stable oil price in the late 1980's. During 1980's, the bituminous coal consumption increased in the fields of steel manufacturing, cement industries and power generation.

Meanwhile, demand for clean energy such as oil, gas and electricity has increased continuously and this portion among energy consumption recorded 57.5% in 1985 and 75.5% in 1991. Also demand for electric power increased 3.2 times from 32,729 GWH in 1980 to 104,374 GWH in 1991, and demand for city-gas recorded the average annual increasing rate of 47.1% during the same period.

Table 2. Primary Energy Consumption

	1970	1980	1985	1990	1992
Petroleum (10^3 BBL)	62,702 (47.2)	182,105 (61.1)	189,191 (48.2)	356,349 (53.8)	514,224 (61.8)
L N G (10^3 ton)	0	0	0	2,329 (3.2)	3,524 (3.9)
Anthracite (10^3 ton)	11,500 (29.3)	20,830 (22.5)	25,836 (21.9)	21,529 (10.7)	13,597 (5.5)
Bituminous (10^3 ton)	80 (0.3)	5,032 (7.6)	14,697 (17.2)	21,878 (15.5)	26,217 (14.9)
Hydro (GWH)	1,221 (1.5)	1,984 (1.1)	3,659 (1.6)	6,361 (1.7)	4,863 (1.0)
Nuclear (GWH)	0 (0.0)	3,477 (2.0)	16,745 (7.4)	52,887 (14.2)	56,530 (12.9)
Firewood (10^3 TOE)	4,251 (21.6)	2,517 (5.7)	2,031 (3.6)	838 (0.9)	589 (0.5)
Total (10^3 TOE)	19,678 (100.0)	43,911 (100.0)	56,296 (100.0)	93,192 (100.0)	116,010 (100.0)

※ The value in the ( ) means composition rate.

2. Prospect of Electricity Demand

During the 1980s, Korea's power production exhibited growth of 2.5 times. The electricity sales amounted to 104,374 GWH in 1991 and reached 115,244 GWH with approximately 10% growth in 1992. Peak load also increased from 19,124 MW in 1991 to 20,438 MW in 1992 by about 7% growth rate. This fast increase was of course due to the improvement of living standards in recent years. The long-term load forecast made by Korea Electric Power Corporation (KEPCO) in 1993 shows that electricity demand will grow at the rate of 6.0% per year through 2006, and the peak load will also increase at 5.6% in average.

This forecast was made based on the projection of real GNP growth of average 5.7% per year and on the assumption that annual peak load could be clipped by approximately 500 MW during the 90's by implementing a load management strategy.

Based on the electric load forecast in 1993, KEPCO made a plan to construct new capacity of 35,965 MW to the existing power generating capacity of 24,120 MW by 2006. Twenty five bituminous coal-fired units with 13,170 MW in total and fourteen nuclear units with 12,800 MW will be constructed during the planned period. One 200 MW anthracite- fired unit, 2,800 MW of seven pumped-storage units and 6,326 MW of twelve LNG combined cycle units will also be commissioned. In 2006, the total installed capacity will be amounted to 53,935 MW, of which 15,290 MW of bituminous coal-fired plants (28.4%), and 20,416 MW for nuclear power (37.8%). The remainder will be backed up with oil-fired plants (4.8%), LNG-fired (17.7%), and hydro power (10.2%) (See Table 3).

Table 3. Planned Power Generating Capacity by Energy Sources

MW (%)

	Nu-clear	Bitu-minous	Anth-racite	Oil	LNG	Hydro	Total
1992 (Results)	7,616 (31.6)	2,680 (11.1)	1,020 (4.2)	4,810 (19.9)	5,496 (22.8)	2,498 (10.4)	24,120 (100)
1996	9,616 (29.3)	6,800 (20.7)	1,020 (3.1)	5,798 (17.7)	6,409 (19.6)	3,110 (9.6)	32,753 (100)
2001	14,716 (32.7)	11,240 (25.0)	925 (2.1)	6,018 (13.3)	7,609 (16.9)	4,515 (10.0)	45,023 (100)
2006	20,416 (37.8)	15,290 (28.4)	600 (1.1)	2,592 (4.8)	9,522 (17.7)	5,515 (10.2)	53,935 (100)

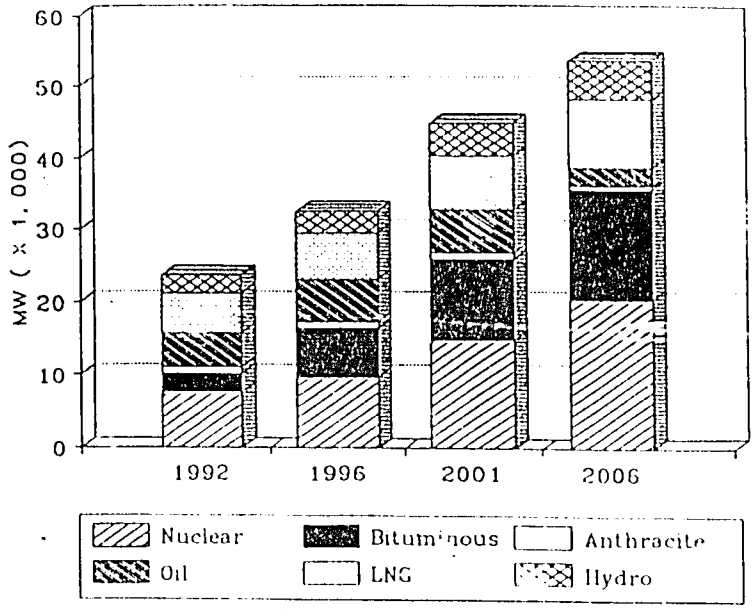

Figure 1 : Planned Power Generating Capacity by Energy Source

In light of power generation basis, nuclear power is scheduled to steadily share approximately 47.6% through the planned period. The coal-fired power will increase to around 32.9% in 2006 in accordance with increased cycling duty and the system load characteristics (See Table 4). At present, 8 units among the 25 planned bituminous coal-fired units are under construction and will be put into service before 1996. However, this forecast was developed without consideration of possible carbon dioxide emission constraints. It is currently under study to see how this constraints will affect the future evolution of Korea's power generation system.

Table 4. Planned Power Generation by Energy Sources

GWH (%)

	Nuclear	Bitu-minous	Anth-racite	Oil	LNG	Hydro	Total
1992 (Results)	56,530 (43.2)	19,157 (14.6)	2,915 (2.2)	35,311 (27.0)	12,187 (9.3)	4,863 (3.7)	130,963 (100)
1996	67,098 (36.4)	46,180 (25.1)	2,701 (1.5)	35,119 (19.1)	27,798 (15.1)	5,125 (2.8)	184,021 (100)
2001	102,193 (41.3)	74,563 (30.1)	3,001 (1.2)	32,763 (13.2)	28,744 (11.6)	6,350 (2.6)	247,614 (100)
2006	145,129 (47.6)	100,344 (32.9)	2,571 (0.8)	13,408 (4.4)	35,987 (11.8)	7,570 (2.5)	305,009 (100)

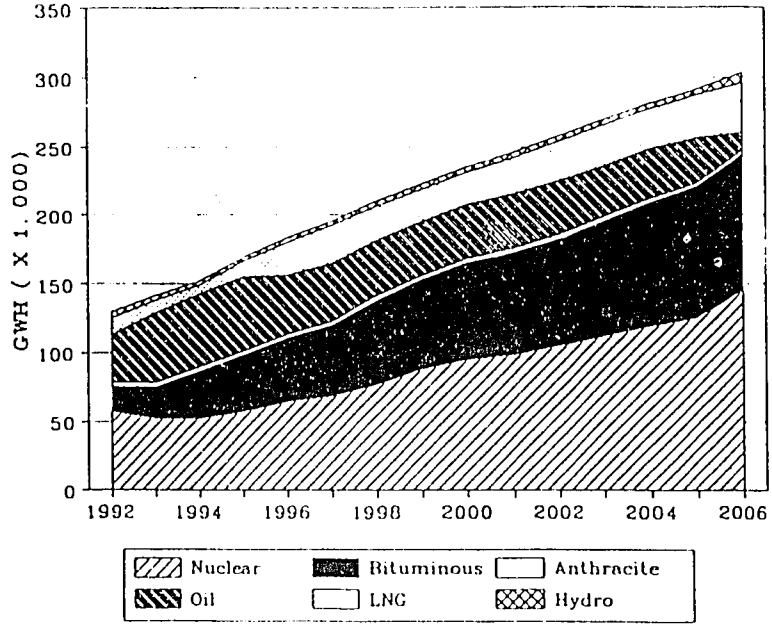

Figure 2 : Planned Power Generation by Energy Source

3. Domestic Coal (Anthracite)

Anthracite is the unique indigenous energy resource in Korea. Total reserve of anthracite is 1.6 billion tons, of which the recoverable amount is estimated to 754.3 million tons. With the economic growth, anthracite has been losing its role due to its rapid diminishing of economic merit and inconvenience of usage compared with other energy alternatives. The share of anthracite in primary energy consumption in 1992 was only 5.5%. It was a significant reduction when compared with the portion of 45.7% in 1966.

About 90% of anthracite produced in Korea is used in the residential and commercial sector for space heating in the form of briquette. In this sector, anthracite consumption increased very rapidly by 6.2% per annum during the 1970's for replacing firewood. During the first half of the 1980's, anthracite consumption continued to increase by 5.1% per annum. However, in the middle of the 1980's, anthracite demand in the residential and commercial sector significantly decreased. This anthracite demand decrease results primarily from switching fuels for space heating in both new and existing households.

Table 5. Anthracite Demand

(unit: Thousand Ton)

	1970	1980	1985	1990	1991	1992
Total	11,831	20,830	25,836	21,529	17,557	13,597
Industry	669	708	383	283	303	443
Electricity	574	1,865	1,778	1,983	2,070	1,945
Res. & Com	9,910	18,037	23,567	19,217	15,184	11,189
Others	347	220	108	46	-	-
Stocks	1,668	5,075	6,426	8 013	8,272	7,725

Res.: Residential, Com.: Commercial

In order to support domestic coal industry, the government has been enforcing a policy for the maximum development and utilization of anthracite with various kinds of financial supports including subsidies and loans However domestic anthracite has low calorific value (below 5,000kcal/kg) due to high ash content and low volatile matter. In addition, its mining conditions are getting worse, because Korean coal seams are very irregular, steep and discontinuous and are deepening by about 25 meters a year. Therefore its production cost has increased year by year. Although the generation cost of domestic coal-fired power plant is much higher than those of other fuels, to maintain domestic coal demand for power generation, KEPCO will construct one unit of 200MW class anthracite fired power plant, which will be equipped with circulating fluidized bed combustion (CFBC) boiler for reducing environmental and operational problems.

4. Improted Coal (Bituminous)

Bituminous coal market in Korea has a very simple structure. Since there is no domestic production, Korea depends wholly on imports for the supply of bituminous coal. Korea imports bituminous coal from many countries like Australia, USA and Canada among others. These foreign markets are evaluated to be so stable that the quantity of bituminous coal determined by the demand side can be supplied at stable prices. The demand side also consists of selective industrial sectors such as iron and steel industry, cement industry and power generation. As these industries are expected to keep on growing, bituminous coal consumption will continue to increase. Bituminous coal import from abroad in 1992 was 29.2 million tons in contrast to 7.2 million tons in 1981.

Since bituminous coal has a strong price competitiveness over oil, especially in the power generation sector, new oil-fired power plants are not included in long range power development program. It should be noted that bituminous coal consumption in the power generation sector sharply increased from 545.7 thousand tons in 1983 to 6,322 thousand tons in 1992, while petroleum consumption decreased from 8,043 thousand KL(Kilo Liter) in 1982 to 1,172 thousand KL in 1987 and increased again to 7,544 thousand KL in 1992.

Electicity generation by bituminous coal-fired power plants was 19,157 GWH which was 14.6% of the total electricity generated in 1992. Furthermore, there is a long-term plan to build a number of new bituminous coal-fired power plants during the next 20 years. Therefore bituminous coal demand in the electricity sector is expected to increase by 9.4% per annum.

Bituminous coal consumption in the other industries is also forecasted to increase steadily. Its consumption in the iron and steel industry almost doubled from 5.9 million tons to 11.7 million tons during the last decade and that in the other industries including cement industry approximately tripled during the same period. These industries are projected to keep on growing so that their bituminous coal demand will increase steadily.

Table 6. Bituminous Coal Supply and Demand

(Unit : Thousand Ton)

	1981	1986	1990	1991	1992
Imports	7,245	16,437	22,848	27,906	29,208
Demand (total)	7,434	15,290	21,876	24,835	26,217
Iron & Steel	5,941	6,995	11,739	13,951	14,375
Electricity	-	5,363	5,723	5,776	6,322
Cement	1,493	2,932	3,534	4,223	4,443
Others	-	-	882	885	1,077

5. Environmental Concern

Since the Korean government introduced new environmental conservation law in 1977 that is focused on SOx, NOx and particle emissions, a number of special acts and regulatory standards have been promulgated. And the emission control for coal-fired power plant has been strengthened steadily, but due to availability of high grade coal, the current emission standards can be met without any environmental equipments. That is, the SO_2 emission standard can be met by burning low sulfur coal below 0.7%. Nitrogen oxide(NO_x) emission can be also controlled properly through new combustion technologies. Electrostatic precipitators or bag filters for small particles can be effectively utilized.

However, as concern grows over acid rain and other environmental problems, particularly with fast increase of coal use, the emission control is to be made more stringent through the 90s. Current and prospective emission limits for the coal-fired power plant and actual emission level are as follows.

Table 7. Emission Limits for Coal-Fired Power Plant

Pollutants	Current Limits	Prospects		Actual Emissions
		'95	'99	
SOx (max PPM)	700	500	270	240 - 570
NOx (")	350	350	350	330 - 340
Particulates (mg/sm^3)	250	100	50	190 - 220

To cope with the expected stringent environmental emission standards, KEPCO is planning to install flue gas desulphurization (FGD) equipment in new coal-fired units to be commissioned after the mid 90's and to retrofit or repower existing plants appropriately. The prevailing concern is focused on the capital and operating costs of these schemes. For example, these costs of the wet lime/limestone FGD system are estimated to account for more than 25% of the total plant construction cost.

Two cogeneration projects near Seoul area using LNG as main fuel and many other similar district cogeneration projects are under consideration. With further refinement on pollutant emission reduction target, it is likely that integrated gasification combined cycle (IGCC) units will gradually replace some of coal-fired power plants after 2000.

As for the global warming problems, the major reason for CO_2 emissions is to use fossil fuels such as coal and oil. The quantity of CO_2 emitted will increase 1.7 times in the year 2000 and 2.2 times in 2010 compare to the present level. Although total CO_2 emissions from oil is slightly over those from coal at present, coal had been the major fuel emitting CO_2 in Korea by 1990. CO_2 emissions from anthracite will reduce since anthracite consumption will decrease rapidly. On the other hand, CO_2 emissions from bituminous coal will approximately triple the current level in 2010 mainly due to the expansion of coal-fired power plants.

The government makes efforts to reduce CO_2 emission levels in many ways : reinforcement of energy conservation measures, improvement of oil refinery technology, development of clean coal technologies, etc. An environmental protection objective was newly formulated in the 1988 revision of the sixth five-year economic development plan (1987-1991). More specifically, the energy policy, measures and strategies that have been implemented or announced by the government are: (1) Expansion of gas use in urban areas, (2) Raising the portion of low-sulfur diesel, bunker-C oil and unleaded gasoline, (3) Reinforcement of environmental impact assessment (4) Moving briquette plants to outside of cities, (5) Increasing the government expenditure to 150 billion Won (equivalent to U$190 million) during in the next five years on R&D related to environmental issues.

Table 8. Forecasted CO_2 Emissions by Fuel Type

(Unit : Million Ton)

	CO_2 Emission			Increasing rate	
	1990	2000	2010	91-00	01-10
Petroleum	34.0	62.0	80.7	6.2	2.7
Natural Gas	1.6	5.8	7.7	14.0	2.8
Coal	28.2	41.2	51.1	3.9	2.2
Anthracite	11.3	6.2	3.2	-5.8	-6.6
Bituminous	16.9	35.0	47.8	7.5	3.2
Renewable	1.0	1.2	2.4	2.6	6.9
Total	64.7	110.3	141.9	5.5	2.6

6. Development of Clean Coal Technologies

Traditionally, development of new energy-related technologies has been regarded as an alternative providing for the exhaustion of fossil fuel. Recently, however, as the seriousness of environmental pollution has been widely recognized, it is understood from a different viewpoint. In other words, the innovative improvement of energy efficiency and the research and development of low pollution type advanced energy utilization technologies are being highlighted not only for the preparation for the exhaustion of fossil fuels but also for mitigating environmental degradations. ♠

While making every effort to develop new technologies under a stable condition of energy demand, developed countries insist on the restricted use of fossil fuels to protect global environment. However, many developing countries, which desperately require more energy for the continuous and sustainable growth of economy, do not even have sound technological background and thus are likely to suffer more bitterly from this world situation.

Accordingly, some developing countries urge developed ones to transfer the related technologies more actively. It is foreseen, however, that the technology transfer would not be readily done due to the international tendency reinforcing the technology protectionism characterized by the patent copyright. As a result, considering that the energy security for the 20th century had been obtainable by securing the energy resources, it could be said that the possibility of self-economy and the energy security for the 21st century would be dependent on whether the new energy-related technologies can be achieved or not.

Due to the lack of oil supply around the end of the 1990's and the reinforcement of environmental regulation, it is predicted that the use of conventional fossil fuel will be limited.

Also, there are limitations in expanding supply of nuclear, LNG and renewable energy. Therefore it is inevitable to use coal continuously which is the most abundant energy resources in the world. However, coal is one of the main factors deteriorating global environmental problems. So it is impossible to use more coal without an application of clean coal technologies in the future. Various clean coal technologies are under development throughout the world, the major subjects which are under reasearch and development stage in Korea include the followings :

- Advanced coal cleaning
- Fluidized bed combushon
- Integrated coal gasification combined cycle
- Flue gas desulfurization

7. Prospect of Coal Use in Korea

Anthracite consumption, mainly used for floor heating in the residential sector, will decline substantially in the near future. Being an inconvenient and dirty fuel, anthracite is hardly used for floor heating in newly built dwellings. Furthermore, existing anthracite based heating systems are being switched to systems using other fuels. About 10 million tons of anthracite are expected to be consumed in 2000. That is about 50% of the current demand level. The Korea's coal mining industry is suffering from a serious shortage of miners. As a result, the future of anthracite in Korea is dismal.

Korea Energy Economics Institute (KEEI) implemented a research on the choice of briquette by residential sector in 1991. It is found that the probability of choosing briquette as a main fuel has a reverse relationship with income and floor space used. Since the living standard is expected to increase steadily, the briquette for household will lose its importance continuously. In Table 9, the demand forecast for briquette in the residential sector is showed under the assumption that income rises by 5%, 7% and 9% per annum during the next 20 years.

Table 9. Anthracite Demand Forecast in the Residential Sector

(Unit : Thousand Ton)

* \ year	1995	2000	2005	2010
5 %	12,930	11,452	9,610	7,825
7 %	12,569	10,263	7,339	4,794
9 %	12,184	8,947	5,065	2,441

* Income Growth per annum.

On the other hand, the bituminous coal market in Korea is promising. Not only the industries mainly using bituminous coal are flourishing but the electricity sector is also planning to construct a number of bituminous coal-fired power plants. Bituminous coal will play a major role in the electricity sector together with nuclear power. It is expected that coal will contribute to reducing Korea's dependence on imported oil. In order to meet the anticipated coal demand increase, the government is enhancing the developemt of overseas coal, the construction of coal receiving facilities and development of advanced coal utilization technologies.

There is an active discussion on the power development program in Korea. Despite advantages of nuclear in improving energy supply security and environmental management, Korea faces ever increasing anti-nuclear movements. One of the obstacles to the expansion of bituminous coal-fired power plants is to obtain public consensus on environmental deterioration. The quantity of bituminous coal demanded by the electricity sector is projected in Table 10 under the long-term power development plan released recently.

When a decision to build new coal-fired power plants is made, the external costs like CO_2 emissions should be taken into account as well as the internal costs like construction costs and operating costs. The external cost is difficult to evaluate. However, it is believed that the external cost has a positive relation with the income level. Unless proper measures are taken to meet the emission standards, there would be social resistance to coal use in Korea. In this sense, it is very urgent in Korea to develop clean coal technologies to reduce environment pollution.

Table 10. Demand Forecast of Bituminous Coal by Sector

(Unit : Thousand Ton)

	1995	2000	2005	2010	Increasing Rate
Total	37,194	47,612	52,190	66,671	5.7 %
Iron & Steel	15,698	15,560	15,544	15,513	1.4 %
Electric	14,706	24,717	28,302	39,495	9.0 %
Cement	4,768	4,666	4,393	3,611	0.1 %
Etc	2,062	2,669	3,951	8,052	5.7 %

8. Conclusions

Power demand in Korea will continuously increase to keep pace with the growth of national economy and accordingly improvement of the living standards, which requires construction of power plants using economically variable energy resources.

Because of its wide distribution and the relative abundance, coal is one of the most important energy resources for power generation. However, it must be taken into account that large amount of coal utilization needs careful consideration for minimizing environmental impact. Therefore, it is now required to develop the highly efficient and environmentally friendly power generation systems like a pressurized fluidized bed combustion cycle system(PFBC) and an integrated coal gasification combined cycle system(IGCC), and other various clean coal technologies. For this, Korea is exerting every effort to catch up with advanced countries in the development of coal utilization technologies.

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The E7 Network of Expertise for the Global Environment

IEA Second International Conference on Clean and Efficient Use of Coal and Lignite: Its Role in Energy, Environment and Life

"Coal in Power Generation: How the E7 Utilities Look at Technology Transfer to Developing Countries"

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RWE Energie

Hong Kong Marriot
30 November - 3 December 1993

RWE Energie AG
Head Office

Essen, 24.11.93
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IEA Conference on Clean and Efficient Use of Coal and Lignite
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Coal in Power Generation:
How the E7 utilities look at technology transfer to developing countries

Introduction

One of the main conclusions of the 1992 World Energy Conference (WEC) in Madrid was that the developed countries must take the leading role in facilitating the transfer of energy technologies to the developing countries. The E7 members support this general statement without reservation. Utilities in developing countries should have access to the technological expertise which has been accumulating in the developed countries for decades.

Coal is the leading primary energy resource in global power generation. According to the WEC analysis there is no reason to doubt that it is likely to remain the major source over the next few decades. Regardless of the difference in prevailing conditions developed and developing countries are planning at least part of their electricity future on the basis of coal. Therefore, technology transfer to improve power generation in developing countries primarily means the transfer of coal technologies.

State of coal based power generation in the E7 countries

Coal fired power plants have been the backbone of industrialization all over the world. This means that engineering, design and construction have today reached a high standard and are well proven. Coal fired power plants can be built in

almost all parts of the world, the design can easily be adjusted to the specific objectives and conditions of a country and a site. Up to a certain degree operation and maintenance procedures are standardized, and in most societies coal technologies are well accepted by the public.

The present level of technology was reached over different periods. During each period development efforts were concentrated on design goals which had been imposed by economical, technical or political reasons (Figure 1):

- Starting in the 1950's the capacity of the units increased in order to take advantage of the degression of costs. In parallel, plant efficiency was increased in order to save fuel.

- In the 1970's the utilities tried to improve plant availability in order to avoid costly extension of their generation capacity.

- In the 1980's pollution control became a major objective though in most cases it is contrary to efficiency and economic objectives.

- In the 1990's we recognize that the utilities are forced to master the squaring of the circle i.e. to improve pollution control even further and to reduce costs at the same time.

The increase in unit capacity during the 1950's and 1960's took place in three major steps: Starting from about 125 MW beyond 250-300 MW up to 600 MW after the mid 1960's. Today units with more than 800 MW are considered. According to a rough estimation made by EDF the total production cost per KWh is cut by 15% when the unit capacity is multiplied by the factor 2.

An example for the increase in plant efficiency is shown in Figure 2. Within the last three decades efficiency of RWE's lignite and hard coal plants grew continuously though it was hampered by the integration of the flue gas cleaning units during the 1980's. For the future we expect that new technologies like IGCC, together with advanced gas turbines, will boost efficiency over the 45% mark.

The development of pollution control data of coal-fired power plants are reflecting national policy concerning environmental protection. To compare emission data of single countries needs a very careful discussion of national standards

first. This discussion cannot be part of this paper. However, to give an example, emission data of RWE's lignite-fired plants are shown in Figure 3.
In - furnace technologies and flue gas desulfurization reduced the emission of

- SO_2 to 10%
- NO_x to 25%
- Dust almost to zero

using data from 1983 as a reference.

It is worth mentioning that technological progress aiming at emission abatement in some cases has been initiated by the utilities themselves. This means that prior to the evolution of the public's pollution awareness sometimes the utilities have introduced processes which are less polluting compared to the previous technology generation. In other cases, however, technology just followed the political process imposing standards on utilities, i.e. utilities applied industrially proven or new processes just in order to meet the imposed standards.

In the E7 countries these development steps took place in a more or less pronounced way and led to a variety of plant designs which are applied today. More than 41 million t of hard coal and about 92 million t of lignite are used today by the E7 utilities to generate about 183 TWh per year (Figure 4). This is done under the world's most stringent environmental protection standards in Canada, France, Germany, Italy, Japan and the US.

Future coal based power generation concepts

The share of coal in the future electricity supply of the E7 countries is difficult to predict because there are many different factors that have an impact on the supply structure. Only a few of them can be influenced by utilities themselves.

Of course, it would help to strengthen the position of coal all over the world if new concepts could be developed converting coal to electricity and with less pollution as the existing and well proven ones. The E7 utilities launched several development projects which are shown in Figure 5.

It would go beyond the scope of this paper to report on the single programs which have been launched by the E7 utilities. To sum it up: There are some promising approaches which will lead to improved plant concepts within the next years. However, to be perfectly clear, there will be no revolutionary new technology which will replace the existing plant concepts within the next years.

Probably, the concept of the next generation of plants will be conventional pulverized coal fired with improved heat efficiency by adopting improved steam conditions. As it stands today, utilities in the E7 countries will favour this concept or the optimization of the existing plants and try to extend their lifetime as far as reasonable.

In this process optimization parameters will be (Figure 6):

- Pollution abatement down to a level which is the lowest proven technology can achieve. In most cases national standards will become even more stringent than today.

- Reduction of costs as low as allowed by maximum pollution control.

- Efficiency increase in order to save fuel and to reduce pollution including CO_2 emission.

Presently, there is no clear indication that a concept will be available soon which is capable of reducing plant emissions as well as generation costs. This means that pollution control will stay expensive and that it will always be conflicting with generation costs. However, pollution control and cost savings can walk hand in hand in a certain range when plant efficiency is concerned.

Today, the E7 utilities expect for the future that generation costs - excluding costs of pollution control measures - will stay relatively stable. It is assumed that costs of coal, equipment and even of labor can be quite reliably forcasted in the long term.

Pollution control costs, however, behave like a moving target because they depend on the political evaluation of environmental issues. Present political discussions in the E7 countries on issues such as the taxing of CO_2 emissions or

energy consumption and more stringent pollution control standards will have a considerable impact on the competitive strength of coal in power generation.

Special needs of developing countries

Compared to the situation in the industrialized countries electricity supply in developing countries is and will be subject, of course, to different conditions. As a top electricity generator in its own country, each E7 member is dedicated to using efficient and environmentally sound generation methods. But this capacity does not necessarily qualify the E7 to recognize clearly the circumstances and the needs of a developing nation.

The basic and realistic understanding of the real needs has to be developed by these countries themselves. Above all the desired level of pollution control must be defined by national policy. It is up to each national economy to decide on the extent of the burden the country is ready to undergo for pollution control. Obviously, technologies are available to reach even very challenging standards. However, from our point of view this is not necessarily the guiding argument for a developing country. Our recommendation regarding this is, to encourage and develop local expertise in order to find custom-made solutions. During this process the industrialized countries can provide suppport.

To apply new technologies which are not yet proven in industrial scale over a long period needs money and an integrated industrial structure at a high level. Since both requirements are missing in developing countries to a large extent we recommend to rely rather on proven technologies. This does not mean to speak in favour of old-fashioned equipment but to apply technologies and equipment which can be bought from the shelf or even produced indigenously.

In general terms, when it is intended to build a new plant the following main objectives should be met (Figure 7):

- The plant must operate reliably and with high availability.
- It must be easy and inexpensive to operate and to maintain.
- Design must be sturdy and flexible to minimize costs for any later-installed pollution control or other equipment.

- Plants should include levels of pollution control equipment that use well-proven technologies, which are consistant with local pollution-control regualations.
- Spareparts and wearing parts should be produced indigenously to a large extent.

To give just one example: the limestone-gypsum process which presently is applied in most of the industrialized countries to reduce SO_2 emissions would be a very expensive solution for developing countries. Sufficient desulfurization performance at lower costs could be achieved with other methods like addition of dry calcium compounds for example.

These recommendations are not only concerning the construction of new plants but also the revamping of existing plants as well. In the present situation most of the utilities in the industrialized countries are revamping older plants in order to meet environmental standards, to save costs or to avoid lengthy licensing processes for the construction of new plants. Based on this experience we think that revamping is a cost efficient way for developing countries as well. The major tasks of the revamping process are (Figure 8):

- to analyse subunits with the biggest losses, i.e. to draw up rough energy balances
- to define priorities for necessary tasks
- to assess technical concept, management procedures, operation and maintenance system, storekeeping etc.
- to retrain plant management and operators.

Support by E7 utilities

To support the needs in the developing countries E7 is ready to give advice concerning plant site evaluation, selection of a suitable well proven and optimized plant design, training of personnel etc. It is the mission of E7 to give this advice on the basis of its wide experience as plant operators and utilities, independent of any commercial interest and free of charge.

Regardless of basic differences in prevailing conditions there are numerous areas where utilites in both parts of the world are facing similar technological

or economical problems. Pollution control is a considerable cost factor, for example. Both developed and developing countries are concerned about pollution. But the shortage of financial and energy sources is already imposing severe limitations on the economic development of some poorer countries.

The E7 feels that any organization giving support to developing countries should accept this position. They must find an approach that (Figure 9):

- allocates the available funds in the most efficient way
- creates the best balance between socioeconomic development and impacts on the environment
- gives priority to the use of local resources
- but does not impose additional strain on an already fragile political and economic situation

Conclusion

Developing countries will remain very concerned with basic challenges like food supply and general poverty. There is no doubt, however, that wider access to electricity will be a key requirement to improve living and working conditions. According to WEC the demand for electricity is increasing about three times as fast as in the industrialized world. By 2020 this growth rate would require additional power plant capacity of some 3000 GW, most of it with coal as primary energy source. For many reasons the industrialized world is called upon to support this process.

The E7 utilities are ready to contribute their expertise.

State of Coal-based power generation in the E7 countries

Design goals imposed by economical, technical or political reasons:

- 1950's

  and

  1960's: increase unit capacities and plant efficiency

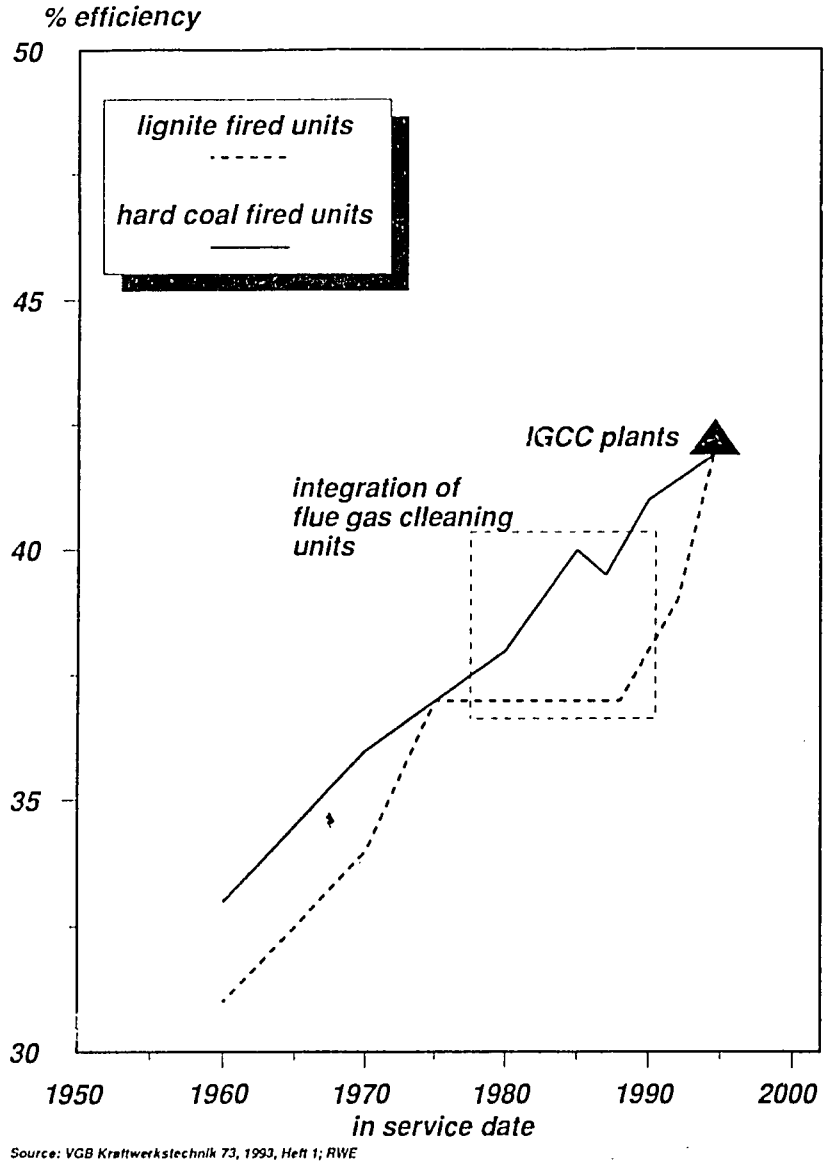
- 1970's: improve plant availability

- 1980's: improve pollution control

- 1990's: improve pollution control even further and reduce costs

	Coal in Power Generation: How the E7 utilities look at technology transfer	Fig. 1

T395-93

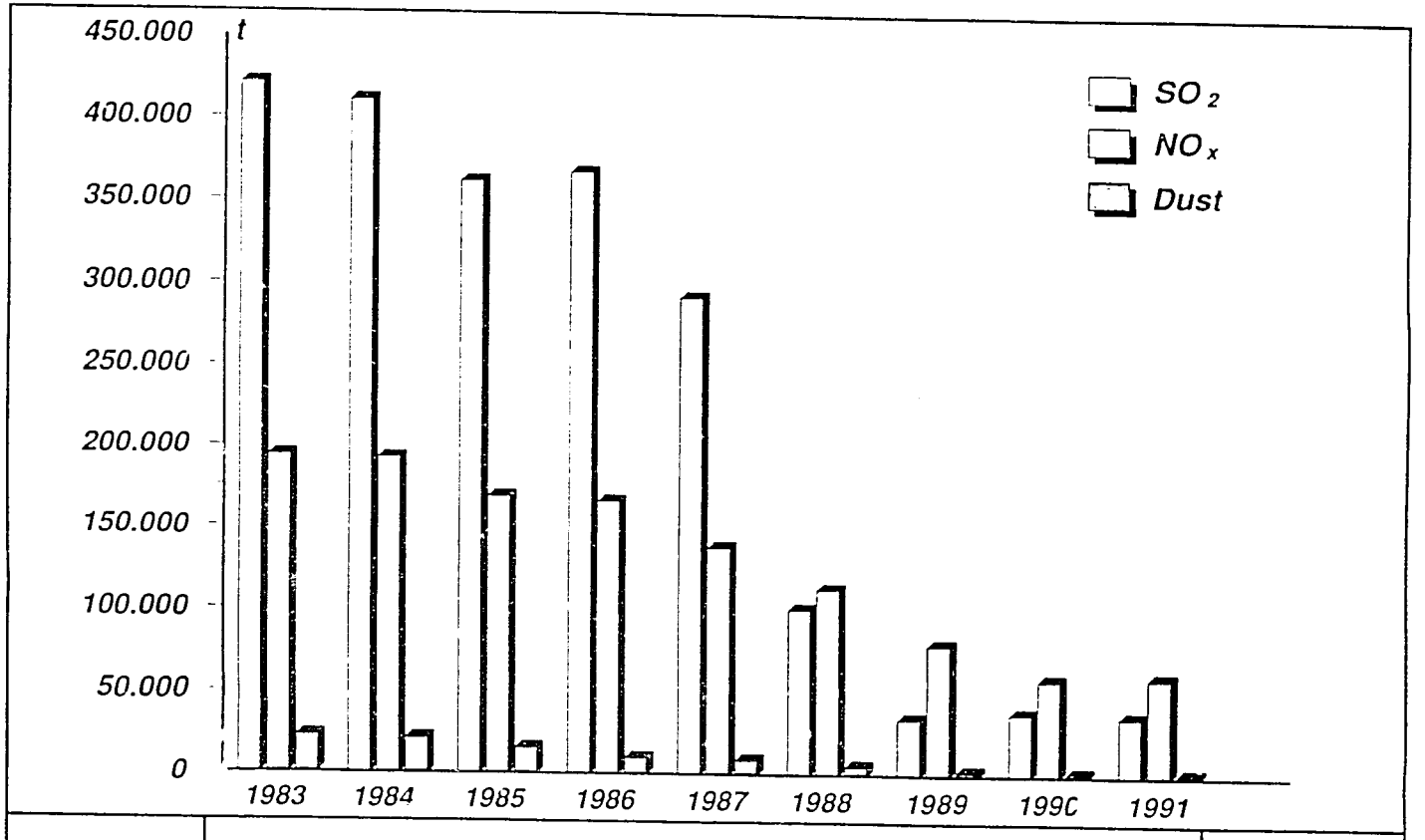


Source: VGB Kraftwerkstechnik 73, 1993, Heft 1; RWE

Efficiency of Fossil Fired Power Plant Units

Fig. 2

93-188



Emissions of RWE's Lignite Fired Power Plants

Fig. 3

		Overall		Coal/Lignite		
		Capacity MW	Sales TWh	Capacity MW	Generation TWh	Consumption million t
EDF	France	95 500	420	8700 / -	26 / -	9 / -
ENEL	Italy	50 900	198	7200 / 300	20 / < 1	7 / < 1
Hydro Quebec	Canada	28 100	145	- / -	- / -	- / -
KANSAI	Japan	33 200	123	- / -	- / -	- / -
Ontario Hydro	Canada	29 300	136	7300 / 500	26 / 2	11 / 1
RWE	Germany	26 100	124	6200 / 8900	28 / 65	8 / 90
Southern California Edison	USA	20 700	74	1600 / -	12 / -	5 / -
TEPCO	Japan	48 400	230	500 / -	3 / -	< 1 / -
Total		332 200	1 450	31500 / 9700	115 / 68	41 / 92

E7's Coal / Lignite - Based Power Generation 1992

Fig. 4

T401-93

Future coal-based power generation concepts developed by E7 utilities:

- *Increased Steam Conditions:*
  Developed by almost each E7 utility

- *Circulating Fluidized Bed (CFB):*
  EDF, RWE

- *Integrated Gasification Combined Cycles (IGCC):*
  EDF, ENEL, RWE, SCE, TEPCO

	Coal in Power Generation: How the E7 utilities look at technology transfer	Fig. 5

T396-93

Future process optimization parameters for existing coal fired power plants:

- *Pollution abatement down to a level proven technology can achieve to meet national standards*
- *Reduction of costs as low as allowed by maximum pollution control*
- *Efficiency increase in order to save fuel and to reduce pollution and CO_2 emission*

	Coal in Power Generation: *How the E7 utilities look at technology transfer*	*Fig. 6*

T397-93

Design objectives for construction of a new power plant in a developing country:

- *reliable operation with high availability*
- *easy to operate and to maintain*
- *sturdy design*
- *spare parts and wearing parts should be produced indigenously to a large extent*

	Coal in Power Generation: How the E7 utilities look at technology transfer	Fig. 7

T399-93

Major tasks for revamping of existing plants in developing countries:

- *analyse sub-units with the biggest heat losses to define priorities for necessary tasks*

- *assess technical concept, mangement procedures, operation and maintenance systems, storekeeping etc.*

- *retrain management and operators*

	Coal in Power Generation: How the E7 utilities look at technology transfer	Fig. 8

T298-93

Criteria for E7 support to utilities in developing countries:

- allcoate the available funds in the most efficient way
- create the best balance between the socio-economic development and the impact on the environment
- give priority to the use of local resources
- but do not impose additional strain on an already fragile political and economic situation

	Coal in Power Generation: How the E7 utilities look at technology transfer	Fig. 9

T400-93

Clean Coal Technology Development, Dissemination and Cooperation Through CCT Center, NEDO of Japan

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Clean Coal Technology Center
New Energy and Industrial
Technology Development
Organization (NEDO)

1. Introduction

At the Earth Summit (United Nations Conference on Environment and Development) held in Brazil in June, 1992, it was decided as a result of discussion about what efforts must be done to make development compatible with environment that we should accept and consider the problem of global environment as a common issue to be solved by all mankind.

In the 21st century, one of the things likely to be most highlighted, favorably or unfavorably, with respect to the efforts of making development compatible with environment, is coal. Most energy specialists agree that coal will be of key importance in solutions to the problem of energy and environment, particularly in the rapidly growing Asian-Pacific region.

Under such circumstances, the role played by clean coal technology is great.

We, therefore, consider that clean coal technology (which I will refer to as CCT) should be addressed extensively enough to include newly developed technologies as well as established technologies, enabling coal to be used cleanly in every stage of its production, distribution, and consumption.

2. Establishment of NEDO's Clean Coal Technology Center

NEDO, organized in October, 1980 as a government agency engaged in the general promotion of technological development concerning oil-alternative energy (except nuclear power), has conducted comprehensive activities in such fields as solar, geothermal, coal, fuel cell and other energy transportation/storage, and alcohol/biomass. Subsequently, overall development of both basic and advanced industrial technologies, technological contribution to the protection of global environment, and other new duties were assigned to NEDO. With its operational territory expanding, NEDO has grown to the present scale of ¥200 billion in capital and some 850 employees. Its international involvement is also active, having formed widespread cooperative relationships with many overseas governments and agencies.

In response to a new trend of policies toward coal and the problem of global environment, as well as to a growing desire to contribute to the world in the field of energy and environment, NEDO established within its organization the Clean Coal Technology Center (which I will refer to as CCTC) in October, 1992.

CCTC fulfills the requirement of a better-organized system capable of promoting, in a comprehensive manner, the development of basic and applied technologies, diffusion of developed technologies, and so on.

In other words, CCTC intends to carry out comprehensive projects to promote the introduction and diffusion of CCT, including model projects for international

cooperation, while continuing to manage necessary long-term CCT-related technological development activities, including coal gasification and liquefaction. We also consider it important to exchange personnel and information, and are active in promoting CCT diffusion with the cooperative assistance of the concerned agencies b sending experts, inviting those involved with CCT from overseas, holding symposi and seminars, and commemorating Clean Coal Day.

3. Technological Development under the New Sunshine Project

In meeting the growing worldwide concern over the problem of global environment, the Ministry of International Trade and Industry of Japan started the "New Sunshine Project" in fiscal 1993, into which the existing Sunshine Project (technical development of oil-substitute energy), Moonlight Project (technical development for energy saving), and technological development for globa environmental problem were integrated. The new project is stressing more emphasis on renewable energy as a new energy source. The development of coal gasification and liquefaction technologies aims to economically produce fluid energy from coal which replaces relatively scarce oil and natural gas as an overwhelmingly abundant source of solid energy. Greater dependence on coal is likely to change the economy of fossil fuels in the present energy system due to the price gap with oil and natural gas. There are increasing factors to be considered in the technological development of coal use such as measures against the problem of global warming (CO_2 control). Nevertheless, the development of these indispensable technologies must be continued in view of the national security of Japan, whose structurally weak energy supply situation has not yet been overcome in a true sense. Furthermore, the accumulation of the past 20 years of technological development under the Sunshine Project has allowed Japan to raise its level of technologies in this field to the world's is highest, even drawing practical utilization within reach. It is necessary to direct technological development efforts toward the objectives of the New Sunshine Project such as by seeking higher energy efficiency and product yields to further improve energy-saving characteristics and economy.

NEDO's major activities currently under pilot-plant research are summarized below.

(1) Development of Bituminious Coal Liquefaction Process (NEDOL Process)

1) Past and present progress - pilot plant construction in earnest

NEDOL Process is a unique Japanese coal liquefaction process developed by merging three liquefaction processes, namely, (a) the Direct Hydrogenation Liquefaction Process, which uses the strength of a highly active catalyst, (b) the Solvent Extraction Process, which takes advantage of a high hydrogen-donating solvent to obtain high liquefaction yields under moderate conditions, and (c) the Solvolysis Process, which spurred the idea to employ recycle of heavy distillate.

In August, 1984, the Advisory Committee for Energy of the Industrial Technology Council proposed pilot-plant research using this process under a public-private close cooperation system which was thought to best suit a national project. In October, 1984, Nippon Coal Oil Co., Ltd. consisting of 19 private companies, was

chosen to undertake the technological development of bituminous coal liquefaction. 10% of the development costs were to be paid by the private sector participants.

The project started with basic/detailed engineering and design of a 250 tons a day pilot plant, but later developments including aggravating financial conditions delayed scheduled construction, forcing the scale to be revamped in March, 1988 (from 250 tons a day to 150 tons a day: on a dry coal basis, hereinafter the same), together with total costs and the period of R&D. In fiscal 1988, design of the 150 tons a day plant started and, in 1991, the design was completed for the commencement of construction in November, 1991. The (about 156 thousand m^2) site is within the threshold of Sumitomo Metal Industries, Ltd.'s Kashima Steel Works in Kashima-gun, Ibaraki-ken.

In fiscal 1991 through 1992, general underground, temporary preparation, foundation, concrete pouring, and other works were completed and, in fiscal 1993, the transportation of equipment started the first stages of final construction.

2) Major features of NEDOL Process

(a) Applicable to a wide-range of coal rank from sub-bituminous coal to bituminous coal

(b) Uses a less expensive and highly active ferrous catalyst (Pyrite; FeS_2)

(c) Concurrent use of a highly active ferrous catalyst and a hydrogen donor, permitting liquefaction under relatively moderate reaction conditions (170 atm, 450 °C, and 40 (wt) % of slurry concentration)

(d) Achievable high liquefaction oil yields (targeted 50% or more of light and middle distillates; in terms of capacity 4 barrels of liquefied oil per ton of coal)

(e) Employment of the highly reliable vacuum distillation system for solid-liquid separation

3) Main problems with pilot-plant research

(a) Collection of engineering data required for commercial plant design

Major elementary equipment items for development include reactors, slurry preheater, slurry heat exchangers (exchange of technology with Germany), high temperature separator, vacuum distillation tower, and letdown valve (quick depressurizer),

(b) Establishment of operation procedures

Technical items include homogeneous and constant mixture of coal and solvent, handling of high-concentration slurry, handling of solid-contaminated fluid at high temperature and pressure, and anti-erosion/-corrosion measures.

(c) Establishment of maintenance procedures including maintenance and inspection of equipment and piping.

(d) Impact of pollutants on environment, pollution countermeasures, etc.

(e) Projection of costs for a commercial plant and studies on evaluation of economy including surveys of conditions of location.

4) Implemented support studies using Process Supporting Unit (PSU)

To support the studies of the operation of a bituminous coal liquefaction pilot plant, a PSU with a 1 ton a day-level coal capacity was built within the site of Nippon Steel Co., Ltd.'s Kimitsu Works (in 1986 through 1988), and operation was started on a research basis. A PSU, which is quicker-wheeling than a pilot plant, allows the running conditions to be more flexible and has enabled data to be accumulated for wider reaction conditions of liquefaction behavior and maintenance operation. Some of these conditions are not possible with a PP.

(2) Development of Brown Coal Liquefaction Technology

1) History of the project

The Brown Coal Liquefaction Project for Victorian brown coal was started in April, 1981 as a Japan-Australia cooperation program under the Sunshine Project. The program included researches on a pilot plant-scale operation with the goal of successfully implementing liquefaction of brown coal abundantly produced in the state of Victoria, Australia. The construction of a pilot plant with a capacity of 50 t/d coal was commenced in Morwell, Victoria by Nippon Brown Coal Liquefaction Co., Ltd., a group of five private companies entrusted to undertake this project by NEDO, and a local Australian company, Brown Coal Liquefaction of Victoria Co., Ltd. Its completion at the end of 1986 allowed for operation research to be conducted from 1987 through October, 1990, which was followed by demolition studies and consolidation studies of overall results. The demolition studies were completed by April, 1992, most withdrawal activities were finished by May, and layoff of local employees, return of the land, and winding up of the local research program in Victoria were concluded by summer in 1992. During its peak operating period, this pilot study project was participated in by a total of about 300 people composed of some 70 Japanese staff members and 230 or so locally hired.

The brown coal liquefaction process (BCL Process) is characterized by suspended-bed primary hydrogenation under relatively moderate reaction conditions, high-efficiency solvent deashing, fixed-bed secondary hydrogenation using a high-durability catalyst, and slurry dewatering with less energy. The five items listed below as the targets of this pilot-plant research project have all been attained (the results parenthesized) with a perfect set of data relating to the 30-item assignments to development including acquisition of scale-up data and establishment of operation procedures.

(a) 50% or more oil yields (52% achieved)

(b) Continuous operation for some 1,000 hours (overall 1,726-hour continued constant operation achieved)

(c) 1,000 ppm or less solvent deashing performance (achieved by establishing a method of deashing with toluene and self-produced naphtha)

(d) Development of a fixed-bed secondary hydrogenation catalyst which withstands long-term operation (achieved a catalyst performance test of 3,374 hours, longer than the goal of 3,000 hours in continuous long-term operation)

(e) Establishment of an economical slurry dewatering process (demonstrated 95% dewatering with the steam generated from the dewatering process as a source of heat (3 times as thermally efficient as conventional))

2) Consolidation studies of results, related research, etc.

(a) Follow-up studies

Even after the pilot-plant research activity, Nippon Brown Coal Liquefaction Co., Ltd. is still engaged in follow-up studies on the suppression of scale formation inhibited and on a deashing solvent recovery method as well as to supplement and complete the process data. The equipment collected into a laboratory of NBCL located in Takasago, Hyogo-ken, includes a small continuous testing device with autoclaves, an improved version of the 0.1 t/d equipment used for the pilot-plant supporting studies.

(b) Consolidation studies

The technical data obtained in the course of pilot plant operation research as well as from supporting and follow-up studies is to be collected for intensive analysis and systematization and will be concurrently reviewed with respect to scale-up and evaluated in terms of economy. In putting together such data for the expected presentation as a project report within fiscal 1993, a detailed review will be made by a promotion committee made up of external experts in various fields. The report is enormous with a total of over 10,000 pages in A-4 format (equivalent to 15 King File volumes), covering every and all study results of this project.

The oil liquefied throughout this pilot-plant research project is stored in Japan as a precious piece of property to become the raw material for future experiments in developing a upgrading process of liquefied oil.

(c) Technical package of coal liquefaction

NEDO desires to complete a technical package of coal liquefaction by the year 2000 on the basis of the results from the technical development of brown and bituminous coal liquefaction processes as well as from the results of current development of methods to upgrade coal liquefied oil. This package includes the data for scale-up to enable the stage to be shifted to a demonstration plant (with a scale of 6,000 tons a day), methods of scale-up, conceptual design of such a plant, economy projection, patent application, simulation results, and operation manuals. Among these, the portion covering brown coal liquefaction (about 700 pages) is expected to be prepared within fiscal 1993.

(3)Development of Entrained Flow Coal Gasification Power Generation Process

1) Development in progress, etc.

The technological development of Entrained Flow Coal Gasification Power Generation Process (IGCC) aims to establish a gas- and steam-turbine combined cycle generation system using an entrained flow gasifier capable of generating electricity more efficiently than conventional pulverized coal firing system. Toward the intended development of a demonstration plant having a 250 thousand kilowatt generation capacity with net, thermal efficiency of 43% or more by the year 2000 at the latest, a 200 t/d pilot plant at Nakoso Joint Thermal Power Plant located in Iwaki, Fukushima-ken is under research for operation. IGCC is a combined coal gas-fueled and exhaust heat-recovery steam turbine power generation system in which a hot dry gas clean-up process is incorporated. In contrast, pressurized fluidized-bed power generation (PFBC) has a combination of steam turbine and exhaust gas-driven turbine processes. Considering that the PFBC generation efficiency is governed by the efficiency of its

predominant steam cycle and is approaching the limits of improvement, efforts will be directed toward IGCC development as an independent technical attempt to put it into practical use in and after the year 2000 under the Sunshine Project.

In 1986, research activities were commissioned to the Coal Gasification Combined Cycle Generation Technical Research Association, which is composed of 9 electric power companies, EPDC and CRIEDI, NEDO started basic/detailed engineering and design of a 200 t/d pilot plant, commenced construction in January, 1988, and completed it in February, 1991. Operation started in June, 1991. 90% of the development costs are being borne by NEDO, which receives grants from the Japanese Government, and the remaining 10% by joint R&D participants, who are required to complete their commissioned activities by the end of fiscal 1994.

To further support this technical development activity, The Coal Mining Research Centre (CMRC), Japan, was commissioned to do the studies from fiscal 1988 through fiscal 1990 using the 40 t/d gasification test equipment in Yubari, Hokkaido, where similar research work had proceeded under the same Sunshine Project.

2) Features of this process

A hot dry gas clean-up method is employed to realize a gas turbine inlet temperature of 1,300 °C in order to achieve high efficiency. Air is used instead of oxygen as a gasifying agent to produce low-calorie gas. The corresponding turbine used is, therefore, compatible with such low-calorie gas. In the 2-chamber, 2-stage entrained flow gasifier, a tangential burner causes a voluted flow of gas to make it better contact the coal. With coal ash collected as molten slag, this process is adaptable to a wide-range of coal ranks. It also emits low levels of not only NOx, soot, and dust, but also CO_2 because of its high generation efficiency.

3) Assignment for development

The features mentioned constitutes elementary items to be developed, but the task of developing a gasification generation system is, as a whole, to embody such development into a demonstration plant that has a capacity of 250 thousand kilowatts with net, thermal efficiency of 43% or more by the year 2000 at the latest. The gasifier operation started in June, 1991, coal gas was passing through gas clean-up in February, 1992, and successful power generation by product gas for the first time in July, 1992 with present-time efforts aimed toward long-term continuous operation.

(4) Development of Coal-Based Hydrogen Production Process (HYCOL Process)

1) Development in progress, etc.

The development of Coal-Based Hydrogen Production Process aims to establish a technology which permits constant production and supply of low-cost hydrogen in large quantities using coal as the raw material. In the HYCOL Process, a hydrogen-Carbon monoxide gas mixture is prepared in an entrained-bed gasifier using oxygen as the gasifying agent. This mixture then undergoes a steam-shift reaction to increase the hydrogen, and then pure hydrogen is obtained through gas purification. The R&D program covers the process stages including coal preparation, gasification,

slag disposal, and dust removal. At present, pilot plant operation research is under way in Sodegaura, Chiba-ken.

Prior to the start of this development project, element research studies were made of a multi-purpose gasifier where oxygen is added to coal to react. In 1985, Industrial Technology Council, Advisory Committee for Energy concluded that this process had proved promising as a method of producing low-cost hydrogen from coal. It was, therefore, decided that pilot plant research would be promoted starting from fiscal 1986 under the Sunshine Project. The Research Association for Hydrogen-from-Coal Process Development was set up in May, 1986 as the chief R&D organization, and it included participation from 9 private companies. Construction of the pilot plant was completed in 1990. This was followed by the commencement of trial operation in February, 1991, and of 30-atm gasification testing in March, 1992.

2) Features of this process

The core equipment of this process is an oxygen-blown one-chamber and two-step spiral flow gasification system together with a multi-burner system and a char recycle. This brings high gasification efficiency and compatibility with a wide-range coal ranks. Another feature of gasification in the high temperature reduction atmosphere is that it does not generate NOx, exhibiting highly environment-friendly characteristics combined with the method of recovering coal ash as stable molten slag.

3) Assignments for development

The operation research has cleared many of the fundamental development assignments, with part of the development goals already achieved by successful (a) gasification at 30 atm and (b) gasification of carbon at a rate of 98% or more with cold gas efficiency of 78% or more. Another recent success is continuous operation for more than 200 hours in September, 1993. Review of equipment upgrading and operation conditions will contribute toward achieving longer-hour continuous operation on a laboratory basis.

4. Development of Next-Generation Coal-Based Processes

CCTC, in its development effort to achieve clean coal use by focusing on the utilization process, including combustion, thermal decomposition, and preparation (coal cleaning), has just started related survey and research activities as part of CCT development efforts. The fields covered are summarized as follows:

(1) Environment-friendly coal combustion process

Intended development of a combustion system with few environmentally damaging substances (e.g., CO_2, NOx, and SO_x) discharged from its coal-fueled boiler.

1) Oxygen combustion technique

For a coal boiler, oxygen is used instead of air to achieve high-efficiency combustion as well as to increase CO_2 concentration in exhaust gas for higher possibility of recovery.

2) Topping combustion technique

A pressurized fluidized-bed cycle is combined with partial gasification of coal which is then supplied to the gas-turbine combustion equipment to raise the gas-turbine inlet temperature for the purpose of improving the combined cycle plant efficiency as a whole.

(2) Multi-purpose coal thermal decomposition process

Multi-purpose coal thermal decomposition process is thermal decomposition process where coal is broken down under moderate reaction conditions of medium temperature and pressure ranges in an attempt to more comprehensively utilize coal components. This is done not only to use coal as energy but also to produce chemical, carbon, and other materials from the substances derived from coal decomposition.

(3) Advanced coal upgrading process

Prior to coal combustion, sulfur, ash, and other contents likely to pollute the environment are removed in an attempt to obtain a cleaner fuel.

5. Clean Coal Technology and International Cooperation

(1) Imminent Tasks and Japanese Efforts

Aside from comprehensive problems relating to the protection of natural environment such as global warming and sulfuric oxides and other substances which cause acid rain, a more local form of environmental problem, mainly associated with the effects of sulfuric oxides, smoke, soot on human health and daily life, may become the greatest immediate concern of many countries where future economic growth is likely to involve expansion of coal utilization. From this standpoint, it is an important task to as quickly as possible introduce and promote the diffusion of CCT-related measures which are applicable at the present, including coal preparation, ingenious combustion methods,and exhaust gas treatment.

In June, 1993, Outline of a Report on the Meeting of the International Coal-related Problem (chaired by Toshiaki Ikuta, President of The INSTITUTE OF ENERGY ECONOMICS, Japan), a personal gathering held by the Director of the Coal Mining Department, Agency of Natural Resources and Energy, Ministry of International Trade and Industry of Japan, proposed that policies should be clearly identified toward how the problems concerning coal facing not only Japan but also the surrounding Asian Pacific region must be addressed in the coming 21st century. The outline also stated that environmental problems relating to coal use in the same region should be coped with by supporting each country's endeavor to use coal in an environmentally friendly manner. This indicated a direction in which Japanese policies should advisably be oriented, and is explained as follows:

1) Encourage the introduction of equipment that contributes to energy saving and mitigated environmental damage from coal use, such as through the implementation of model projects and through joint research activities to protect the environment.

2) Contribute to the relaxation of economic burdens due to compliance with environmental regulations, and reduce costs of environment-protective equipment by means of joint R&D programs with all countries. It will be necessary to cultivate

related fringe industries (e.g., special steel components and control equipment parts) in each country, enabling environmental and other facilities and equipment to be manufactured and installed. Assistance should also be given to improve the conditions, in terms of both hardware and software, under which the regulatory system to control as well as measure environmental damage is enforced in such countries.

(2) Green Aid Plan and CCT

As one of the planned projects to actively propel the above proposals, the Green Aid Plan is comprehensive. The Green Aid Plan is implenting energy/environment improvement projects based on Japanese past experiences with anti-pollution measures in accordance with the need and situation of each developing country. This project was proposed by the Ministry of International Trade and Industry of Japan in August, 1991 in an effort to support self-help developing countries in grappling with energy/environmental problems. The fields covered include water/air pollution control, disposal and recycle of wastes, energy saving, and substitute energy. Support programs are to be carried out via the following two stages:

1) Inter-governmental dialogues to be held

Between Japan and the partner country, inter-governmental policy dialogues are held on both the high and working levels to encourage the realization of mutual energy/environmental strategies.

2) Comprehensive energy/environment-related assistance policies to be put into effect

In the second stage, the above policy dialogue outcomes are used as a base for putting into effect the energy/environmental problems-related projects including:

a) Technological cooperation relating to energy/environment

The enforcement of energy/environmental policies in the partner country is enhanced by sending experts and receiving trainees. At the same time, cooperation efforts are extended to jointly research energy/environment related technologies which conform to the needs of the partner country. Feasibility studies are also made regarding environment-related measures if requested by the partner country.

b) Demonstration tests

For the purpose of developing the technologies which best suit local needs, tests are carried out to demonstrate the effectiveness of measures such as desulfurization, effective use of energy, and development of clean energy. Efforts are now being made toward the implementation of the Green Aid Plan in Asian countries including China, Indonesia, and the Philippines, along with policy dialogues with these countries.

Particularly for China, promotional measures are making steady progress with a number of tests, including tests on a coal thermal power plant's desulfurization process at HUANG DAO of Chingtao City in Shantung Province, China by Electric Power Development. An agreement was made concerning this project in April, 1992, between the then Minister of International Trade and Industry of Japan, Kozo Watanabe and State Council Chief AOU JIA HUA, of China. The position of coal utilization technology in this plan is crucial, considering that in China, coal consumption has exceeded 1 billion tons, accounting for nearly 80% of primary energy spending. The June, 1993 Japan-China vice ministers' high-ranking official working-level conference

confirmed the willingness to substantially expand mutual cooperation in these fields. Concrete measures include master planning for environmentally friendly use of coal, and model project programs as requested by China for desulfurization equipment, fluidized-bed boilers, shaped coal production, etc. As for the above master planning and CCT model projects, CCTC is expected to play the core role of promoting international cooperation programs, making the best of the excellent knowledge and experience possessed by prominent organizations in these fields, including technically advanced private companies.

(3) Multilateral Cooperation - APEC, IEA, etc.

NEDO, since before implementing bilateral cooperation projects concerning CCT including the above-mentioned Green Aid Plan, built up, in connection with technological development in a variety of fields, many diversified international cooperative relationships. These relationships include Japan-Australia research cooperation, which is based on the extensive exchange of information and the brown coal liquefaction project, and technical cooperation with China for coal liquefaction under the Japan-US and other bilateral agreements on scientific and technical cooperation. Other than these bilateral cooperation projects, NEDO is also participating in many of the IEA (International Energy Agency) projects, APEC (Asia-Pacific Economic Cooperation Minister Conference) energy-related CCT projects, and other activities.

1) Cooperation through IEA

IEA places emphasis on energy trends concerning coal and environmental problems in East Europe and Asia, providing timely and meaningful opportunities for us to meet such as at this international symposium today held here in Hong Kong.

NEDO, to serve as a window through which coal-related affairs in IEA activities are accessible, is quite active in participating in international cooperation implementation agreements on technical information delivery services, fluidized-bed combustion, and coal liquid fuel mixture (CLM) and is also sending staff to the IEA for coal research.

In the next year, an IEA Coal Research Committee meeting and another international conference on CLM are slated to be held in Japan.

2) APEC/CCT experts' meeting

In APEC, 10 energy and other working groups are organized under the ministerial conference and high-ranking officials' working-level meetings.

Regarding energy, 5 cooperation fields have been formed including one entitled "Energy and Environment," in which CCT is a main theme discussed in CCT experts' meetings.

In September, 1992, APEC successfully held its first CCT seminar in Thailand. The agenda there contained review of a CCT training program to be included as one of APEC's future missions, together with seminar activities. NEDO is willing to participate in such programs and activities aggressively for the benefit of all APEC members.

The Reality of Coal Technology for Today and Tomorrow

By

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To be presented at

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Its Role in Energy, Environment and Life

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The Reality of Coal Technology for Today and Tomorrow

INTRODUCTION

My talk this morning deals with the reality of coal technology for today and tomorrow. In keeping with the underlying theme of this conference (that is, Coal's Role in Energy, Environment, and Life), I shall focus my talk on coal-based power generating technology and its closely coupled relationship to the environment and to our standards of living.

This paper will start with a few salient facts about coal and its role in power production. The drivers affecting coal-based power generation technology development will then be discussed. A likely scenario for the development of the various power options will then be outlined. The paper concludes with a call to accelerate technology development and technology transfer between developed and developing countries.

ELECTRICITY, GNP, THE ENVIRONMENT, AND COAL

Coal is the most abundant fossil fuel in the world and makes up for 80% of the world's fossil fuel reserve [Slide #1]. Over 40% of the world's electricity generation is by coal. In the U.S., we anticipate that over the next 40 years, coal-based electricity generation will maintain its share. In the developing countries, the percentage will be higher. Worldwide, it is forecast that the use of coal will double over the next 30 years.[1] The U.S., CIS, and China are countries with the largest coal reserves (Slide #2).

Slide #3 is a forecast of new worldwide generating capacity requirements for the next 10 years. As you can see, Asia will need the lion's share. Slide #4 is a breakdown by fuel type of this capacity addition. Coal will be the dominant fuel, particularly in the Asian market. It is therefore appropriate and timely to hold this conference now at this place.

Slide #5 is a graph of electricity consumption vs GNP from 1960 to 1990.[2] This relationship has withstood the acid tests of time. Electricity production, unlike total energy consumption, had no interruption in growth rate as a result of the 1973 oil shock. Its one-to-one relationship to GNP growth is obvious. Therefore, coal must continue to play a crucial role in maintaining and improving the world's standard of living since it is expected to be the dominant fuel for power generation.

The intense industrialization of the last half century has made us even more aware of the damages we have done and are still doing to the environment. We in the

U.S. have passed more and more stringent laws to combat environmental pollution. The most comprehensive of these culminated in the 1990 Clean Air Act Amendments which, among other things, place caps on the total amount of pollutants such as SO_2 that all the power plants can emit. For example, by the year 2000, a 8.9 mm ton/yr cap is put on SO_2. Of course, pollution is not a local but a global concern. This is attested to at the 1992 Rio de Janeiro Earth Summit. The U.S. has agreed to abide by the Rio Accord which, among other things, pledges the signers of the accord to cap their CO_2 emissions to the 1990 levels by the year 2000 (Slide #6).

The implications of these policy limits are clear and severe! We must accelerate our technology development in power generation in order to accommodate these limits so that we are not hampered in our quest to maintain and improve our standard of living. Since coal is expected to be the key fuel for electricity generation, it is essential that we concentrate our efforts to develop the proper mix of coal-based technologies to move into the next century.

COAL-BASED ENERGY CONVERSION SYSTEMS FOR TODAY AND TOMORROW

Given the background on the interdependence among the competing requirements, it is instructive to list the drivers and the corresponding attributes of the coal-based systems. The three generic drivers are: Efficiency, Environment, and Economics. These can be further broken down and the desirable system attributes to respond to the drivers can then be listed as shown in Slide #7*. From these attributes, we have constructed a scenario for an orderly technology progression for the USA as shown in Slide #8*. The exact timing and degree of penetration of the various technologies may be open to speculation. By and large, we believe this scenario to be reasonable. This scenario is also likely to apply to the developed countries where coal is a dominant fuel. For the developing countries, we see a time scale displacement, but believe the technology progression may be similar with variations in emphasis to fit local conditions, such as the types of fuels available.

In the next series of slides, I shall give you a brief description of some of the systems we are working on at Foster Wheeler to respond to the current and anticipated demands for coal-based power generation technology, as all of these systems fit within the theme depicted by Slide #8.

Utility Size Circulating Fluid Bed Boiler

Atmospheric Circulating Fluid Beds (CFBs) have been proven in the marketplace in many industrial settings and Foster Wheeler and its licensees have supplied

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*Adapted from U.S. DOE Morgantown Energy Technology Center (L. Salvador) presentations and modified by author for this conference.

or have under planning over 50 fluid bed boilers (13 of these are CFBs) worldwide. The largest units we have built are a pair of 120-MWe CFBs for the Nelson Industrial Steam Company to burn petroleum coke. These are two of the first CFBs incorporating reheat. These units came on-line in mid-1992 and have had over a year of excellent operation. In order to move this technology into a utility setting, Foster Wheeler is supplying a 250-MWe unit to Air Products and Chemicals, Inc., as part of the U.S. DOE's Clean Coal I program. This unit will be located in York County, Pennsylvania and will fire bituminous coal. Slide #9 is a sectional elevation of the unit. This unit contains some unique features including an Integral Recycling Heat Exchanger (INTREX[1]) which contains the superheater elements and steam-cooled cyclones. The parallel pass design of our very successful conventional pulverized coal boilers is also used here. Essentially, coal and limestone are fed from both the front and rear of the furnace. Primary fluidizing air is used to start the combustion process, with secondary air being injected for staging and NO_x control. Four cyclones are employed to perform solids separation. The solids, after separation in the cyclones, are returned to the INTREX (Integrated Recycle Heat Exchanger) which houses the superheaters. The solids, after transferring heat to the INTREX tubes, return to the furnace. The flue gas, after solids separation in the cyclones, flows over the heat recovery section. The flue gas flow control between the reheaters and boiler sections is done by dampers. The unique FW steam-cooled cyclones are insulated with a very thin layer of refractory which minimizes maintenance and speeds up heat-up of the unit. Sulfur removal is expected to exceed 92%, with a NO_x level of less than 0.21 lb per million Btu. The reliable operation of this unit will assure the viability of CFBs as a utility offering. Because of its adaptability to a variety of fuels, CFBs are particularly suited for regions with a high variety of coals including low-grade coals.

Integrated Gasification Combined Cycle (IGCC)

As part of Clean Coal IV, Sierra Pacific Power Company was awarded an IGCC program to build an 100-MWe demonstration plant at their Piñon Pine site. Foster Wheeler is the prime contractor on the program, and we will be using the KRW gasifier technology marketed by Kellogg—the company that will provide the gasifier design.

Slide #10 depicts the main sections of the process. In broad outline, the facility receives coal which, after drying and crushing, is fed to the pressurized gasifier through a lock hopper system. The bed is maintained in a fluidized form by injecting steam and air through special zones into the combustion zone. The heat of reaction causes the coal in the bed to gasify, leaving the ash behind. To capture the sulfur in the coal, crushed limestone is added to the gasifier. In this process, the sulfur reacts with the limestone to form calcium sulfide which, after oxidation, exits the gasifier along with the coal ash in the form of agglomerated particles suitable for landfill.

The coal gas leaving the gasifier passes through the cyclones to remove nearly all of the particulate matter which is returned to the fluidized bed. The gas leaving the gasifier about 1700°F is cooled to 1050°F before it enters the hot gas cleanup sec-

tion of the plant. There traces of sulfur are removed to a 96+-percent efficiency in a bed using an absorbent. A ceramic candle filter removes essentially all the remaining particulate material before the clean gas enters the combustion turbine. The hot gas sulfur-removal sorbent can be regenerated with steam and air with the regenerator gas stream being sent to the sulfator, where the sulfur reacts with limestone and air, and then exiting the system as calcium sulfate.

The combustion turbine is coupled to an electric generator designed to produce approximately 61 MWe gross. The turbine is of special design to accommodate the low-Btu coal-derived gas. The machine also has the flexibility to burn natural gas or distillate should power be required when the gasifier section is shut down. The heat in the combustion turbine exhaust gases generates steam in a heat recovery steam generator (HRSG) to produce approximately 46 MWe gross. In this combined-cycle mode, the total output of the plant is 107 MWe gross. The NO_x content is expected to be a fraction of the NSPS limits due to the low-temperature process combined with steam injection into the turbine. The plant efficiency for the Piñon Pine configuration is 39% based on higher heating value of the coal. Somewhat better efficiencies can be achieved with an optimized commercial-size unit.

Recently, Foster Wheeler Italiana, a subsidiary of Foster Wheeler Corporation, completed a preliminary design of a 500-MW equivalent IGCC unit, based on the Texaco process, for ISAB—a refinery company in Sicily. This is a heavy-oil IGCC designed to process the high-sulfur residues from the adjacent refinery, and to produce electricity and hydrogen. The electricity will be delivered to the national grid (ENEL), while hydrogen will be returned to the ISAB refinery to upgrade oil products. Although this plant is used to process heavy oil residues, most of the key features of this large-size plant would be applicable to a Texaco coal-based IGCC unit. It's operational experience will be of great value towards further commercializing the Texaco IGCC process.

Advanced (Second-Generation) Pressurized Circulating Fluidized Bed Combustion System

Slide #11 is a system diagram for a Second-Generation Pressurized Fluidized Bed (PCFB) demonstration plant as part of the U.S. DOE's Clean Coal program. Since 1986, Foster Wheeler has been under contract to the U.S. DOE to develop a "Second-Generation" PFB power generation system. We met a major milestone in this effort when a team composed of Foster Wheeler, Air Products & Chemicals, Lurgi-Lentjes-Babcock Energietechnik GmbH, and Westinghouse was selected to build a Second-Generation PFB demonstration plant at Air Product's chemical manufacturing facility in Calvert City, Kentucky under the sponsorship of the U.S. DOE's Clean Coal Technology Round V Program. This demonstration plant will burn Kentucky bituminous coal to produce 95 MW equivalent of power. The steam (300,000 lbs/hr) from this cogeneration power plant will be supplied to the chemicals manufacturing plant and

the power (65 MWe) will be sold to the Tennessee Valley Authority on a long-term basis.

In the simplified Second-Generation PCFB process, shown in Slide #10, coal slurry and limestone are fed to a carbonizer, which is an air-blown pressurized fluidized bed gasifier, to produce a low-Btu fuel gas and char. The fuel gas, after cleaning up by the cyclone, ceramic filter and alkali removal system, is burned in a topping combustor gas turbine. The gas turbine drives a generator and an air compressor which delivers the air to the carbonizer and to a PCFB combustor. The char from the carbonizer, additional coal slurry and limestone are burned in the PCFB combustor. The PCFB combustor generates steam from waterwall and integrated heat exchangers (INTREX) and also provides the combustion air (pressurized flue gas) to the topping combustor. Additional steam is generated in the heat recovery steam generator (HRSG). The steam from the PCFB and HRSG drives the steam turbine generator which, together with the previously-mentioned gas turbine stream, completes the combined-cycle operation. The second-generation PCFB plant can achieve plant efficiency in excess of 45%, based on higher heating value of the coal.

Hybrid Circulating Fluid Bed with Partial Gasifier

In the Second-Generation PCFB combustion system just described, if we substitute the pressurized circulating fluidized bed with an atmospheric circulating fluidized bed (CFB), we will have the hybrid system shown in Slide #12. In this scheme, we would shift more duty toward gasification in the partial gasifier and use this gas in a topping combustor as before. The residual char, after depressurizing, will be burned in the CFB. Additional coal and sorbent can be fed to the CFB to optimize the cycle. This topping cycle scheme can yield a 43% system efficiency (based on higher heating value of the coal), just slightly lower than that of an advanced PFB combustion system with similar emissions characteristics. Such a scheme also lends itself to a retrofit where there is an existing CFB. This system has the advantage of utilizing the wealth of operating experience in atmospheric circulating fluid beds and would be particularly suited for countries such as the PRC where atmospheric fluid bed experience is in abundance.

HIPPS (High-Performance Power System)

As part of the DOE PETC (Pittsburgh Energy Technology Center) "Combustion 2000" program, FWDC is leading a team in the development of a system based on a pulverized-coal furnace that will yield system efficiencies in excess of 47 percent (based on the higher heating value of coal) and meet or better NSPS limits. The unique feature of this system is the use of a novel high-temperature advanced furnace (HITAF), a schematic of which is shown in Slide #13. The key features of this design include a pyrolysis unit to generate the fuel gas that heats pressurized air in a ceramic heat exchanger to a high temperature (1600°F) temperature. A topping combustor then boosts this pressurized air (160 to 200 psi) to a higher temperature (2350°F) to

take advantage of high-temperature high-efficiency gas turbines. To further take advantage of the pyrolysis process and improve plant efficiency, the residual char is burned in a TRW slagging combustor, which generates additional heat in the furnace. The design of the heat-transfer surfaces in this furnace is characterized by high temperature, but low pressure. The heat generated from char combustion, together with the gas turbine exhaust, then generates steam to run the steam turbine, giving us a high-efficiency combined-cycle system. In addition to the high-efficiency targets, this program also aims to achieve SO_2, NO_x, and particulate emissions that are a quarter of the current NSPS levels.

We are collaborating with Bechtel (A/E), TRW (slagging combustor), AiResearch (ceramic heat exchanger), and Research-Cottrell (back-end cleanup) on this multi-phased program. The Phase 1 study is near completion and the results look very promising. Phase 2 will involve engineering, development, and testing of the key features, to be followed by Phase 3 in which a prototype High-Performance Power Generating Plant will be built to demonstrate the technology.

Externally-Fired Combined Cycle (EFCC)

Both the IGCC and PFB cycles require efficient hot gas cleanup devices to function properly. In the EFCC system (Slide #14), this problem is avoided by heating pressurized air inside a ceramic heat exchanger which receives heat from a combustor upstream to a high temperature ($\approx$ 2350°F). This clean, heated air is used to drive a gas turbine. The rest of the system is a conventional combined-cycle plant enabling the plant to achieve efficiency of 45 percent based on higher heating value of the coal. The key component in this system is the ceramic heat exchanger. Foster Wheeler is a member of an industry/utility consortium led by Hague International Corporation, supported by DOE to develop the ceramic heat exchanger system for this cycle. A proof test of a single-span ceramic heat exchanger was completed in 1990. A prototypical multispan ceramic heat exchanger test program is in progress. Foster Wheeler is assisting the consortium in the engineering of the combustor and design and supply of the burner for the test program.

One of the five project selected for the U.S. DOE's Clean Coal V program was based on this technology. In that project, the Pennsylvania Electric Company will repower its Warren Station with the addition of an externally fired gas turbine resulting in a combined-cycle plant in which a new 18.3-MWe gas turbine will be added to an existing 47-MWe steam turbine for a total net output of 62.4 MWe. The project team will consist of Hague International—the technology developer, and Black and Veatch—the architect/engineer, working on behalf of the owner, Pennsylvania Electric Company.

Plant Efficiencies

Slide #15 gives a summary of plant efficiencies for the various systems—all based on higher heating value of coal. A review of this information makes it dramatically clear that high potential exists to increase plant efficiency for future units. To illustrate this effect, let's consider the coal consumption of a conventional 500-MWe pulverized coal steam generator based power plant which typically operates with a plant efficiency of around 35%. On average, such a plant consumes some 200 tons/hr of coal. If we can increase the plant efficiency from the nominal 35% to say 45%, this consumption does down to 150 tons/hr. Additional benefits are lower emissions and solid wastes production.

Advanced Gas Turbines

As you may have noticed by now, the one unifying theme in the advanced, high-efficiency systems is the emphasis on maximizing the Brayton Cycle output through the use of high-temperature combustion turbines. In the U.S., we believe there is substantial room for further improving system efficiency through the development of advanced gas turbines. In fact, the U.S. Department of Energy has recently initiated a major advanced gas turbines development program. The program objectives are given in Slide #16. For the near- and intermediate-term, we believe the gas turbine performance will become a standard by which all future generation systems are measured.

APPLICATIONS OF ADVANCED SYSTEMS TO ASIA PACIFIC MARKETS

From a technical feasibility standpoint, we believe the Asia Pacific countries are well endowed to take advantage of all of the advancements in technology discussed in this paper. Due to special local situations, one technology may be preferred over another. For example, the People's Republic of China has had a wealth of experience in building small atmospheric bubbling fluid bed units. With its high variety of coals, the newer, larger circulating fluid bed units may gain an advantage. With experience gained in atmospheric fluid beds, it may be advantageous for the P.R.C. and for countries with high-sulfur and/or low-grade fuels to consider the Hybrid CFB scheme, as shown in Slide #12, to take advantage of their background in atmospheric fluid beds. Ultimately, the deciding factor will be cost of electricity, which includes capital cost, operating cost, reliability, availability, etc. The competitive markets of the world will sort out the strong from the weak. The projected high growth rates of economic activity in the Asia Pacific countries will undoubtedly provide proving grounds for these advanced systems.

CONCLUDING REMARKS

In closing I would like to offer the following observations:

(1) Slide #17 shows a world population growth curve to 2060.[2] As you can see, the majority of the growth will be contributed by the developing countries.

(2) Today, the developing countries use 19% of the world's total electricity output. By the middle of the 21st century, this percentage is expected to change to 41%.[2]

(3) Environmental preservation has to take a global approach in order to be effective.

(4) The development of high efficiency and low emissions coal-based generating systems is a win-win situation regardless of the final outcome on the global climate (warming) debate.

(5) Developed countries have a strong incentive to transfer the technology to developing countries since there is a high leveraging effect on environmental preservation when the advanced technologies are adopted by the developing countries. The same leveraging effect is also at work from a trade and business standpoint.

(6) Coal is likely to remain the dominant fossil fuel well into the second half of the 21st century. Therefore, the major efforts ongoing to develop advanced coal-based generating technologies deserves our high priority.

(7) A final parting note to this audience: acceptance of coal-based generating systems will face increasing scrutiny from a concerned public. We must pay high-priority attention to educating the public about the good efforts and effective results of our work to develop and commercialize clean coal power generation.

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[1] Yeager, K.E., Torrens, I.M., "Environmental Challenges: Energy Issues and the Role of Technology," 17th Low Rank Fuels Symposium, Energy and Environmental Research Center, University of North Dakota.

[2] Starr, C., "Global Energy and Electricity Futures," EcoWorld '92, Washington, DC, June 14-17, 1992.

The Reality of Coal Technology for Today and Tomorrow

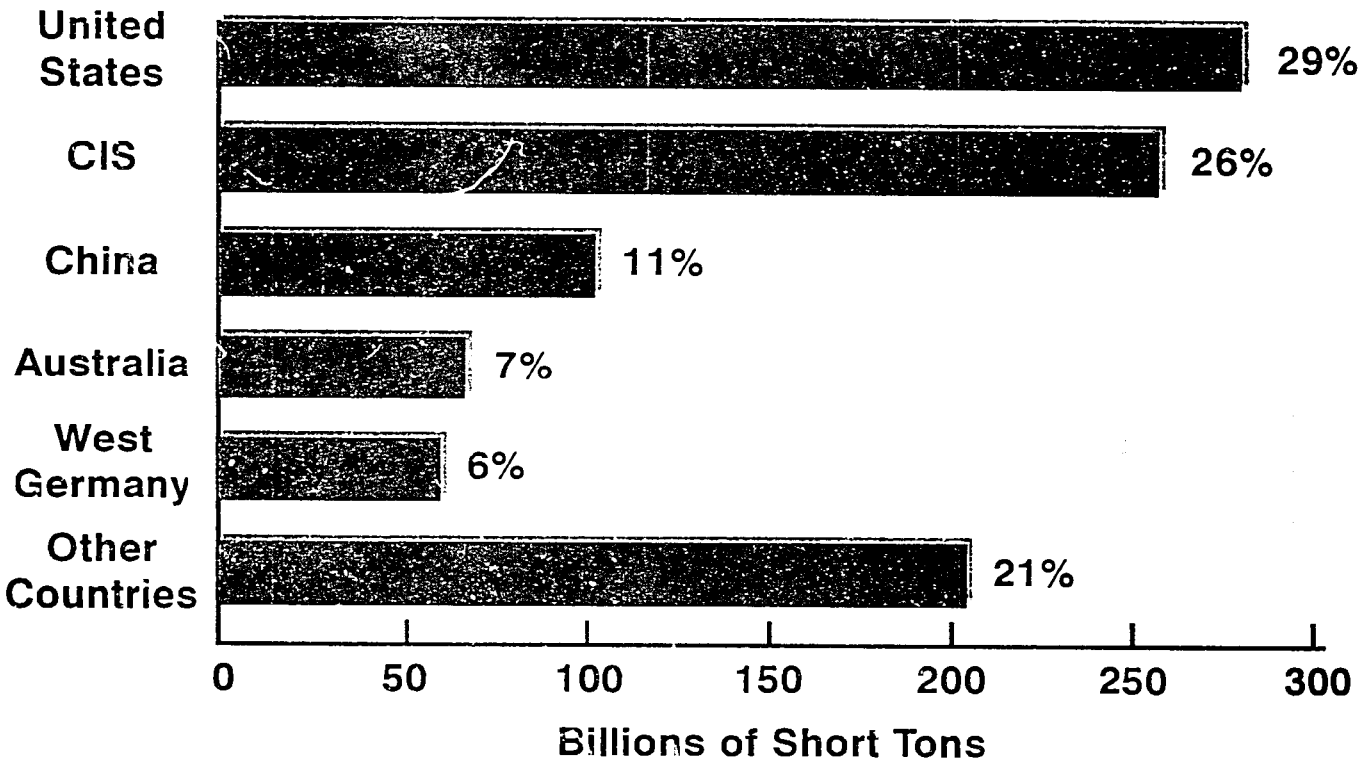
David H. Pai
Foster Wheeler Development Corporation

Some Salient Facts About Coal

- Coal Comprises 80% of the World's Fossil Fuel Reserves
- Over 40% of the World Electricity Generation Today is by Coal
- 41% of the New Capacity Additions over the Next 20 Years are Expected to be Coal Based
- Use of Coal Worldwide is Expected to ***Double*** in the Next 30 Years

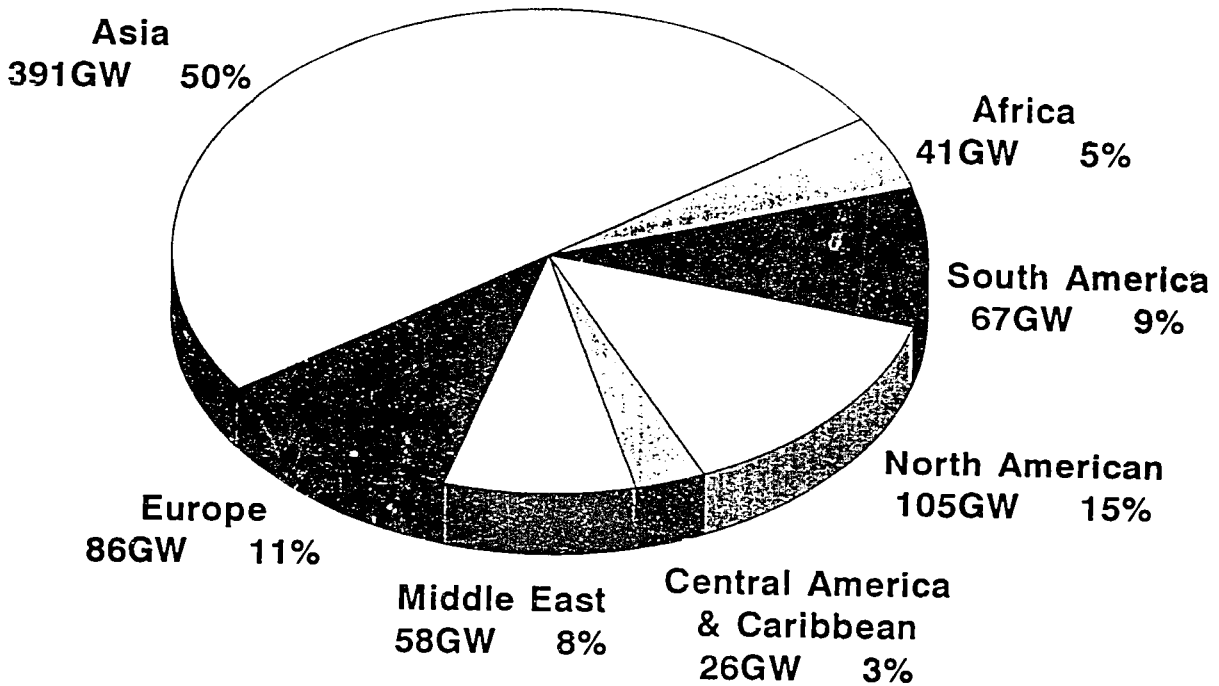
Slide #1

World Recoverable Coal Reserves



Slide #2

World 1993-2002 New Generating Capacity Needed
Breakdown by Region (Total: 774GW)



10-Year Projection

Slide #3

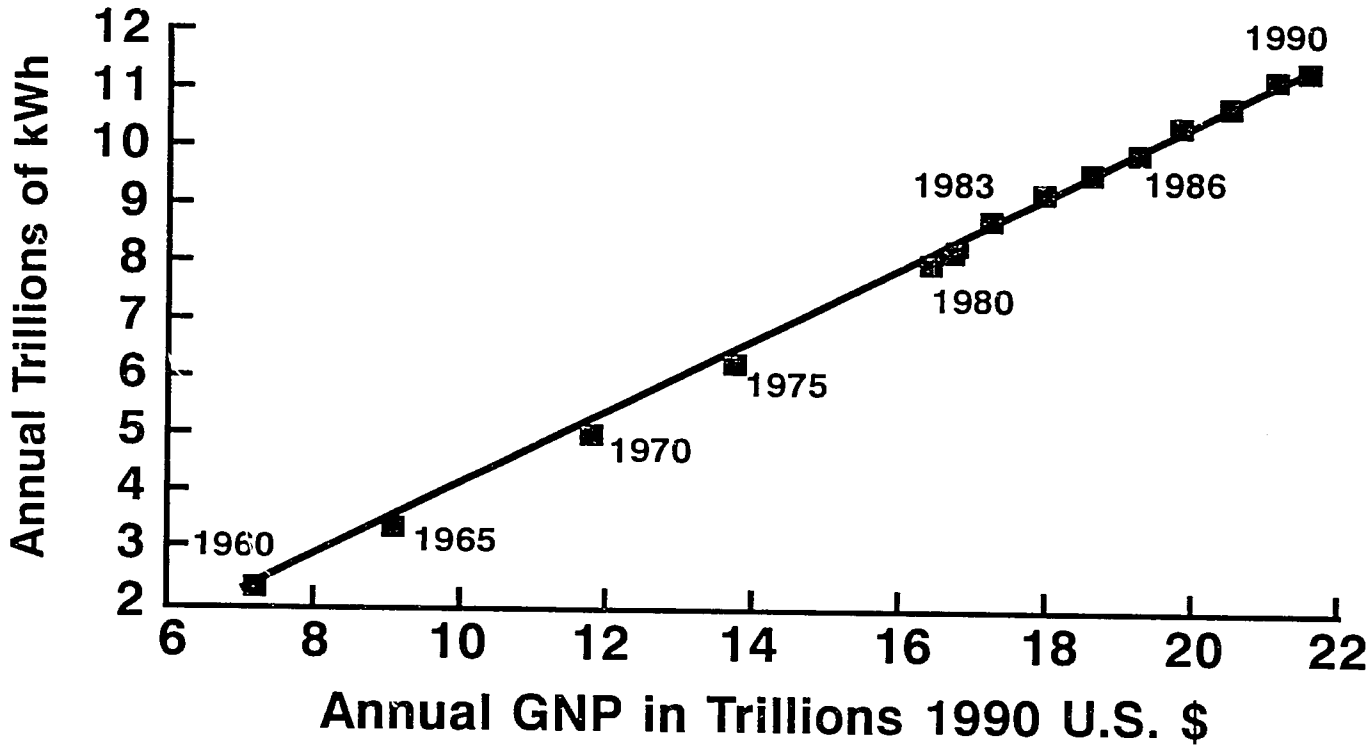
Asia – New Generating Capacity Needed 1993-2002 (GW)

	Coal	Gas	Oil	Nuclear	Hydro	Geothermal Wind Solar	Total
China	99.0	5.0	-	4.0	51.0	-	159.0
India	46.0	8.0	-	6.0	30.0	-	90.0
Indonesia	13.0	6.0	-	-	4.0	2.0	25.0
Japan	8.5	6.6	-	12.0	-	-	27.1
South Korea	8.8	2.0	-	4.7	1.3	-	16.8
Phillipines	10.0	4.0	-	-	1.6	1.4	17.0
Pakistan	3.5	2.5	1.5	-	7.5	-	15.0
Thailand	6.1	2.0	-	-	2.8	-	10.9
Other	13.2	10.2	1	-	4.8	1.0	30.2
TOTAL	208.1	46.3	2.5	26.7	103.0	4.4	391.0

NEW CAPACITY REQUIRED IN ASIA IS 50% OF WORLD TOTAL

Slide #4

World kWh vs GNP (1960–1990)



Slide #5

Potential Limits to Growth

- 1990 Clean Air Act Amendments Imposed a Cap on the Total Amount of Pollutants that Power Plants can Emit (e.g., Cap for SO_2 will be 8.9 Million Tons by the Year 2000)

- The Rio de Janeiro Earth Summit Accord Pledges the U.S. to Cap CO_2 Emissions at 1990 Levels

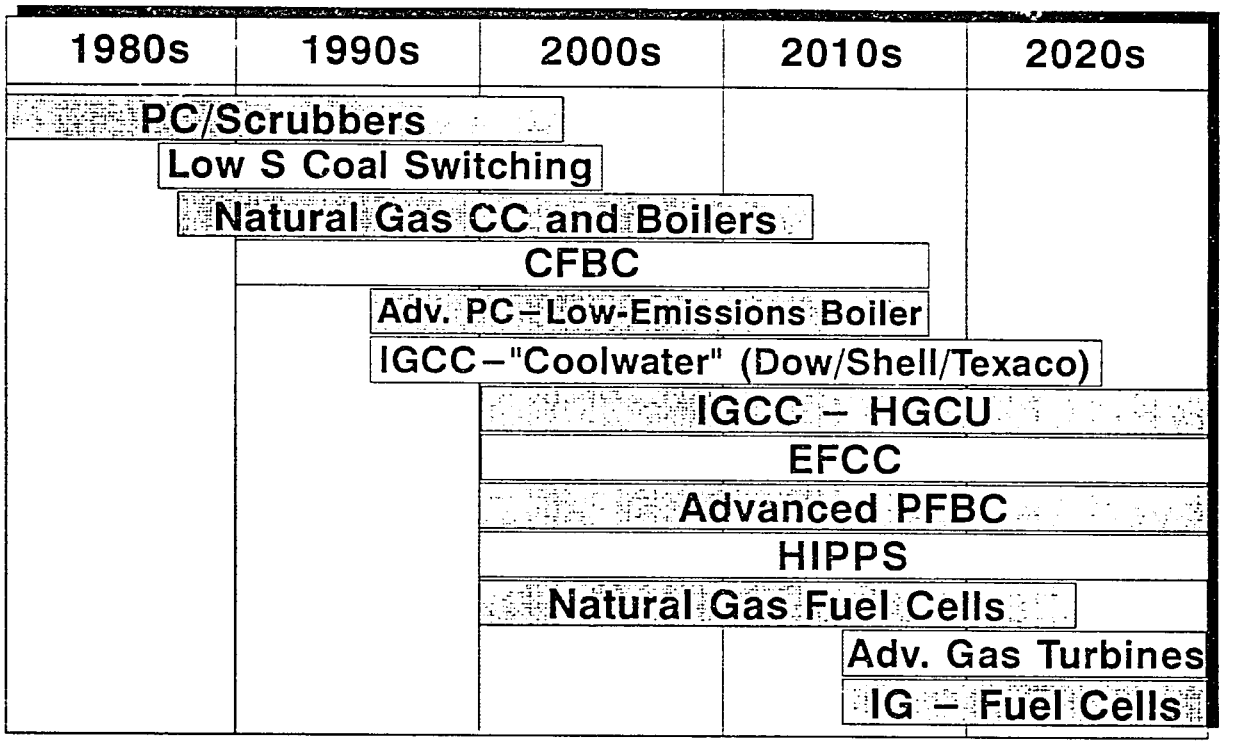
Slide #6

Power Generators Will Seek Systems Whose Attributes Satisfy Market Drivers

Driver	Attribute
Demand Growth	Capable of Repowering or New Capacity
Fuel Flexibility	Operation with Different Coals and/or Natural Gas
Competition	Small, Modular, Low Cost, Efficient
Emission Limits	Low Emissions, Low Toxics, Efficient
Least Cost	Low O&M and Capital Costs, Reliable
Public Acceptance	Clean, Efficient, Low Cost

Slide #7

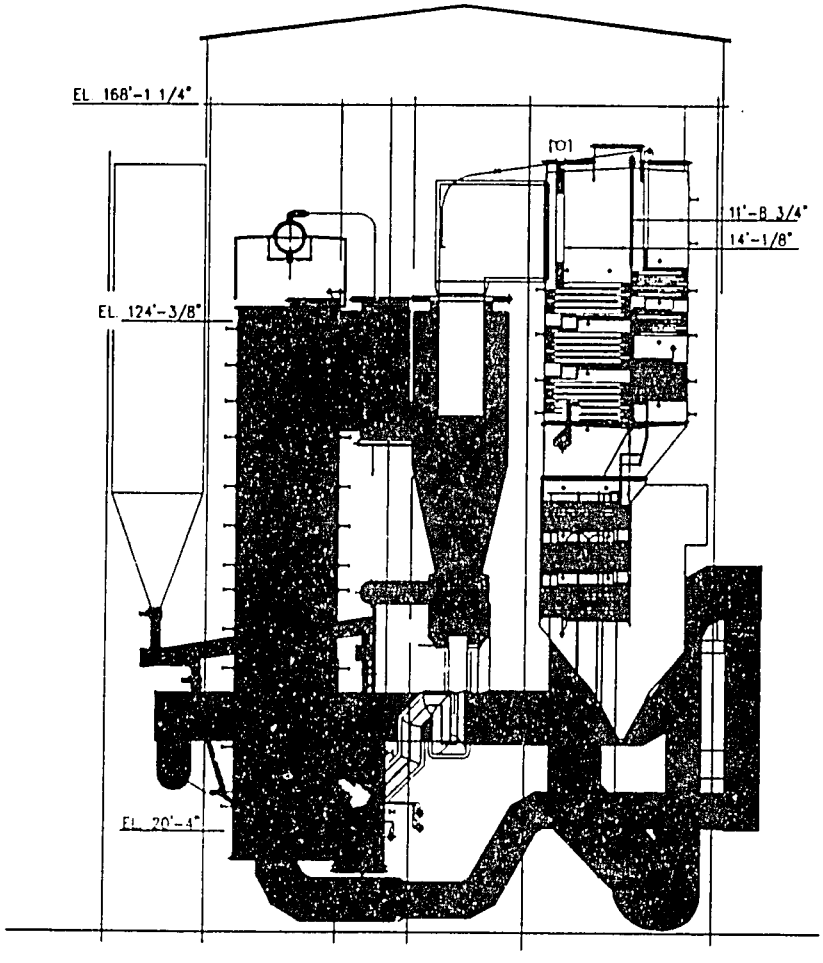
Utility Generation Options – A Scenario



Slide #8

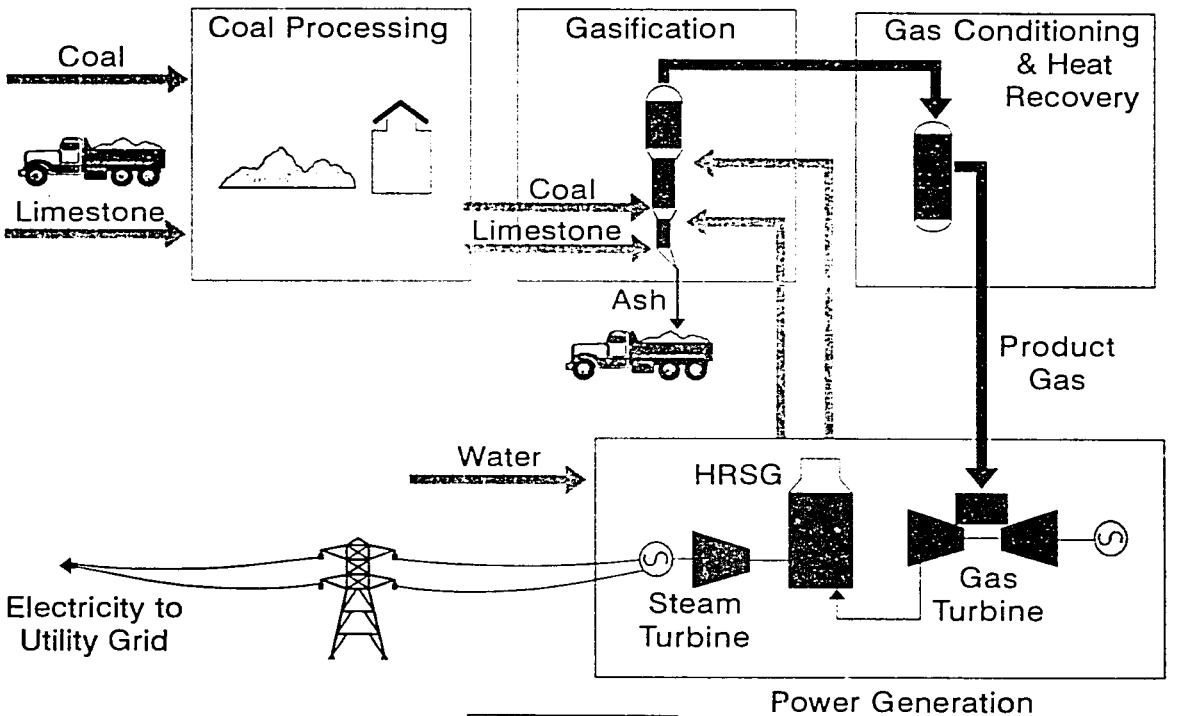
FOSTER WHEELER ENERGY CORPORATION

YORK COUNTY ENERGY PARTNERS PROJECT



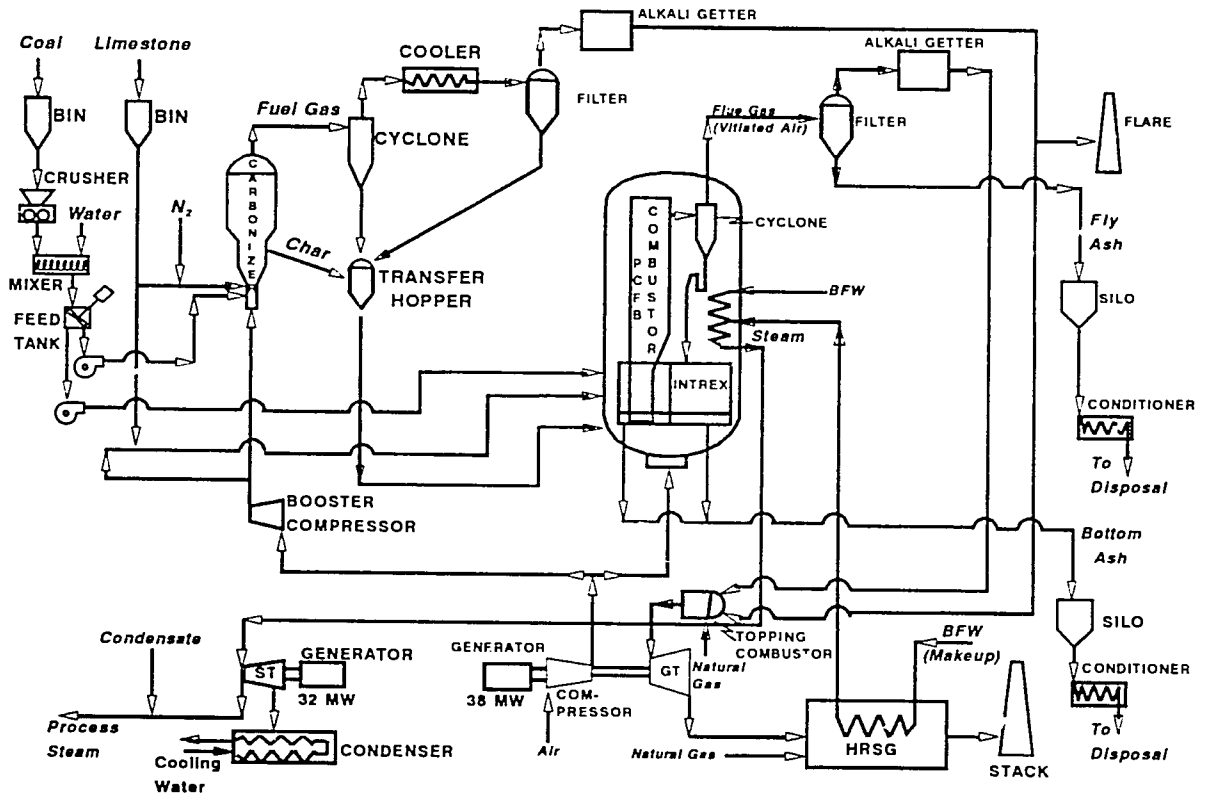
Slide #9

Piñon Pine Power Project
Coal-Gasification Combined-Cycle Schematic



Slide #10

CALVERT CITY ADVANCED ENERGY PROJECT



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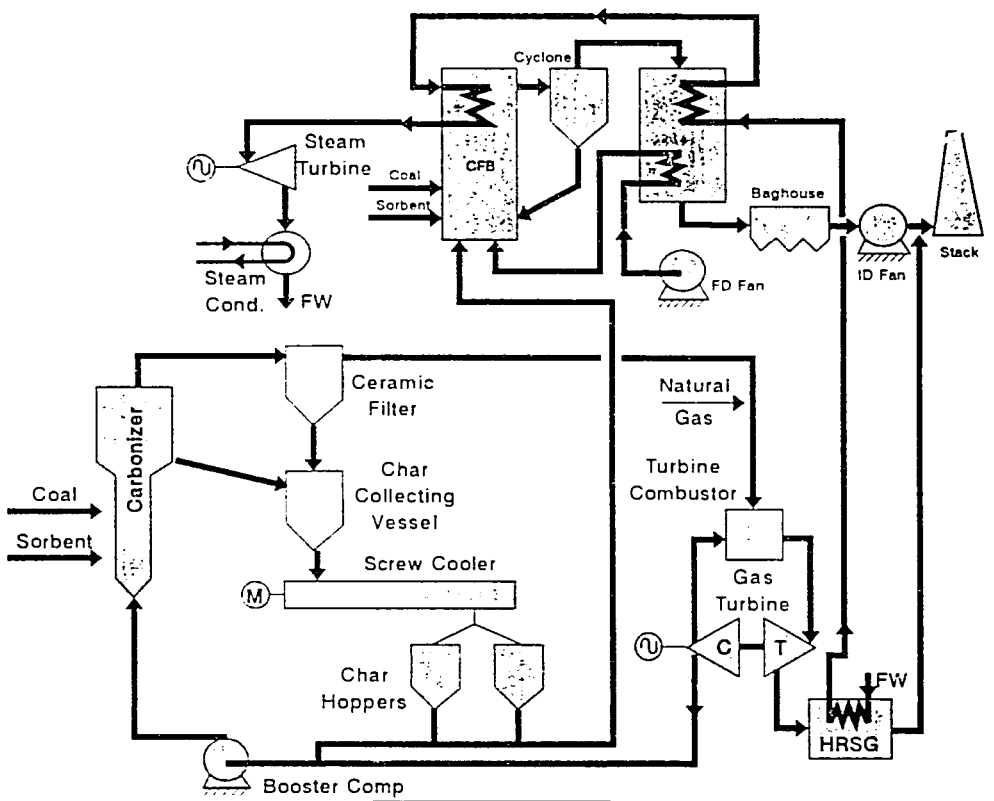
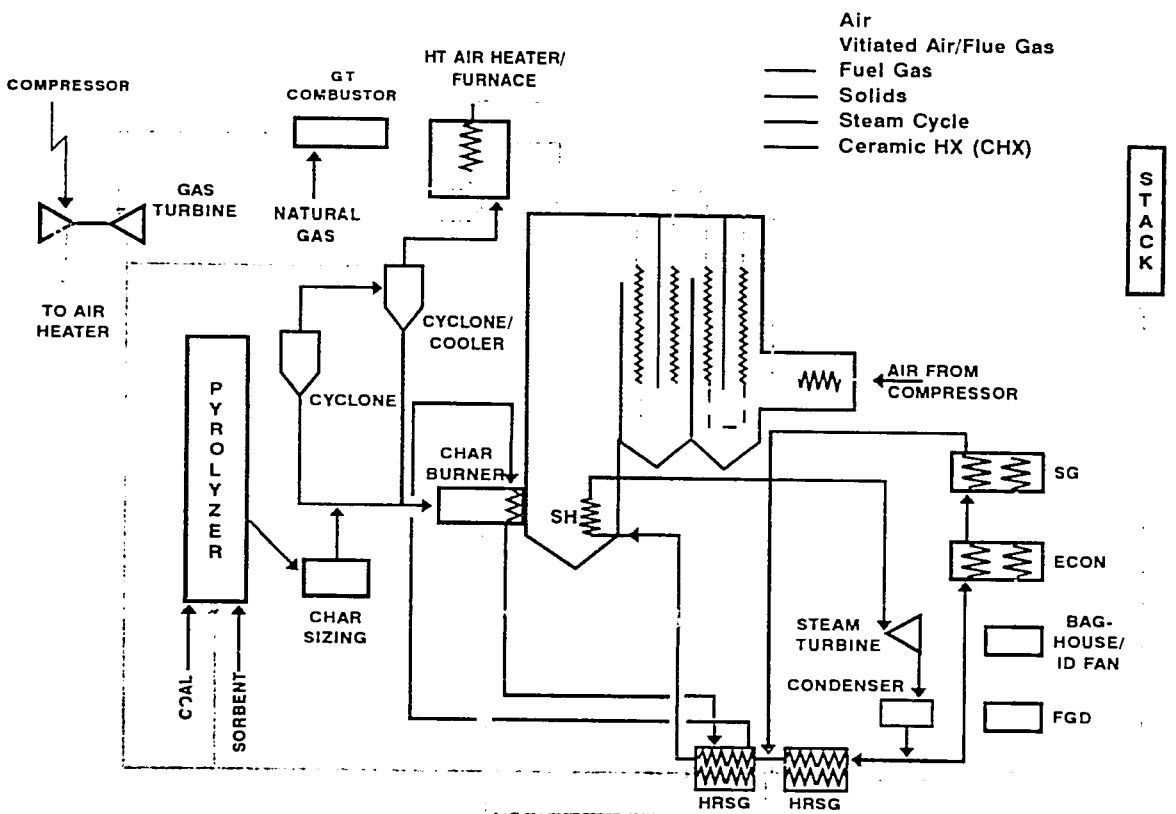
Slide #11

CFB Hybrid System with Partial Gasifier



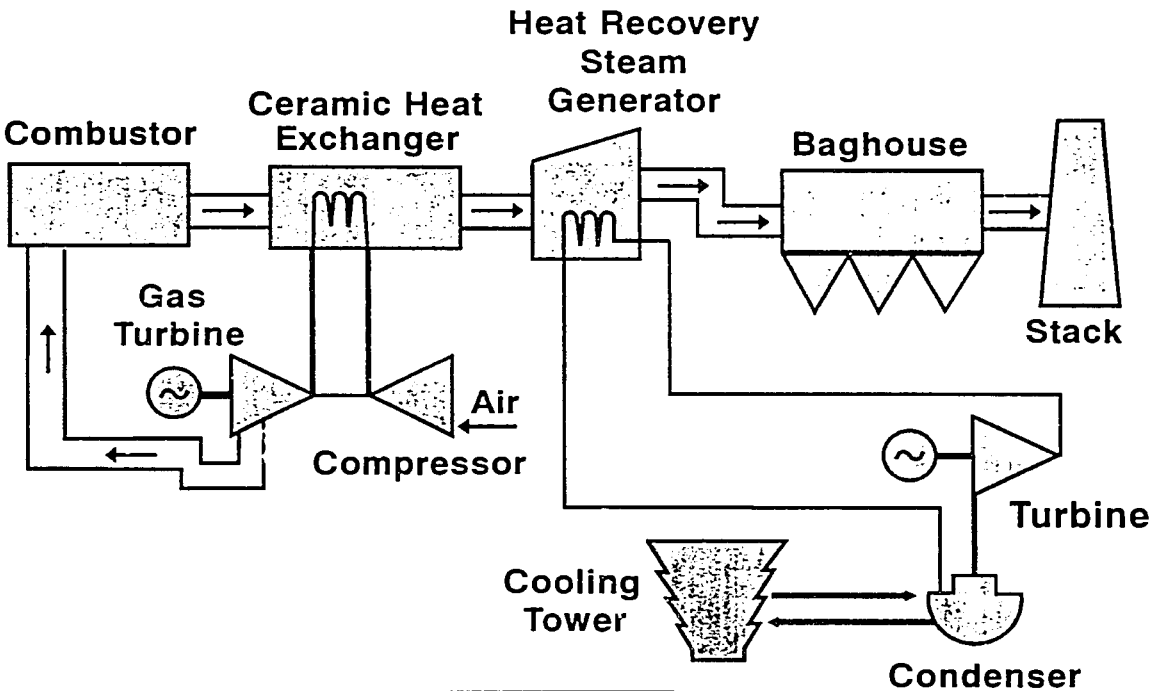
Slide #12

High-Temperature Advanced Furnace

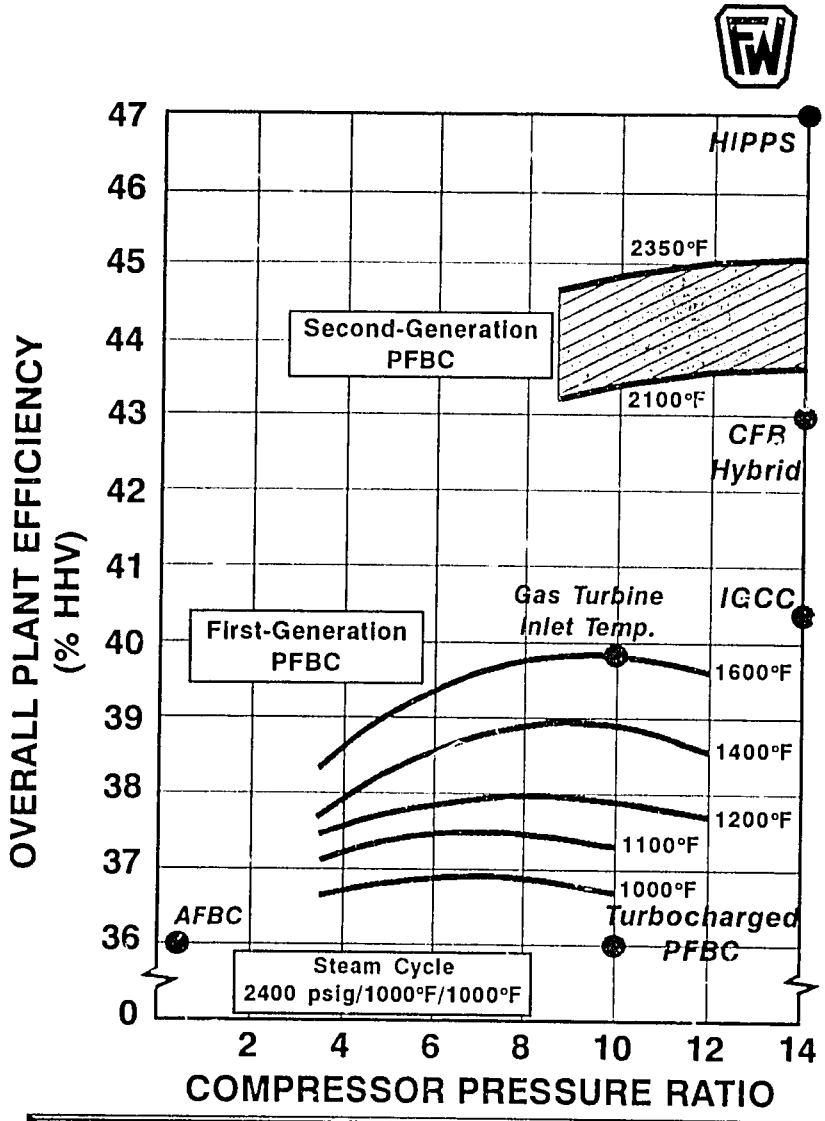


Slide #13

Externally Fired Gas Turbine Combined Cycle Block Diagram



Slide #14



EFFICIENCY COMPARISON

Slide #15

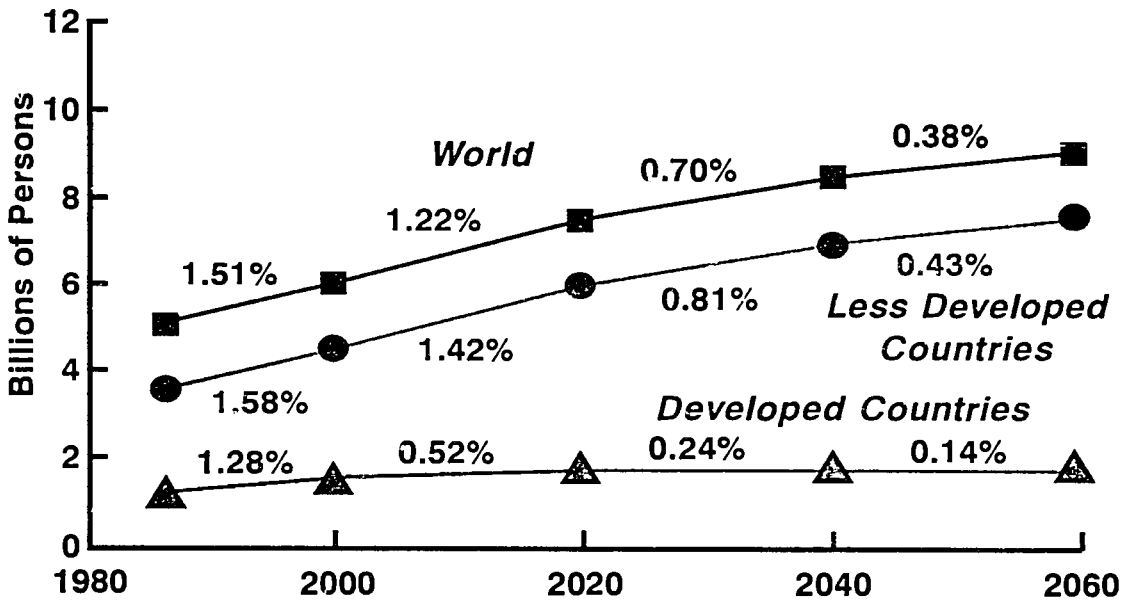
The Advanced Gas Turbine Program Will Provide Ultra-High Efficiency Enhancements to PFB, EFCC, and IGCC Products

PROGRAM GOALS FOR 2005

- 60% Efficiency Utility Turbine System
- 9 ppm NO_x without SCR
- Fuel Flexible – Natural Gas/Coal Gas
- Cost of Electricity 10% Below Current Turbines
- RAM Equivalent to Current Turbines
- High Inlet Temperature Plus System Enhancements

Slide #16

WORLD POPULATION
1980 – 2060



Slide #17

WORKSHOP A1

FINANCING

HUNTON & WILLIAMS

JOHN J. BEARDSWORTH, JR.
PARTNER

INTERNATIONAL ENERGY AGENCY SECOND INTERNATIONAL CONFERENCE ON THE CLEAN AND EFFICIENT USE OF COAL AND LIGNITE

Barriers to Investment in Emerging Power Markets

Hong Kong
2 December 1993

I.

INTRODUCTION

The trend towards the generation of private power in emerging nations has created vast new investment opportunities for private power developers. Some countries are attempting to privatize or upgrade existing generating facilities using private sector investment while other countries are in the process of introducing new private generation facilities into the existing electric supply structure. Private power developers and their lenders interested in investing in such projects are finding, however, that the development and operation of private energy projects in emerging nations is considerably different from private power transactions in the US and UK and that additional and somewhat different issues must be considered when analyzing a potential project; particularly in a country with little experience in private power or private sector involvement.

Certainly the key goal of any power project, domestic or international, is that the project be financible. The greater the risks and barriers associated with a particular country, the more difficult it will be to obtain financing and the higher the risk premium that will be required. Before agreeing to finance any energy project, a lender generally will ask for assurances that a project has the potential to generate an adequate revenue stream, that appropriate security for the debt will be available and that the project will result in a fair rate of return. In an international power project, however, reconciling these factors can be considerably more challenging because of the many factors that are not necessarily in the developer's control. For example, some countries have restrictions on whether the government may a guaranty the local utility's obligations under the power purchase agreement.

Energy projects are commonly financed on a limited recourse basis. This type of limited recourse financing is where the only security for the debt that finances the project are the assets of the project and the stream of revenue expected from the project. Simply put, the project itself is the lender's security. How "investment barriers" operate in the context of these projects now becomes evident: How does the developer assure the lender that the debt will be serviced when the law of a nation does not permit the government to guaranty the payments to the developer? How does the developer assure the lender that the laws of a nation will not be changed in such a way that will cause the developer to lose the plant leaving the lender with no security? How does the developer assure the lender that the credit of the underlying utility and the flow of money from end-use electric consumers is adequate to support the project – and will continue to be for the term of the financing? This paper will briefly identify the most important and difficult investment barriers associated with international power deals in emerging nations and will offer suggestions for avoiding or reducing the impact of these barriers.

II.

IDENTIFICATION OF INVESTMENT BARRIERS

LEGAL BARRIERS

1. Legal Authorization

The first issue that should be considered when analyzing a potential independent power project in an emerging nation is whether the laws of that country permit the private ownership of generation facilities. Many countries that experienced a period of socialism or nationalism nationalized or simply expropriated all of the existing generation facilities and enacted legislation prohibiting private ownership and operation of such facilities. Even without this historical basis, the legal framework of some countries precludes private ownership and operation of power facilities. Where there is an express prohibition, unless the law permits the developer to obtain a special permit or waiver, it is often necessary to obtain a constitutional amendment, the passage of new legislation or a presidential order or mandate. To the extent that the government is committed to private power, new legislation is feasible but often a very lengthy process. Equally problematic is where the existing legal framework is unclear or complicated or where the law is simply silent on the issue of private ownership. In this case, new legislation or a mandate are equally advisable to avoid the risk of later different interpretations or to satisfy stringent qualifications of lenders or their counsel.

2. Regulatory Framework

The absence of specific regulations or an operative regulatory framework under which private power projects can operate also raises many concerns. The absence of a regulatory framework raises many concerns. First, the parameters of what a private developer may and

may not do under the law may not be clear -- critical elements of command and control regulation. Second, there may be no protection against changes in end-user rates or other changes in law that make the completion or operation of the project, as contemplated, illegal or uneconomical. An investor must also be concerned with changes in environmental or labor standards. Third, the absence of a regulatory framework may not provide the developer with legal recourse in the event that the purchasing utility does not perform its obligations under the power purchase agreement. Legal considerations in developing a regulatory framework are the subject of a separate paper (delivered to The world Bank in April 1993) attached as Appendix A. That paper provides a menu of considerations -- it does not suggest the full panoply of regulations as a solution.

3. **Government Guaranties**

Because many countries have been unable to establish credit, a developer's lender may require that the payment obligations of the local utility be guarantied by the government. In some countries, however, the law does not permit the government to guaranty debt. Other alternatives such as commercial lines of credit, accounts receivable security packages or even the World Bank's Enhanced Co-Financing Program each raise possibilities but pose problems as well.

4. **Fuel**

A developer may have problems obtaining adequate fuel supplies depending on a country's fuel supply laws. For example, there may be a government or private monopoly over sources of fuel, or there may be restrictions over the type of fuels that may be used. In such cases, the cost of fuel may be so high as to make the project uneconomical. In addition, any barriers to a long-term fuel supply contract (with public or private sector providers) or passing through the variable price of fuel to end use consumers may create barriers to investment.

5. **Lender Protections**

There may be lender specific legal barriers such as lack of adequate laws protecting the lenders lien priority over the facility. Since the lender's main sources of security for the debt is the facility and the assignment of security rights over the power purchase agreement, the lender will insist on a first lien over the real and personal property comprising the plant and a security interest in the power purchase agreement. Both must be permitted by law. In addition, the laws must create real rights in the event of a default. Having a security interest is not enough if there is no "real world" way to realize on the security in an event of default. A cause for further lender concern may be an absence of, or lack of clarity in, the laws that govern foreign ownership of real and personal property.

6. **Labor Laws**

Labor laws may often seriously affect the viability of a private power project. For example, many emerging nation's labor laws require that certain percentages of national labor must be employed at the power plant. Other laws may make it difficult to reduce employment at any time -- even though the construction period is obviously more labor intensive than operation. While labor laws will not act as a barrier to investment, they are extraordinarily important in making an investment decision and should be studied carefully. In the case of the privatization of an existing facility, a developer may encounter laws that prevent the downsizing of a large number of underemployed existing personnel.

7. **Commercial Restrictions and Risks**

There are numerous commercial restrictions and risks that must be identified generally prior to making an investment in the power sector of any country. These can each impact the availability of investment money and thus any of them would act as an investment barrier. For purposes of this paper I will note only that they vary from country to country and must be examined carefully. Some of the most significant include:

a. Restrictions on the repatriation of profits.

b. Restrictions on the convertibility of currency.

c. Unusual and, therefore, expensive insurance requirements.

d. Customs duties.

e. High import taxes.

f. Restrictions on imports of equipment, fuel and machinery.

g. High income or property taxes.

h. State of the local economy.

POLITICAL BARRIERS

There are many political uncertainties that must be considered when investing in the power sector of any country.

1. **Government Commitment and Support**

The commitment of the government towards a private power project can be instrumental to the success of the project. A supportive government will be willing to pass legislation, assist the developer in obtaining permits and create an overall helpful atmosphere. However, because many nations from time to time suffer political instability, a supportive government can be replaced by a non-supportive government over a short period of time. Such a change can result in hostility towards the developer and the project so that it is impossible for the developer to complete construction and operate the project. Changes in government control can also result in the expropriation or nationalization of a project leaving the lender with no security and the developer with a complete loss of equity.

2. **Funding Sources**

In cases where a multilateral organization such as the World Bank or the Asian Development Bank have provided investment or loan funds to the state-owned utility whose credit underlies the Power Purchase Agreement, a change in government may result in such

funding being cut for political reasons unrelated to the project. Because, in the final analysis, the success or failure of a project is dependent upon the credit of the utility purchasing the power, the financial status of that utility is always an issue.

3. **Political Unrest**

Political unrest may lead to physical attacks and/or damage to the project, attacks on foreign nationals working at the facility, strikes or other economic slow downs so that the developer is unable to operate the facility. Often these sorts of risks, where they impose a barrier, can be handled by an Implementation Agreement (which will be discussed later).

4. **Religion**

In certain countries religious law may control some aspects of a business deal. For example, the religious "Shariat" Court decision in Pakistan determined that the payment of interest was "repugnant to Islam" which, if followed, would have made any private power project in Pakistan unfinancible. This legal issue was ultimately resolved, but it underscored the need to examine the full range of potential legal barriers.

5. **Relationships To Other Countries**

The relationship of a host country to other countries should be considered. Military hostilities with other countries can result in physical damage or destruction of the facility, harm to personnel, or a general slow down of the economy.

III.

AVOIDING OR MINIMIZING INVESTMENT BARRIERS

There are two important methods for avoiding or minimizing the effects of investment barriers. The first and probably most critical method, is the removal, by the host

government, of any legal prohibitions to private ownership of power generating facilities and the development of a regulatory framework in which a private power developer can operate with a substantial degree of certainty. The second method is for the developer, local utility and host government to enter into a set of carefully drafted contracts governing the performance of the parties to the transaction.

1. **Legal and Regulatory Requirements**

As an initial step, the government must remove any existing legal and regulatory barriers to private ownership of power generating facilities and the sale of power produced by such facilities. This step can be accomplished either through the passage of new legislation or through the issuance of an executive or presidential order authorizing private activity in the power generation area. Regulations must be put in place that provide a structure within which private power projects can be solicited, evaluated, developed and financed.

In addition, legal risks associated with the following must be made consistent with foreign investment in the power sector:

a. Property rights;

b. Currency convertibility;

c. Repatriation of profits;

d. Non-discrimination against foreign/private companies; and

e. Custom duties; import taxes.

There may also exist certain permits and licenses required by national and state or provincial regulatory bodies for the construction and operation of a power project. The ability of a project to receive those necessary documents is a risk that is likely beyond the ability of any party to protect against, but which must be addressed before a project can be financed. A willingness by the local utility or government to provide guidance and assistance may be the difference between an investment barrier or none.

The legal framework may also include incentives for the use of certain fuels, use of certain technology, projects of a certain size, or projects located in certain geographic locations. This can be done generally by providing tax credits or exemptions for projects meeting the criteria specified in the regulations. Alternatively, the government may choose to negotiate incentives or concessions individually with each developer and include them in the implementation agreement to be discussed below.

2. Contractual Agreements

A significant investment barrier is the inability to negotiate financible contracts. While each contract has variations, there are certain common threads among successful contracts throughout the world.

a. Power Purchase Agreement.

The Power Purchase Agreement (PPA) is generally the most important document in a power project because it carefully sets outs all of the rights and obligations between the developer and the purchasing utility. The PPA is the document that sets out under what circumstances the developer, and thus the lender, will be paid. The PPA also allocates to each of the parties the risks discussed above. Customary PPA provisions that address some the investment barriers discussed above include:

1. Purchase obligation: The key is a long-term (10-15 years or more) obligation to purchase capacity and energy from the facility. A short term contract will not support a sufficiently long amortization period to result in reasonable rates.
2. Payment provisions: A capacity payment that covers fixed costs plus a return and an energy payment that covers fuel and variable operations and maintenance expenses. In the alternative a single payment structured to cover both components may be used.

3. Permit provisions: The utility agrees to assist the developer in his efforts to obtain permits.
4. Force Majeure provisions: Define the developer's rights and obligations during events such as natural disasters, war, strikes, failure of fuel supplier to perform under a fuel supply agreement, political risks, including changes in law that make completion or operation of the project uneconomical.
5. Default: Provisions that provide the developer and utility with remedies in the event of non-performance.
6. Provisions that limit and define the developer's insurance obligations.
7. Provisions that allocate import taxes and duties to the purchasing utility.

b. Fuel Agreement.

The fuel agreement is the document under which the developer secures fuel supplies. The fuel supply agreement should be for a term at least as long as the financing, thereby eliminating the supply risk. The price risk is generally passed to end-use electric consumers through appropriate indices that are parallel in both the Fuel Agreement and the PPA. This document also provides for the transportation mechanism that will permit fuel to reach the plant and provides for rights and remedies of the fuel supplier and developer in the event of non-performance by either party.

c. Implementation Agreement.

Where the legal and regulatory structure or legal protections necessary for the project to be feasible are not in place and new legislation is not available, an implementation agreement between the developer and the host nation may provide the alternative necessary comfort to both the developer and the lender. Implementation agreements are particularly common where no established credit market for the utility's financings is in existence, as is

exemptions for the use of domestic contractors and domestically-produced equipment; and (d) use of government land and equipment without charge, or at a reduced charge.

6. Agreement to participate in the World Bank Enhanced Co-Financing Program.

Incentives and protections such as can be found in an implementation agreement can ameliorate some of the risks associated with investing in an emerging nation and may differentiate between projects that will be financed by an international lender and those that will not. To the extent that the host government is unwilling to enter into some form if implementation agreement, the local utility must be willing to provide a higher return on invested capital in a project due to the perceived higher risks.

OTHER CONCERNS

1. Lack of Information

An underestimated barrier to investing in emerging markets is the unavailability of information to non-locals. The so-called "rules of the road." It is usually advisable to engage a local company or individual familiar with the local market place to help guide the due diligence process. The following are examples of the type of information that a developer will need to gather during the due diligence process:

a. Restrictions on foreign investment.

b. A legal opinion from a local attorney qualified to interpret the laws governing utilities and power producers.

c. Identification of the permits necessary to construct and operate the project and of the appropriate government agencies and officials that can assist with the acquisition of local permits.

the case in many emerging nations. Implementation agreements are also becoming more important to address potential changes in law related to environmental concerns as environmental standards are progressively being raised worldwide. The following are the types of provisions that may be included in the implementation agreement:

1. Terms equivalent to a regulatory framework for projects in countries where a power sector regulatory framework does not yet exist.
2. A commercial framework for the project, addressing particularly:
   a. Nature of land title (ownership in fee or held by lease, ability to encumber with lien, availability of title insurance);
   b. Rights to foreclosure of the property and assignments; and
   c. participation in international arbitration and adjudication conventions (for example, the waiver of sovereign immunity and the enforceability of judgments).
3. Of primary importance to the developer and its lenders, if available, the implementation agreement can provide governmental guaranties relating to (a) the availability of currency convertibility for repatriation of foreign investment, (b) the government-owned utility's contract compliance — principally the making of payments due under the PPA, (c) expropriation or nationalization, and (d) inflation.
4. The implementation agreement may also provide insulation against changes in taxes and duties, inflation and exchange rate fluctuations and other types of political risk.
5. As discussed above, the implementation agreement may provide incentives to developers such as (a) exemption from income taxes for the developer and its personnel; (b) exemption from custom duties and taxes on imports of equipment, fuel and machinery; (c) tax credits and

d. Identification of reputable suppliers and local supply prices.

e. Identification of reliable fuel supplies and fuel transportation arrangements.

2. Finding and retaining experienced managerial and technical personnel to construct and operate the facility.

3. Availability of alternative fuel supplies.

4. Inability to procure land and/or equipment at a reasonable cost from either the government or a private individual. Issues arise concerning whether the utility can exercise any eminent domain powers on behalf of the private power developer.

5. Unusually high costs for providing adequate protection and security for the project site and personnel.

IV.

CONCLUSION

The international private power market is expanding and providing enormous investment opportunities. Many of the opportunities are located in emerging nations with little or no experience in private power generation. It is crucial for both developers and local utilities and governments to understand the risks and uncertainties faced by each other, especially those concerns that become barriers to investment. If all parties become familiar with the legal and regulatory framework in place and the terms of the contractual documents that will make a project financible, then any barriers can be isolated, addressed and hopefully corrected so that the investment appetite of power developers can be used to satiate the power needs of emerging nations.

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SEMINAR ON PRIVATIZATION OF INFRASTRUCTURE

Washington, D.C.
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UTILITY PRIVATIZATION: THE CREATION OF A REGULATORY STRUCTURE

I.

INTRODUCTION

This paper examines the major issues relating to the creation of an independent regulatory agency and that agency's powers and duties in regulating privately-owned electric utilities. Specifically, this paper examines: (1) the role of the regulatory agency and the relationship between the regulatory agency and the regulated utilities; (2) the problems faced by the regulatory agency in performing its duties and in assisting in the transition to a privatized power sector; (3) the legal powers needed by the regulatory agency to perform its duties; and (4) the laws required to create and establish the regulatory agency.

These issues, of course, are affected in large part by the ultimate power sector structure sought to be achieved by a particular government. For example, one government may wish to retain complete control over some aspects of power supply, such as retail distribution, whereas another government may want to create privately-owned distribution companies. In each case, the relationship between the regulatory agency and the utilities will be quite different.

Because the issues relating to the regulatory agency are necessarily dependent on the particular power sector structure sought to be achieved, the issues discussed in this paper are based on two assumptions. The first assumption is that the government in question currently owns, operates, and completely controls all aspects of its country's power supply. That is, all generation, transmission, and distribution facilities are owned and operated by the government under a vertically integrated, "bundled" power supply system. The second assumption is that the government ultimately wants to achieve a power sector structure with the following characteristics:

- Private, competitive, generally unregulated generation companies responsible for all generation, and selling power to both private, regulated distribution companies and large industrial/commercial users.

- A privately owned, regulated national transmission and dispatch entity, responsible for the integrated operation of the electric power sector and a wholesale electricity market.

- Market arrangements allowing large industrial/commercial users to purchase power directly from generators, with the transmission and distribution entities providing transportation and related services in a non-discriminatory manner.

- Privately-owned distribution companies, providing both regulated natural monopoly distribution or "wire" services and retail "supply" services that will be regulated for some customer classes and competitive for large industrial customers. These distribution companies will not be permitted to build or own their own distribution plants. They will provide government mandated and subsidized "lifeline" services and rural electrification using direct financial support from the government.

- An independent national regulator or regulatory agency ("the Regulatory Agency"), staffed with industry experts and professionals. Some of the regulator or Regulatory Agency's responsibilities include maintaining competition, controlling monopoly activities (e.g., rates for services provided by the transmission entity and the distribution companies), ensuring reliable and adequate service, and accumulating information regarding industry performance and market developments.

The primary intent of this power sector structure is to maximize competition among generators and suppliers thereby allowing market forces, rather than a regulator or state-owned monopoly, to play the major role in investments, operations, and pricing. This ultimate power sector structure is depicted on Attachment A. Such a structure is consistent with the three principal goals of privatizing the power sector:

1. The enhancement of capital formation;

2. Improvement in the efficiency of the power sector; and

3. A rationalization of prices and social subsidies.

This paper recognizes that the regulatory structure must have the flexibility to serve the assumed initial phases as well as all transitional phases on the way to the final, unbundled "ultimate" power sector structure.

Before addressing the role of the regulator in the power sector paradigm set forth above, this paper will provide some background to the paradigm by examining the regulatory experience in the United States and the lessons that have been learned from it.

II.

BACKGROUND

A. Overview of Utility Regulation in the United States

Traditionally, most regulated utilities in the United States have offered unified or "bundled" generation, transmission, and distribution services to their wholesale, retail, and large industrial customers without competition from other sources. In the electric industry, for example, a regulated utility usually is awarded a certificate by a state regulatory body which grants the utility the exclusive right to provide service within a defined geographical area. The utility has the right and the obligation to generate, transmit, and distribute electricity to all those in its service territory who desire it on a nondiscriminatory basis. But no other entity could compete with the utility for either the generation, transmission, or distribution of electricity within that utility's certificated area. Thus, the certificated utility, and only the certificated utility, provided these services on a unified basis without competition from any source.

In recent years, however, Congress and the Federal Energy Regulatory Commission (the FERC) have begun to introduce some form of competition into the generation of electric power.

In 1978, the Public Utility Regulatory Policies Act (PURPA) was enacted into law.[1] Under PURPA, Congress introduced a form of competition into the generation of electric power by requiring utilities to purchase power from private, independent producers, called Qualifying Facilities (QFs), at the utilities' "avoided cost."[2] PURPA thus has the effect of putting utilities into competition with private power producers -- most of whom are not subject to the regulatory constraints imposed upon utilities -- for the generation of electricity. If a utility needs additional power, and if a QF can generate and sell this power to the utility at or below the utility's avoided cost, then the utility must purchase its requirements from the QF. Thus, utilities and QFs have an incentive to produce power more efficiently.

PURPA also creates competition for the generation of electricity by creating competition among QFs. For example, if a utility needs an additional 100 megawatts of additional capacity, there may be dozens of QFs willing to supply all or part of the needed capacity. In some states, utilities or state regulators have created competitive bidding schemes in which QFs submit sealed bids to the utility for all or part of the bidded capacity. Those QFs with the lowest bids are awarded contracts. Thus, PURPA creates another "layer" of competition by pitting QFs against one another.

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[1] See Pub. L. No. 95-617, 92 Stat. 3117 (1978) (codified at 16 U.S.C. §§ 796 et seq.).

[2] "Avoided cost" is defined by FERC as the incremental cost to an electric utility of electric energy or capacity or both which, but for the purchase from the QF, such utility would generate itself or purchase from another source. 18 C.F.R. § 292.101(b)(6) (1993).

Moreover, Congress, through the National Energy Act, and the FERC, through several proceedings, have taken steps to increase competition for generation by their efforts to encourage wheeling. This concept of "competition through wheeling" can be explained by the following simple hypothetical:

> Utility A, serving in the midwest, has an excess amount of power that it would like to sell to Utility C, a utility serving in the south that is in dire need of additional power. Located between Utility A and Utility C is Utility B, which refuses to wheel Utility A's excess power to Utility C thereby forcing Utility C to purchase its power from Utility B.

In the above hypothetical, Utility C is a "captive" customer of Utility B. The efforts of Congress and the FERC to encourage wheeling would help eliminate such captive customers. If Utility B were required to wheel Utility A's power at a certain price, Utility C would have a choice among different (and competing) suppliers. Thus, an open access transmission (wheeling) policy would encourage competition in the generation and sale of electric power.

B. Lessons Learned From United States Experience

As discussed, Congress, FERC, and state regulators have taken steps to promote competition and to foster efficiency in the generation and transmission of electric power. The lessons learned in the United States' experience can be used in the privatization efforts in other countries. Specifically, the generation of electric power could be "unbundled" and the scope of regulation reduced while allowing private monopoly control in other areas, such as transmission and generation, in order to fully realize economies of scale.

A county seeking to privatize its electric industry must, of course, determine when competition can adequately protect the interests of consumers and when regulation must be used. Borrowing from the United States' experience, competition may adequately protect the interests of consumers in the generation (production) of electric power. If there exists or can be developed a sufficient number of independent, privately owned generating plants, then competition among these plants will ensure a reliable source of supply at reasonable rates. (As discussed infra, however, in the early stages of privatization a purely competitive scheme for the generation of electric power may not be possible. Perhaps a competitive bidding scheme could be used similar to that used by some states under PURPA, where the regulated utility produces some electric power but may be required to purchase some of its capacity from independent, privately owned producers thorough competitive bidding.)

Regulation, however, still is required for transmission and distribution. As in the United States, to fully realize economies of scale, a single, regulated monopoly should own and operate the wholesale transmission grid. Given the nature of electric power transmission and the cost of creating a unified wholesale transmission grid, competition is not feasible. For these same reasons, competition for retail distribution also is not feasible. Rates and charges for retail distribution must be regulated. (As discussed infra, some competition may be feasible for large industrial customers.)

This mix of competition and regulation should lead to: (1) a competitive power generation market; (2) rate and quality of service regulation of transmission and retail

distribution services; and (3) perhaps some competition for large industrial customers. This "mix" is reflected in our power sector paradigm discussed on pages 2 and 3.

III.

THE ROLE OF THE REGULATORY AGENCY

Given the characteristics of our power sector paradigm, the role of the Regulatory Agency[2] will be to: (1) regulate those aspects of the electric power sector that remain a natural monopoly (such as transmission and distribution); (2) foster and preserve the competitive structure of the electric power industry; and (3) ensure the coordinated, reliable and adequate supply of electric power. This role, and the problems faced by the Regulatory Agency in performing its role, are discussed in this Part III.

Please note, however, that the Regulatory Agency's role and the appropriateness of the Regulatory Agency's regulation will change over time as the state-owned power supply system becomes privatized. In other words, the privatization paradigm set forth in Part I will not develop overnight. Privatization is a process, not an event. The unique problems resulting from the privatization process, and the unique challenges facing regulators during this process, are addressed in Part IV.

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[2] This paper assumes that the privatized power sector will be regulated by a "Regulatory Agency" consisting of several commissioners. A government, however, may decide to use a single regulator rather than an agency. A single administrator may be more efficient than a commission, in part because he possesses all the decision-making powers. His decisions can be rendered more expeditiously and he can handle difficult issues, such as politically sensitive rate design issues, more decisively.

A. Regulation of Natural Monopoly Functions

1. Rate Regulation

In our paradigm, the national transmission entity and distribution companies will be monopolies with captive customers, therefore the rates, terms, and conditions of transmission, dispatch, and distribution "wire" services must be subject to strict regulatory scrutiny and approval.

To ensure the financial viability of transmission and distribution companies, tariffs must permit recovery of the full costs of providing these services plus a return on equity sufficient to attract financing for capital improvements and new construction. The return on equity will depend on the business climate and the financial health of the regulated utility.

There are two primary ratemaking techniques available to the Regulatory Agency to determine the utility's return: cost of service regulation or indexation regulation. Under cost of service regulation, the regulator closely evaluates utility expenses after they have been incurred and then decide whether such costs should be recovered from customers and what rate of profit should be allowed. Generally, cost recovery is permitted if the regulator concludes that the expenses were "prudent," that is, reasonable in light of the circumstances known to management when the expenses were incurred. Utility rates are set to recover the allowed costs and profits. Cost reductions by the utility below the projected, approved levels result in higher profits to the utility until its rates are reviewed and possibly adjusted. In this way, management has an incentive to perform its duties as efficiently and as prudently as possible.

Indexation regulation achieves the same result but in a different manner. With this type of regulation, instead of closely reviewing management decisions to determine what costs should be recovered from customers, the Regulatory Agency would establish an initial price ceiling and indexation formula and allow the regulated utility to earn as much profit as possible by cutting costs below the ceiling price.

Whichever ratemaking technique is used, the Regulatory Agency must not "guarantee" recovery to the regulated utility, but instead must use its ratemaking powers to promote management efficiency so that rates for services are at their lowest possible level.

Rate regulation poses many difficult problems for the Regulatory Agency. One significant problem the Regulatory Agency will face in determining the appropriate return for a utility is balancing the need to compensate investors for the perceived risks of newly privatized ventures (thereby encouraging and retaining private investment), with the political reality that such a return likely will be higher than is traditionally acceptable to the public and politicians. This is a difficult balancing act, and will require not only the skill of the regulator but the support of the government. In this regard, the regulator's actions must be made palatable to the public, perhaps through public relations efforts, as the public must have faith in the long-term results of the privatization process. The required rate of return should drop significantly over time, as investor confidence is achieved.

Another problem the Regulatory Agency will face is to balance its goal of ensuring "reasonable" rates to all customers with other, less clearly defined social goals, such as rural

electrification and the provision of electric service at "lifeline rates" to those who would otherwise be unable to afford it (i.e., cross-subsidies). Under our paradigm, the government itself will mandate and subsidize "lifeline" services and rural electrification. Nevertheless, the Regulatory Agency might be required to address these issues, at least indirectly, in determining the appropriate rate design for utilities, and certainly will have to address these issues if cross-subsidies are to be gradually phased-out rather than eliminated all at once.

Finally, the Regulatory Agency likely will be forced to balance competing national interests in designing rates, in determining the appropriate rate of return, or in reviewing the prudence of management decisions. For example, the Agency may want to encourage conservation, reduce pollution, or encourage the use of certain types of fuel. The regulator must decide how big a factor these goals should play in its decisions.

2. Command and Control Regulation

In addition to rate regulation, the Regulatory Agency will be responsible for certain "command and control" regulation, whereby utilities must obtain regulatory approvals before undertaking certain activities. The purposes of such regulation include: (1) ensuring that utilities do not undermine their financial viability by engaging in unreasonable or unnecessary activities; (2) ensuring that utilities meet their obligation to provide electric service; (3) ensuring the reliability, coordination, and provision of electric power; (4) protecting national security interests; and (5) developing an electric power industry that is consistent with national priorities regarding the use of natural resources.

Command and control regulation usually requires a utility to obtain a government granted franchise or certificate to provide utility services within a certain geographical area. Usually, there are many conditions attached to receiving and maintaining a certificate, such as the requirement that the utility provide service to all who request it in a nondiscriminatory manner. Thus, under our paradigm, the Regulatory Agency would be responsible for granting certificates and ensuring that the regulated certificate holders meet their obligations.

The Regulatory Agency also can use command and control regulation to require utilities to provide socially desirable services or to conduct business in a manner consistent with certain national objectives. For example, utilities can be ordered to provide rural electrification, to use certain fuels, and to engage in energy conservation and load management. These goals of command and control regulation are also achieved (and supported) by the Agency's use of rate regulation.

The Regulatory Agency can use command and control regulation to require preapproval of certain regulated utility activities, such as: (1) the issuance of securities; (2) the construction of new facilities; (3) the acquisition or sale of major assets; (4) agreements between affiliated interests; and, possibly (5) the execution of power purchase contracts with private generating companies. Such regulation can help ensure the continued financial viability of a utility and also help ensure that significant management decisions are made prudently. For example, when a utility wants to construct a new facility, the regulator can condition the construction of the facility on the utility's receipt of a "certificate of need." Before the facility may be constructed,

the utility must prove to the Regulatory Agency that the particular facility is necessary. In this way, the regulator, the public, and the regulated utility are reasonably certain that a particular facility is needed and that resources will not be wasted.

This type of command and control regulation complements and perhaps provides an alternative to rate regulation. For example, suppose the regulated distribution company in our paradigm must decide whether to purchase additional supplies of electric power and if so, from whom and at what price. The utility can make a decision on its own and hope that it can prove to the Regulatory Agency in a subsequent rate hearing that its decision was prudent and that rate recovery should be allowed. If, however, preapproval of the contract is required under the Agency's command and control regulation, the utility would know that its decision is a prudent one and that it will be allowed to recover its purchase through rates <u>before</u> the contract is entered into.

These different methods of regulated utility decisions raise the question of which method the Regulatory Agency should adopt. This is a difficult decision for the Agency, as it requires the Agency to balance competing policies. A command and control preapproval approach creates less risk to the parties and might make utility financing activities easier to manage and less expensive. Of course, such regulation requires greater involvement by the Regulatory Agency in the management decisions of the utility, requires greater Agency resources, and is more time consuming. Conversely, using after-the-fact rate regulation increases the risks on all parties, including the regulated utility who might be precluded from recovering its costs, the

private, unregulated generator who might not be able to recover the full contract price from the regulated utility if costs are disallowed, and financial institutions who finance the private generators. In sum, after-the-fact rate regulation provides greater management flexibility, but results in increased and perhaps less-financable risks.

B. Regulation to Ensure the Coordinated, Reliable, and Adequate Supply of Electric Power

In our paradigm, the Regulatory Agency will regulate the transmission and distribution of electric power by the national transmission entity and the distribution companies. The Agency can ensure the coordinated, reliable, and adequate supply of electric power by monitoring transmission and distribution company planning and through rate regulation.

The Agency also can help establish and monitor the national grid and the power pooling and dispatch system. Regulation may be necessary to ensure the coordinated economic dispatch of generation and to provide pricing stability.

Finally, to the extent the government wants to integrate social programs such as rural electrification into the operation of the private power sector, it can require the Agency to collect information on transmission and distribution facilities' construction and pricing that will be important in developing a national energy strategy.

IV.

PROBLEMS IN THE PRIVATIZATION PROCESS

Part III discussed the role of the Regulatory Agency and some of the recurring problems and issues the Agency may face in fulfilling its role. Most of the problems discussed there, however, are common to many regulators in established, private power systems.

This Part IV will focus on several of the unique issues and problems facing regulators in countries that are in the process of changing from an unbundled, state-owned power sector to a privatized power sector.

A. Inability to Rely on Competition

Perhaps the most significant and most difficult problem facing the government and regulator in our privatization paradigm is the inability to immediately rely on competition in the generation of electric power or in the sale of power to large industrial or commercial customers. Put another way, some form of regulation will be required during the transitional phase until such time as "sufficient" competition exists to control the market. Thus, the Regulatory Agency will be required to regulate generation and large power purchases while at the same time promoting competition. The Agency (and the country) will go thorough a "transitional phase" in which the Agency will at first regulate the generation companies and large power sales and then gradually ease the regulatory burdens until competition develops.

This transitional phase raises an interesting issue: Who will decide when "sufficient" competition exists to ease the burden of or eliminate regulation? If this decision is left to the Regulatory Agency, will the Agency voluntarily relinquish its control? Moreover, will the Agency be able to "reregulate" these entities if competition proves to be ineffective?

These issues should be specifically addressed in the laws empowering the Agency. These issues of gradual deregulation and possible reregulation are similar to the issues faced by the Federal Communications Commission (FCC) in deregulating the provision of long-distance telecommunications services. The FCC is responsible, under statute, for regulating the rates and charges for interstate communication services provided by common carriers. In moving to a competitive long-distance environment, the FCC "detarrifed" the services of certain "nondominant" carriers, i.e., carriers that the FCC believed did not possess monopoly power. Thus, dominant carriers were subject to greater regulation than nondominant carriers. The FCC's deregulation policy, however, was struck down by a federal court, which held that the FCC was without the statutory authority to detariff the services of any common carrier, even if a carrier was nondominant. Applying this case by analogy, the Regulatory Agency must be given the express power to deregulate regulated services and entities as circumstances warrant, as well as the power to reregulate should competition prove ineffective.

B. Phase-Out of Cross-Subsidization

As discussed earlier, there likely will be a phase-out of preexsiting cross-subsidization of electric service. Such a phase-out likely will be opposed by consumers receiving the subsidies and their elected politicians. The Regulatory Agency must be able to control this opposition and must remain shielded from political pressures.

This particular problem raises the issue of public participation in the Regulatory Agency's hearings. For example, if the Agency is addressing the issue of reducing cross-subsidization in a rate hearing, and if public participation in that hearing is permitted, the Agency might be unduly influenced and the hearing likely will last much longer and require greater Agency resources. Moreover, any decision might be unreasonably delayed. These events might erode investor confidence in the regulatory system and create unfinancable risks for capital improvements. At least during the early stages of privatization, the governing body or Regulatory Agency might want to limit public participation in hearings. This could be done by the legislature by enacting appropriate statutes or by the Agency itself thorough promulgation of rules governing Agency proceedings.

C. Miscellaneous Issues

There are, or course, many other problems that likely will develop during this transitional phase that the Regulatory Agency must be prepared for and must solve. For example, during the privatization process, as state-owned entities convert to private ownership, there may be

"downsizing," i.e., layoffs, which might result in strikes. The Regulatory Agency (and the government) should be prepared for this event. Moreover, the sale of major assets to private companies during this transition phase must be financable. The private investors and financing entities will want some assurances that the Regulatory Agency and the government is committed to establishing a private power sector and that the risks associated with such investments are reasonable.

The Regulatory Agency thus plays an important role -- especially in the early stages of privatization -- of ensuring that risks are financable and of creating an atmosphere that encourages investment in the power sector.

V.

LAWS REQUIRED TO CREATE & EMPOWER REGULATORY AGENCY

Having discussed the role of the Regulatory Agency and the problems it will face in regulating a privatized power sector, this paper will now discuss the laws required to create and empower the Regulatory Agency so that it may fulfill its role and solve the problems it will face.[4]

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[4] This paper does not discuss all the laws that may be required to effectuate an entire privatization program. For example, some countries' constitutions may prohibit the transfer of state-owned property to private companies. The constitutions in such countries must, of course, be amended to permit the transfer of state-owned generation, transmission, and distribution facilities to private companies.

A. Laws Creating the Regulatory Agency

1. The National Constitution

Because the Regulatory Agency will be performing judicial, legislative, and executive functions, the country's national constitution must be reviewed to determine whether the national government has the constitutional authority to delegate or vest the power for such functions in an independent agency. If not, the constitution must be amended.

Alternatively, the constitution could be amended to expressly provide for the creation of the Regulatory Agency, rather than merely granting the legislature the power to create one. In the United States, for example, although there are no federal constitutional provisions governing the creation of any specific agency, many state constitutions contain such provisions. If the Regulatory Agency is a creature of the constitution rather than the legislature, it might be more autonomous and less susceptible to political pressure.

2. Statutes

Regardless of whether the Regulatory Agency is a creature of the constitution or a creature of the legislature, it is likely that some statutes will be enacted to govern at least some aspects of the creation of the Regulatory Agency, such as:

- The number and qualification of the commissioners.
- Whether the commissioners will be elected or appointed, and by whom.
- The length of each commissioner's term, and whether a commissioner may be reappointed.

- Whether the decisions of the Regulatory Agency will be appealable, and, if so, to whom or to what court.

Existing statutes must, of course, be reviewed and either amended or abrogated where they conflict with those creating, affecting, or empowering the Agency.

B. Laws Empowering the Regulatory Agency

Perhaps the most important laws, and the laws that will be most frequently invoked, are those granting specific powers to the Agency or those imposing specific requirements upon the regulated utilities (i.e., those laws enabling the Agency to regulate rates or engage in "command and control" regulation). These laws are necessarily a function of what the Regulatory Agency will regulate and the relationship between the Agency and the regulated utility.

1. Laws Relating to Rate Regulation

As discussed, part of the role of the regulator will be to regulate the rates for monopoly services. Thus, laws must be enacted which will enable the Agency to perform this function. The most important laws are summarized below:

- An Administrative Procedures Act or similar act regulating the Agency's rate regulation hearings. Such an act could provide interested parties with notice of hearings and an opportunity to be heard.

- Laws governing the standards by which the Regulatory Agency must decide various rate issues, such as the "prudency" standard for the construction of new facilities, or a "reasonableness, non-

confiscatory" standard when determining a regulated utility's revenue requirements.

2. Laws Relating to Command and Control Regulation

The Regulatory Agency must, of course, possess the power to engage in command and control regulation. The Agency's enabling legislation should grant the Agency the power to issue certificates to the regulated distribution companies and to revoke such certificates should a company fail to fulfill its obligations. Other laws necessary for the utility to exercise its command and control regulation include the following:

- Laws governing a utility's issuance of securities.
- Laws requiring a certificate of public need for the construction of new facilities or the acquisition or sale of major assets.
- Laws prohibiting agreements between utilities and their affiliated interests unless Agency approval is first obtained.
- Laws or enabling legislation requiring or permitting the Regulatory Agency to pre-approve power purchase contracts between regulated utilities and private generating companies.

3. Laws Relating to Information Flow

One of the most important resources the Regulatory Agency will rely on in performing its duties is, quite simply, information -- information about a utility's construction projects, financing, affiliated transaction, profits, planning methods, rate design, and so on.

Laws must be enacted to ensure that the Regulatory Agency has access to such information and to ensure a flow of information from the utility to the regulator. Such laws include:

- Enabling legislation authorizing the Regulatory Agency to promulgate rules requiring information to be provided. The rules promulgated by the Agency should explicitly identify the information required form the utility when approval of actions or cost recovery is sought from the Agency.

- Laws requiring the regular reporting of general financial information, such as annual reports to shareholders (e.g., SEC 10-K reports), and regulatory agency annual filings (e.g., FERC filings).

4. Laws Must Provide Flexibility

Finally, all the laws discussed here must be flexible to accommodate changing circumstances during the privatization process. For example, as discussed previously, at least during the early stages of privatization the governing body or Regulatory Agency might want to limit public participation in hearings. Thus, the laws governing Regulatory Agency hearings must provide the Agency with flexibility to change the procedures governing the hearing process. Similarly, the laws empowering the Agency must be flexible so that the Agency can respond to the development of competition. The Agency should be given the express power to deregulate regulated services and entities as circumstances warrant, as well as the power to reregulate should competition prove ineffective.

IEA Second International Conference on the Clean and Efficient Use of Coal and Lignite: Its Role in Energy, Environment and Life

30 November - 3 December 1993

Finance Alternatives

"Financing Coal and Lignite Development and Electricity Projects - A Perspective of the Export-Import Bank of Japan -"

Masahiko Agata, Special Advisor to the Governor

The Export-Import Bank of Japan

Abstract:

Private-sector financial communities, particularly the Japanese commercial banks and institutional investors, are staying cautious and selective in their approach to lending opportunities overseas. Meanwhile, the Export-Import Bank of Japan, a Japanese governmental institution, is playing a catalytic role to encourage the country's private-sector capital outflows, and offering various types of loans, not only in support of Japanese exports but also for development of essential natural resources overseas for importing them to Japan, Japanese direct investments overseas, etc. Particularly, its untied loans for economic development projects and structural adjustment policies of developing countries, under the "'Funds for Development' Initiative" of the Japanese government, will be noteworthy. The Bank, with general concern about energy worldwide and, hence, experiences of financing coal and lignite development and electricity projects as well, will be contributing further to these sectors, by extending loans itself and by mobilizing private sources.

Now that issues of environmental protection require increased attention of the Bank, it is dealing with them on a number of different levels; *i.e.*, macro-economic level, project selection level, and on a non-operational level which is to advocate to Japanese companies their contribution to the project countries' environmental protection, while being determined to foster sustainable development of the world economy. However, it believes that the primary responsibility for environment protection lies on the government and the people of the country concerned, and hopes that every effort will be made by them to ensure public acceptance of the projects to which the Bank and other foreign lenders consider finance.

Finance Alternatives for Coal, Lignite and Electricity Development
Workshop A(1) Financing

Financing Coal and Lignite Development and Electricity Projects - A Perspective of the Export-Import Bank of Japan -

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2 December 1993

I The Export-Import Bank of Japan

1-1 From familiarity with other similarly named institutions many people might imagine that the Export-Import Bank of Japan ("JEXIM") is just another export credit agency offering services only for Japanese export; *e.g.*, financing coal-fired thermal electricity stations, in the context of this conference. That is not quite correct. The share of export credit has fallen to around 15% of the Bank's entire annual activities recently, and other areas of function have grown dramatically. Those functions, described in 1-3 below, are all active, making the Bank truly multi-functional.

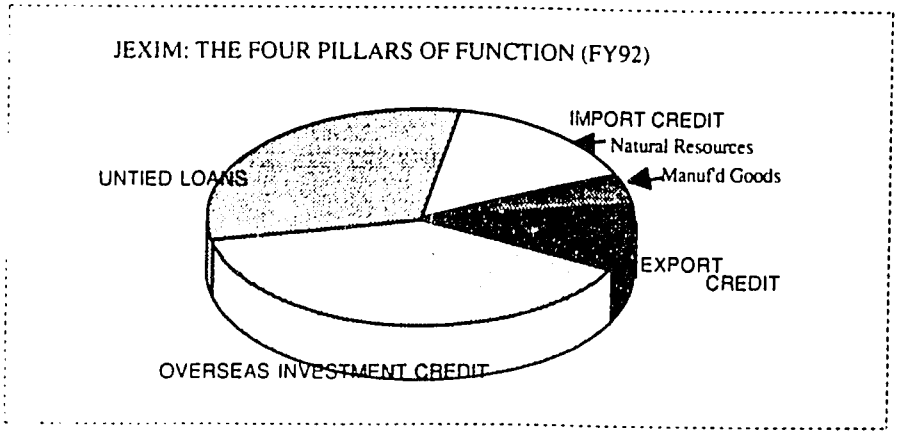
1-2 Using these various financing modes JEXIM has made at least US$5 billion-worth of credit commitments since FY1983, for the development of coal and lignite and construction of coal- and lignite-fired thermal power stations outside Japan (further details in 1-4-2). With regard to coal, the above counts only steaming coal and lignite, although there have been a number of additional cases of financing coking coal development.

1-3 In dealing with those projects, the Bank applies such diverse financing facilities, medium- and long-term in principle, as follows.

1-3-1 [Export Credit] Financing for export of capital goods and services from Japan. This operates strictly in accordance with the Consensus on Guidelines for Officially-supported Export Credit ("the Consensus") adopted at the OECD. The Consensus requires official export credit to observe minimum interest rates, maximum length of credit maturity, minimum cash payment, and maximum local cost financing, etc.. The Japanese export credit system allows a highly generous inclusion of third-country costs in a Japanese prime-contracted export package. This feature, together with JEXIM's cooperation agreements with other national export credit agencies like the EXIM Banks of the U.S. and Korea, Mediocredito Centrale of Italy, Swedish Export

Credit Corporation (SEK), and the Export Finance and Insurance Corporation of Australia, is intended to promote multinational collaboration in exporting to third-country markets.

[Graph-1]



1-3-2-1 [Import Credit - for Essential Natural Resources] A typical case of this is one in which a Japanese importer of a natural resource (*e.g.*, steaming coal) enters into an agreement with an overseas mine-owner to purchase the material on a long-term basis, the same importer agrees to provide a loan to the mine-owner so that the mine can be developed and produce the supply for Japan. JEXIM provides a loan to refinance such importer's loan. In this type of operation, the loans aim at securing a stable long-term supply of essential resources (energy, ferrous- and non-ferrous metals, timber, etc.) needed for economic activities in Japan, but not at exporting Japanese goods and services to the project. The Bank can also directly lend to foreign bodies subject to its satisfaction about the credit standing of the borrower.

1-3-2-2 [Import Credit - for Manufactured Goods] This program was launched in 1983 as part of the policy framework of the Japanese government to adjust Japan's balance of payments, making the economy more harmonious with the international environment. The facility, available to both importers in Japan and foreign corporations exporting to Japan, offers specially preferred rates of interest in view of its policy priority. "Manufactured goods" in this instance are defined as items listed in Items 5 through 8 in the U.N. SITC.

1-3-3 [Overseas Investment Credit] This is finance to support overseas direct investment by Japanese corporations. A typical case is the Bank providing a loan to refinance a Japanese corporation's equity investment and/or a shareholder's loan. The Bank is also empowered to

lend directly to foreign corporations which have Japanese equity therein, and to take equity in the Bank's own name as well. The facility is available for manufacturing and various other business activities overseas (including natural resources development and R & D) provided that they are productive, financially sound, and socially accepted by the local economy. The Bank attaches a special significance to supporting overseas direct investments since they help deploy private initiatives and foster industrialization of the host countries without causing additional external public debts. The Bank's loan proceeds can be used for procurements from sources of any nationality.

1-3-4-1 [Untied Loans] The term "untied" means that the loan proceeds have no strings attached requiring export of goods and services from the loan-provider's country. However, for untied loans provided by official agencies, it is common to strictly specify the purposes of such loans; *e.g.*, certain projects and/or clearly-defined economic policy packages. JEXIM's untied loans were long restricted to those borrowed only by foreign governments and their parastatal entities, until the Bank's statute was amended in 1989. Now legally it can extend untied loans to the private sector, and the Bank is studying prospective criteria for dealing with foreign private borrowers.

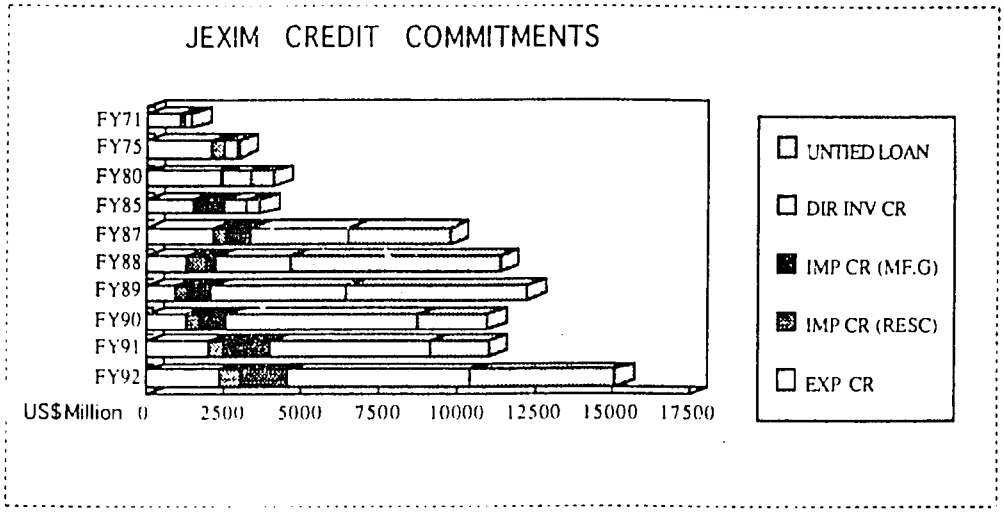
1-3-4-2 The Bank's full-fledged untied loan operations began in 1987 when it assumed the responsibility to provide them mainly to developing countries, in the magnitude of $9 billion (later increased to $23.5 billion) during the five years of 1987 through 1992 under the "Fund Recycling Program" of the Japanese government. For various priority projects and structural adjustment policies of developing countries, many of which were then tackling external debt problems, it eventually reached an aggregate of $23.7 billion in making untied loans and purchasing public bonds (issued on the Tokyo yen private bonds market) by the end of the program period, end-June 1992. In the course of these operations, the Bank participated in the so-called "Brady Initiative" actions for several countries, and very frequently co-financed with multilateral agencies like the IBRD, IMF, Asian Development Bank, and Inter-American Development Bank. The most characteristic feature in operating this facility is the principle of international competitive bidding in the cases of loans for certain projects. This is needed to maintain impartiality and transparency for truly untied loans.

1-3-4-3 Having completed the first five-year program successfully, the government of Japan embarked on another similar program. This new five-year program, announced and launched in June 1993 under the name of "'Funds for Development' Initiative", has an overall size of $120

billion. Within this $120 billion framework of the government, JEXIM was assigned to handle $35 billion, a simple annual average being $7 billion, equivalent to some 40% of the Bank's entire annual operation. In the program, two specific areas of emphasis are prescribed, one of which is "infrastructure projects" while the other is "environment-related investments." With this new task in mind, the Bank decided to introduce the new approach of offering guaranty to loans which are funded entirely by private sources so that private financiers in Japan can more actively provide loans without fear of country risks.

1-4-1 Throughout these credit operations, historical commitment of which is shown in Graph-2 below, the Bank has consistently considered it quite important to direct its resources to energy-related issues.

[Graph-2]



1-4-2 To depict a part of its energy-related loans, during the FY1983 - 93[1], loans for developments of steaming coal aggregated approximately US$1 billion, lignite $100 million, and coal-fired[2] thermal electricity generation, $4.1 billion. With regard to electricity projects at large, at least $7.6 billion in JEXIM's export credit was granted worldwide (or $4.6 billion for Asian projects) in the ten years, and some $2.5 billion (worldwide, or $1.4 billion for Asia) of untied loans during the five years of the Fund Recycling Program.

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[1] FY1993 covers only April - August period.

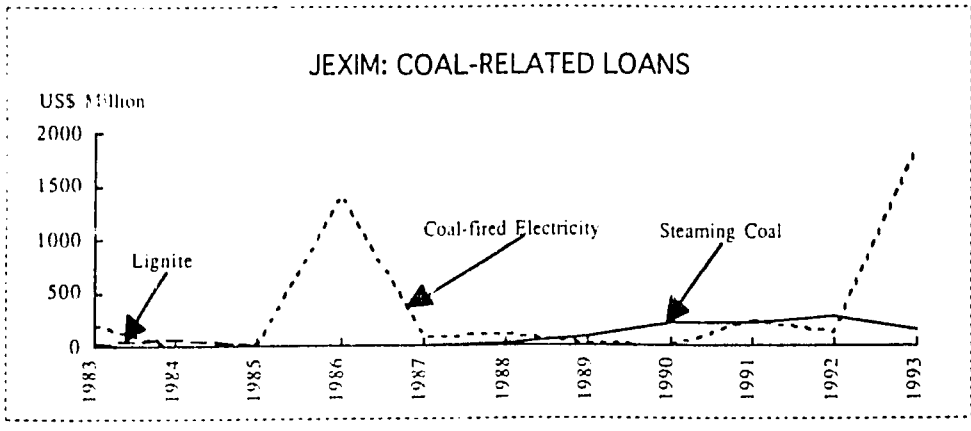
[2] Inclusive of lignite.

II Some Observations over the Bank's Record

2-1 [Grown Demands of Japanese Utilities for Steaming Coal]

Obviously, Japanese utility companies (all private) shifted their primary energy inputs from petroleum to LNG as well as coal, which is reflected in the number of cases of developing and term-contracting steaming coal overseas. The Bank's record also reflects it with increasing new loan commitments since the late 1980s (see Graph-3).

[Graph-3]



2-2 [Energy Demand in Developing Countries]

There has been a surge in electricity demand reflecting the economic growth in developing countries. A typical example is the Philippines where an acute shortage of electricity has prevailed. Those countries have energy development as a top priority area, and they appear to take a strong interest in natural gas-based combined-cycle power plants and/or coal-fired plants. Among the latter, indigenous lignite, where available, has become more popular in the early 1980s than several years before, presumably in the light of technological advancement in dealing with relatively low calorie fuels and environmental control. The Bank's loans for projects to develop lignite for local electricity generation were directed to Turkey as well as to such other countries as Indonesia and the Philippines. China has been actively utilizing the Bank's loans for coal development, both for export to Japan and for its own consumption.

2-3 [Privatization and Finance Availability]

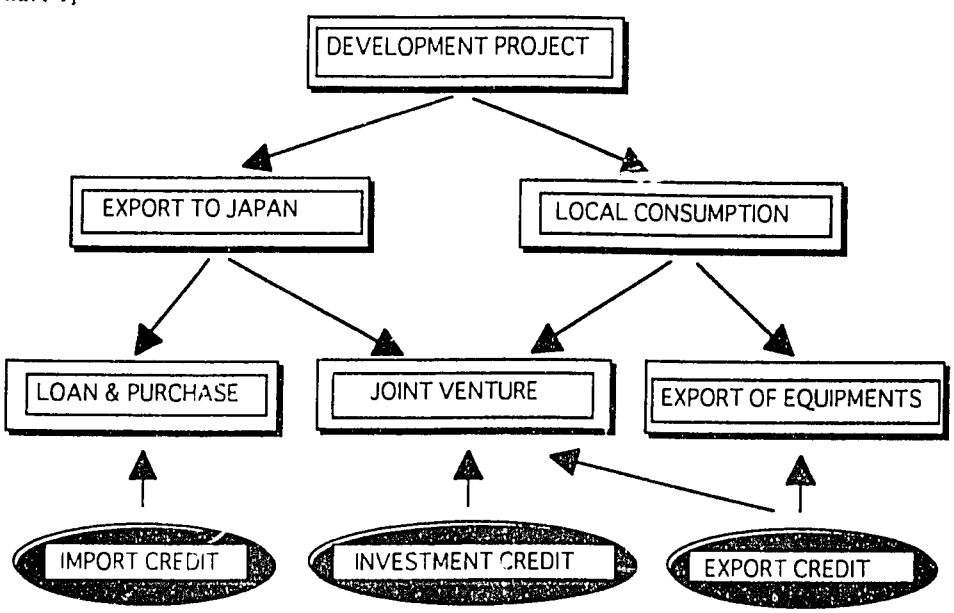
The local authorities, having persistent fiscal deficits and difficulties in incurring external public debts to back those expenditures, now have to prioritize projects more carefully. Additionally, the "efficiency factor" is an incentive to consider privatization. Thus prevailed the tide of

privatization and the "Build-Operate-Transfer," or "BOT," scheme. While it appears that the term "BOT" is talked more loudly than the actual number of cases which have proved successful, the shift of infrastructure projects to the hand of the private sector is an undeniable trend that urges financiers, both local and foreign, to adopt a substantially different approach toward those projects. At present, however, commercial banks and other private financiers are extremely cautious and selective about loans they make. There are some lenders who are more positive than others on overseas loans. Such differentiation among the lenders will be even more acute in their attitude toward privatized infrastructure projects, particularly BOT projects. JEXIM has made one precedent of making a loan to a BOT- structured power project in the Philippines, the Pagbilao coal-fired power plant; however, the project was somewhat exceptional for it involved such multilateral agencies as the IFC, the Asian Development Bank, and the bilateral official agencies like the CDC of the U.K. and the EXIM Bank of the U.S., enabling all these financiers to share costs and risks.

III Some Examples of Applying JEXIM Facilities to Coal-Related Projects

3-1-1 For Development of Coal (Lignite)

[Chart-1]

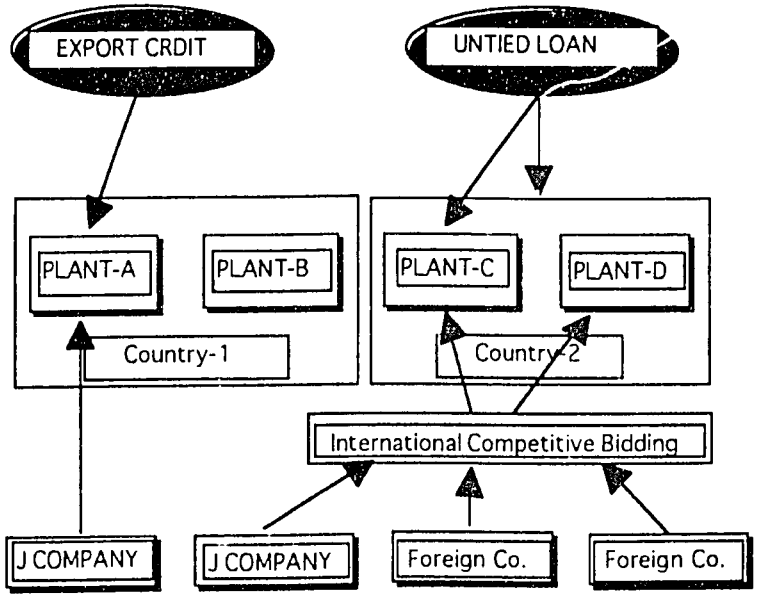


In Chart-1 above, "Local Consumption" can be read also as "Export to Third Country Markets", and "Joint Venture" as a "100% Japanese-owned Foreign Company."

3-1-2 As part of supporting direct investment overseas, the Bank was empowered in 1989 to make equity investment in its own name. The first case of such investment was realized in March 1993, when the Bank decided to take a 10% equity share in the Los Angeles Export Terminal project. The project increases the steaming coal-handling capacity of the Port of Los Angeles, strengthening the Coal Chain between the western states of the U.S. and Japan as well as other western Pacific countries.

3-2 For Construction of Power Plants

[Chart-2]



3-3 For Environmental Protection

JEXIM has created the Global Environment Office within the organization and adopted internal environmental guidelines for assessment and control of the environmental impacts of the Bank-financed projects, and it has also been approaching the problem directly by providing untied loans for pollution control, like the National Industrial Pollution Control Project of Brazil. The Brazilian project, for example, includes such investments as air and water pollution control and waste treatment facilities. The loan, signed in September 1992, was extended to Banco Nacional de Desenvolvimento Economico e Social for relending to Brazilian private companies which make such investments.

IV Conclusion - A View on Environmental Issues

4-1 JEXIM, providing international financing for export, import, overseas direct investment, and economic development of other countries recognizes the significance of the environmental issue and is determined to foster sustainable development of the world economy. It deals with this issue on a number of different levels; *i.e.*, macro-economic level, project selection level, and on a non-operational level which is to advocate to Japanese corporations their contribution to the project countries' environmental protection. The Bank receives visits and letters from various people concerned about the safety and environmental impact of the Bank-related projects and the welfare of local people (all included in "environmental issues" in a broad definition).

4-2 As a bank, JEXIM has every right to select projects which are assured of bankability from the economic, technical, commercial, financial and social points of view. At the same time, as a governmental bank of Japan, it faces two rather contradictory challenges; *i.e.*, on the one hand, its official character requires the Bank to be acutely conscious of the risk of intervening with other countries' sovereignty, and, on the other, observers tend to expect it to use its influence on the foreign government to which private citizen has little effective access for appeal. These characteristics often put the Bank in an extremely difficult and complicated position, especially in dealing with issues related to environment. JEXIM firmly believes that the political and social aspects of each project must be fully taken care of by the local authority themselves. The local governments should always take sufficient steps, properly with enough transparency and at the earliest possible stage, so that each project will have obtained true public acceptance by the time a loan request is made to foreign institutions like JEXIM. Otherwise, JEXIM must, as it has in the past, withhold its commitment until all controversies are confirmed to have been cleared. JEXIM, as a financier, is one who helps projects but not one who creates a project.

□□□□

Annexed: "Access by Non-Japanese Corporations to JEXIM Facilities"

ACCESS BY NON-JAPANESE CORPORATIONS TO JEXIM FACILITIES

I THROUGH COLLABORATIVE EXPORT TO THIRD COUNTRIES (J-EXIM'S EXPORT CREDIT)

The Japanese official export credit system offers probably the most generous treatment of non-Japanese costs included in Japan's export contracts. As much as 70% of the value of a contract awarded to Japan, may be procured from non-Japanese sources worldwide (subject to certain conditions), whilst up to a maximum of 85% cover is available from J-EXIM (credit) and MITI (insurance).

[Minimum Requirements for Non-Japanese Costs' Eligibility]

1. A Japanese company must be the "*main contractor*" responsible for the entire scope of the contract, under which non-Japanese companies can be "*subcontractors*."*
   - The Japanese export credit system can support only those contracts which are deemed to be "**export from Japan**."

   * Conversely, if a case is so interpreted that the Japanese supplies are destined not for the final buying country but for an intermediary country (a *relaying country*), the credit terms applicable will be those for the relaying country instead of the final destination.

2. The Japanese main contractor supplies the nucleus under the contract (re: above 1.).

3. A "Re-export Insurance Policy" is written by MITI for the non-Japanese components.

II THROUGH EXPORT OF MANUFACTURED GOODS TO JAPAN (J-EXIM's IMPORT LOAN FOR MANUFACTURED GOODS)

In 1983 J-EXIM launched a new facility in conjunction with the government's policy to promote Japan's import of manufactured goods. This special promotional-interest rate medium-term loan facility is made available to both importers in Japan (foreign-owned companies inclusive) and foreign exporters who cause Japan's import of manufactured goods, including virtually all manufactured goods except foods, arms and conspicuously luxurious items. The facility can be arranged either for single trade transactions or, if used by an importer, to establish a line of credit for future multiple transactions.

III FOR ICB-BASED PROJECTS (J-EXIM'S UNTIED LOANS)

To certain countries (typically, developing countries and Eastern Europe), J-EXIM is providing loans which are <u>not tied</u> to Japanese goods and services but made for purposes strictly selected by J-EXIM (and occasionally in

conjunction with multilateral development financiers) as being specifically conducive to the restructuring the economies of the recipient countries. Those loans, being "untied", can be used by contractors of any nation provided tht they are awarded with eligible contracts through international competitive biddings (ICBs) in accordance with relevant loan agreements.

[Project Initiation/Preparation]

Each project is initiated and prepared by and at the responsibility of the loan-recipient-to-be. An engineering consultant may be employed in the preparatory stage; however, whether the consultant thus employed continues to act as the project implementation consultant is subject to ICB (see below).

[International Competitive Bidding]

1. It is to be held after J-EXIM's relevant untied loan has been signed.

2. Each tender invitation is to be publicized by the loan-user in at least one local newspaper of general circulation. It is recommended to loan-users to advertise it also in the "*Development Business*" published by the United Nations.

3. The ICBs are conducted in accordance with the "Procurement Guidelines" provided to and made conditional by J-EXIM under the loan agreement. The Guideline's contents are generally similar to those of the World Bank's.

4. Information on prospective untied loans is not available to the public of any nationality. However, as for the loans already committed, information is available from some mass media publications and also from J-EXIM offices upon specific request.

□□□□□

IEA Second International Conference on the Clean and Efficient Use of Coal and Lignite: Its Role in Energy, Environment and Life

30 November - 3 December 1993

Processes for Encouraging Investment and Technology Cooperation in the Electric Power Industry

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Edison Electric Institute

Electric utility companies in the United States have a long and successful tradition of providing technical assistance to their counterparts. For more than six decades, the managerial staff of U.S. electric utility companies have systematically shared data, analytical methods, and experience to improve their power system engineering activities. In addition, since the earliest years of interconnected operations, electric utilities have provided mutual assistance in their day-to-day operations both to maintain reliability under emergency conditions and to share in economic benefits whenever possible. This paper discusses processes for extending this type of assistance to electricity suppliers and users in other nations.

Mutual Interests and Mutual Benefits

The first premise of this paper is that transnational technology transfer and technology cooperation are most likely to take place between organizations when there are mutual interests to be served and when there are mutual benefits to be gained.

On a world-wide basis, the professionals in the electric power industry share a mutual interest in choosing the best available energy resources and technologies to supply electric power which is reliable, reasonably priced, and environmentally-beneficial. There is also a mutual interest from the "demand side," that is, in assuring that industrial, residential, and commercial customers are given assistance in effectively and efficiently using electricity to meet their needs.

In a larger sense, the mutual interests of professionals in the electric power industry transcend the objectives of optimizing supply-side and demand-side operations. With geopolitical, humanitarian, and business factors in mind, industry leaders have become increasing concerned with the need for "sustainable growth", the development of international environmental policies, and the movement toward truly global markets. In each case, it is possible to identify mutual interests and mutual benefits.

Unfortunately, the inference sometimes associated with the term "sustainable growth" is that adequate environmental protection can only be achieved through stopping or delaying further energy development. This is misleading for a number of reasons. First, growth requires more than environmental protection. The survival of people who are starving, freezing or without adequate medical care obviously requires actions beyond those required to preserve the natural environment. Specifically, to meet the survival needs of people in developing countries and in some of the "economies in transition," as well as to improve the quality of peoples' lives, it will be necessary to take actions to provide reliable and economic energy supplies. These actions can be accomplished within a process of technology transfer and technology cooperation.

Moreover, it is important to recognize that it is not necessary to choose between environmental protection and additional energy development. These two objectives can be accomplished simultaneously, through an integrated approach, by making intelligent decisions about the alternatives for energy development and use. It is now being more widely recognized that increasingly using energy in the form of electricity provides a means for maintaining the quality of the natural environment and for promoting economic growth. This becomes apparent when one considers that many materials, including naturally renewing materials, may be used as resources for electricity production, and in many applications, modern electrotechnologies powered by electricity generated at central stations are more efficient than processes powered by the direct burning of fossil fuels.

All nations can benefit from developing rational international environmental policies. For example, to effectively address concerns about ozone depletion and climate change, it will be necessary to develop environmental public policies in international forums using cooperative and collaborative approaches. It is in our mutual interests that international environmental and energy policies are based on the best possible data, accurate scientific models, and pragmatic assessments of alternatives. This will require a very high level of focused technological cooperation. Electric utility organizations have begun to work more closely together in these areas.

It is now widely recognized that equipment markets are becoming "globalized" and engineers around the world are, of necessity, conforming to international standards. The mutual interests in this area are to assure that equipment will be available at a reasonable price, and to the extent possible, to make this equipment compatible with all systems. This is of critical importance both to equipment suppliers and to equipment users. Another consequence of the globalization of equipment markets is that engineers around the world are increasingly using more similar practices. This trend will result in developing more mechanisms for transnational information exchange and there will be increased justification for traveling to international conferences and developing information systems for collecting and disseminating data, experience reports, and solution techniques.

Many other examples and anecdotes could be provided to support the conclusion that the mutual benefits which can result from transnational technology cooperation in the electric power industry can be significant. However, establishing the existence of mutual interests and mutual benefits is a necessary condition, but not a sufficient condition, for technology transfer to occur.

Identification of Needs and Opportunities

The challenge in transnational technology transfer is not only

to assure that mutual interests are served, but also to clearly identify specific technology needs and associated opportunities for cooperation.

Technology needs vary greatly from region to region and, in some cases, even vary within single countries. Technology needs are influenced by a variety of factors including political systems, cultural traditions, educational levels, economic conditions, natural resource availability, the range of weather variation, existing environmental conditions, and other health and safety considerations.

In transnational discussions, needs are sometimes difficult to identify because a limited amount of time may be available and it is often necessary to exchange information through a process of translation. However, the success of technology transfer efforts critically depends on having a comprehensive and accurate understanding of the factors that determine technology needs.

Some information about technology needs can be collected through discussions with managerial personnel in conference rooms, but a much better understanding can be achieved through site inspection visits and direct contact with operations and maintenance personnel. Specifically, most countries can benefit from efforts to better maintain power plants, and from more advanced information systems or telecommunications systems to improve monitoring and control. The improvement of performance in electric power systems may be accomplished by having engineering experts spend several days at power plants and control centers to closely inspect operating practices and consult with local engineering and technical staff. Also, inspection teams may suggest new technologies such as "clean coal" technologies which offer significant promise for making environmental improvements and meeting increased power supply needs.

Once again, however, caution is needed in making generalizations about technology needs. These needs can be vastly different.

For example, in parts of the developing world and in some of the "economies in transition" technology recipients critically need information about engineering economics and the fundamentals of decision making in a market-economy. Conversely, in other countries, where these things are well understood or where privatization is not occuring, the primary need may not be for training but rather for equipment which can achieve improved environmental performance or increased energy efficiency through demand side electrification.

Efforts are needed to develop mechanisms to accomplish technology transfer in a way that not only is effective in meeting the actual needs of technology recipients, but also maximizes the opportunities available to technology donors. From the view point of technology donors some of the possible areas of opportunity include:

1. Opportunities to more efficiently use staff -- During periods when load growth is slow or construction programs are in a hiatus, staff may be productively put to work in transnational technology transfer activities. Recently retired engineers and executives may also see these activities as opportunities for second careers.

2. Opportunities to build staff expertise -- Transnational technology transfer activities can provide broadening opportunities for middle managers, and can provide basic technical traning for entry-level staff. In both cases, the opportunity to motivate staff through these activities may be equally as significant as the opportunity to provide training and development.

3. Opportunities to learn different techniques -- The most modern technologies are not always the best technologies. When technical staff from the more advanced countries study operations and maintenance techniques in less advanced countries they may discover different and more effective techniques which they can adopt.

4. Opportunities to invest in projects -- There are currently many opportunities to make financial investments in energy technologies in developing countries and economies in transition. The likelihood of receiving an acceptable return on these investments can be increased by being involved in associated technology transfer efforts.

5. Opportunities to support foreign policy objectives -- One of the most effective ways for U.S. industry to assist the U.S. government in implementing foreign policy objectives is through assisting in technology transfer efforts. Cooperative arrangements between the public and private sectors are essential for successful transnational energy assistance efforts.

Conclusion

This working paper discusses some of the considerations which should be taken into account in designing processes for technology transfer but certainly does not provide a complete or comprehensive discussion of the many factors that must be considered. Consideration must also be given to trade policies, the protection of intellectual property rights, and many other legal, financial, policy, and institutional issues.

U.S. electric utility companies have a great deal of experience and a network of expertise which can be employed in programs of technology transfer and technology cooperation. Additional efforts will be needed to develop or improve mechanisms for coordination between the U.S. electric utility industry and the U.S. government. These efforts will require identifying the proper tasks for industry and government, assuring that resources are available for these tasks, and overcoming institutional problems and barriers.

Effective needs assessment, as discussed earlier in this paper,

will require input from both the industry and government. Government has, or is able to assemble, detailed information on the availability of natural resources, possible political changes, variations in currency exchange rates, and related data. The electric utility industry is best equipped to undertake fact-finding efforts which identify cost-effective solutions to short-term problems and assess the technical expertise and training needs of technology recipients.

From the "technology donor side," industry associations can play an important role in making technology transfer efforts more effective. Industry associations have committee structures, information systems, and contacts with foreign electric utilities and governments which can expedite accessing expertise. The inefficiency of misdirected or duplicative efforts can be avoided if government contractors do not directly contact companies but rather ask industry associations to play a coordinating role in identifying technology donors.

Additional thought needs to be given to approaches taken for the funding of technology transfer efforts. Clearly both industry and government have an interest in increasing the export of U.S. products and services, and it is appropriate that the funding for trade missions and associated feasibility studies should be shared. However, the rationale for funding programs and activities which support humanitarian or diplomatic objectives is more difficult to formalize. Some U.S. electric utility companies have expressed a willingness to support certain of these programs and activities without reimbursement. However, in those instances where a company's management and/or regulatory body requires that the cost of such activities be reimbursed or cost-justified in the interest of the rate-payer, it will be necessary to find mechanisms for the recovery of expenses and/or labor costs through government contracts or grants.

Additional effort also needs to be directed toward overcoming impediments to technology transfer which may exist in government. There is a fundamental need to improve the coordination of technology transfer programs within government. Industry can assist government in identifying legal or regulatory impediments, and in designing ways to overcome these impediments.

ASSISTING FINANCABILITY THROUGH RATE STRUCTURE DESIGN

By: Dale M. Keith, CMC and Robert A. Bibb, PE

INTRODUCTION.

The World community is going through profound change. Gone are the days of "Business as Usual." Once familiar sources of capital are not as readily available today. Potentially billions of HK$dollars are needed for infrastructure improvement, and new capacity additions. Efficiency in the use of scarce and non-renewable resources, and environmentally benign methods and technologies are the order of the day.

To attract needed capital in this day and age for infrastructure improvement and construction of needed new capacity, profound changes are required in the ways governments, institutions and businesses have functioned in the recent past. Elimination of wasteful use must be a goal for all, and more effective methods of using the facilities and resources that we have must be implemented. Additionally, the tariffs -- or charges -- for equipment, resources and services must be set at least equal to -- or near -- total revenue requirements, or the costs of service, without substantial governmental subsidies. This is necessary to attract potential investors, and to bring lenders back to the market. They want to be assured that sufficient revenue streams will be available to pay the costs of operations, and the return of-and-on capital investment. If tariffs are not sufficient to recover total revenue requirements, or costs of service, investors and lenders will continue to be risk averse, and the massive quantities of needed capital will not be forthcoming.

So why are we addressing this issue at a conference on coal and lignite? We are addressing this issue because the ultimate price of energy should include the total costs so that all costs are recovered, including the total costs of coal and lignite delivered to power plant burners. By knowing that total costs are being recovered by tariff rates, including the costs of fuel delivered to burners, potential investors or lenders will perceive that an operating entity

-- such as an electric utility -- is assuming full responsibility for cost recovery; that the revenue will be there to pay for the costs; and that translates into less potential risk for investors and lenders. The logic extends to utility purchases from an Independent Power Producer (IPP) and/or cogeneration facilities. When investors, lenders and developers can see that the costs of output from their facility will be paid by ultimate consumers through the organization's tariff rates, then they will be less risk averse and will be more willing to move forward with project development.

REVENUE REQUIREMENTS - A DEFINITION.

Revenue requirements can be generally defined as the total costs of operations, for creating, transmitting and delivering a product or service to ultimate consumers, which can include operation and maintenance expenses, depreciation expense (return of capital), taxes or tax equivalents, and a fair return on investment, including a risk premium. Let's look at each of these components in more detail. In so doing, we will use a coal or lignite fired power plant as the example or model. Other models could be described, but a substantial user of coal or lignite serves the purpose.

Operation Expenses.

Operation expenses can include supervision and engineering, fuel, steam expenses, boiler feedwater makeup, electric expenses, steam power expenses, rents, and operation supplies and expenses. Operation expenses can also include the total costs of purchases of power and energy from another source, such as from an IPP or cogeneration unit. The majority of operating expenses tend to be variable as the facility is operated, and are therefore primarily a function of -- in the case of a power plant -- megawatt-hours generated. The majority of operating expenses for a power plant tend to be for fuel and purchased power and energy.

Maintenance Expenses.

Maintenance expenses can include maintenance supervision and engineering, maintenance of structures, boiler plant, electric plant and steam

production plant. Maintenance expenses are generally those costs that are required to keep existing plant in good operating order over its useful life, including preventive maintenance. They are the costs other than the costs of operating the facilities and the original capital investment required to design and build the facilities. Maintenance expenses can be incurred whether or not a facility is operated. The majority of maintenance expenses -- 50 to 70 percent -- tend to be fixed over the useful life of a facility.

Depreciation Expense.

Depreciation expense is a non-cash expense representing loss of useful life due to wear and tear not offset or replaced by routine and preventive maintenance. Although it is a non-cash expense, it is a cost to be recovered through tariff rates none-the-less, over the useful life of the asset. The purpose of depreciation expense is recovery of capital investment. An alternative to annual depreciation expense is annual debt service expense on outstanding debt.

Taxes, or Tax Equivalents.

Taxes are a cash expense to corporations and certain other legal entities, for the privilege of being in business, to have an opportunity to earn a profit. In the U. S., taxes are assessed by federal, state, and local governmental entities. For those systems which are owned and operated by governmental entities, contributions in lieu of taxes are made to the owning governmental General Fund.

Return On Investment (ROI).

Return on investment is an actual cost to be recovered by tariff rates, in addition to O&M expenses, Depreciation expense and Taxes or tax equivalents. The amount, or level, of ROI is usually expressed as a percentage of an investment base. The investment base can be negotiated, but usually includes at least net plant investment, which is gross plant investment less accumulated depreciation reserves. There are other ways to

determine ROI, but the main point to be made here is that ROI is a cost which must be recovered from ultimate consumers.

In the U.S the percentage ROI is usually a function of the weighted cost of capital, plus a risk premium. For a regulated investor owned utility -- or power plant -- the cost of capital usually consists 40 to 50 percent debt with a fixed or variable interest rate; 5 to 10 percent preferred stock with a fixed dividend payment; in some cases short term debt is included in the calculation; with the balance being common stock equity having a higher cost than either debt or preferred stock. (For IPP projects, the equity component is usually much lower than the debt component, allowing the developer and financiers to achieve lower total cost due to the lower cost debt component.) The risk component is a premium representing opportunity costs, compensating the developers and owners for giving up other potentially profitable opportunities to do something else with their money.

Additional Revenue Requirements.

In our example above we talk generally about the revenue requirements for a power plant. The theme repeats itself for bulk transmission facilities, distribution to ultimate consumers, and general plant including general office headquarters. Additional revenue requirements are a function of load dispatching, operating and maintaining substations, overhead and underground lines, and for distribution plant line transformers, service drops, meters, and street lighting and signal systems.

Other non-plant related revenue requirements are incurred at District and Regional offices, and General Office headquarters for Administrative and General salaries and wages, general engineering, legal, personnel and purchasing services, insurance (if any), customer service, fuel acquisition, accounting, meter reading and billing, and other general support functions which the organization must have to function on a day-to-day basis.

All of these cost components can make up the total revenue requirements to be recovered from ultimate consumers by tariff rates. Once the proper level

of tariff rates are in place, and investors and lenders are assured that revenue streams will be available to pay for all costs, they will be less risk averse and needed capital will be forthcoming. The same applies to recovery -- through tariff rates -- of purchase power and energy costs under power purchase/ sales agreements with IPP's and cogenerators. When those developers and financiers see that their costs will be recovered from ultimate consumers, they will be less risk averse also, and will move forward with providing needed capacity and energy, at very competitive prices. Less risk aversion means lower total costs, as a result of lower risk premium embedded in ROI, and lower total costs means lower tariff rates for ultimate consumers.

The details of defining and quantifying total revenue requirements are much more extensive than what has just been described. The main point is, however, that the proper **level** of tariff rates is to recover the total costs of service from ultimate consumers, without governmental subsidies. The ultimate price that consumers must pay for the service they receive should be close to the value of that service. Total cost may be the best proxy for value.

RATE STRUCTURE DESIGN.

Much debate has been going on for years throughout the World regarding whether tariff rates should be based on embedded costs, incremental costs, marginal costs, or be Market Based (i.e., "whatever the market will bear"). We won't get into philosophical discussions regarding the differences of these methods, but will generally describe instead basic structural matters regarding tariff rate design. The following focuses on an electric utility. The logic could apply to other services as well.

The most expensive service provided by an electric utility is service to Residential consumers, who are served from secondary distribution facilities. This is because more plant facilities are required to generate, transmit and distribute electric service to secondary Residential consumers than for any other consumers as a class. To compound that reality, the tariff rate price to low load factor Residential consumers should be higher than the price to high load factor consumers, if the tariff rates are to be based on

costs. It may cost slightly less to serve low load factor customers due to the diversity among their loads, but they provide fewer billing units over which to recover the costs, therefore the tariff rate price needs to be higher. This reality ignores any concepts dealing with social welfare in tariff rate design. Conversely, it may cost slightly more to serve high load factor customers due to less diversity among their loads, but they provide the more billing units over which to recover the costs. Therefore, the cost justified tariff rate price to them is slightly lower. Again, this reality ignores social ratemaking philosophies.

The second most expensive service provided by an electric utility is service to Small Commercial establishments who tend to also take their service from secondary distribution facilities. A cost based tariff rate price for them is very similar to that for Residential services. The same arguments regarding low load factor vs. high load factor, and high diversity vs. low diversity apply to this class of service as well.

The third most expensive service is to commercial and manufacturing establishments that take service from primary distribution facilities. They do not incur the costs of secondary distribution facilities, and the primary distribution system serves both primary and secondary distribution customers. Many people perceive that the tariff rate price for primary service should be higher than for secondary service, under a false perception that primary facilities cost more. This is not correct. Since the primary system serves both primary and secondary service customers, the costs of both primary and secondary facilities are embedded in the tariff rate prices for secondary service -- such as for service to Residential and small secondary Commercial customers -- and primary service customers do not use secondary facilities, then tariff rate prices to primary service customers are lower than for secondary service. The same arguments for low load factor vs. high diversity and high load factor vs. low diversity apply here also, if tariff rates are properly designed.

The least expensive service provided by an electric utility is to Large Industrial loads which take service directly from high voltage transmission systems, and provide their own transformation to utilization voltages. These

customers do not cause the utility to incur the incremental costs of additional transformation, sub-transmission, or primary and secondary distribution facilities. Again, many people perceive falsely that tariff rate prices to large industry should be higher than for (say) Residential service, based on what they see in the way of high voltage facilities serving large industrial loads. What they don't see is all of the incremental facilities required to get power and energy delivered to customers at lower voltage levels, over a large geographical area.

Tariff rate prices for high load factor Large Industrial loads are -- if properly designed -- lower than for lower load factor service for the same reasons described previously: low diversity among loads vs. high diversity, and more billing units over which to recover costs for high load factor service than for low load factor service.

Another driver which causes cost based tariff rate prices to be incrementally higher as power and energy is stepped down through the system from high voltage transmission facilities to secondary distribution is incremental capacity and energy losses, at each service voltage level. Capacity and energy losses are not the same. Capacity losses during periods of maximum loading conditions can be either the same as average energy losses, or can range from 1.2 to 2.0 times average energy losses. Capacity and energy losses can represent significant costs. This reality should be taken into consideration in properly designing tariff rates. Properly designing tariff rates to include incremental losses at each voltage level is critical to recovering all costs, especially the costs of fuel and purchases of power and energy from outside sources, such as an IPP or cogenerator.

CONCLUSION

If properly designed, cost based tariff rates recover all costs (i.e., Revenue Requirements) for generation (production), high voltage transmission, sub-transmission, primary distribution and secondary distribution, incrementally from customers connected at each voltage level within the system. The results are a set of cost based prices which reflect the cost

continuum from the power plant step-up substation bus bar, all the way down through the system to secondary voltage deliveries.

When investors, lenders, developers and other potentially effected parties can see that the organization has a set of cost based tariff rates in place, and that those rates are being properly administered; that revenue for services rendered are being collected, and that the financial health of the organization is not dependent on some form of governmental subsidy which cannot be assured, then they will know that the business is self supporting and is probably a good choice or candidate for investment in some form. Without cost based tariff rate pricing in place, however, the operation will continue to be viewed as risky, and outside parties will not be as willing to invest in the enterprise in any way, unless the risk premium they can expect from their involvement more than offsets the chances they are taking. Higher risk premiums translate into higher costs, so a best path to attracting third party investors and lenders may be to establish a pricing structure which recovers the costs of the system from those who use it and benefit from it.

IEA Second International Conference on the Clean and Efficient Use of Coal and Lignite: Its Role in Energy, Environment and Life

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Critical Issues In Power Project Financing

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Abstract: Private Power Projects provide significant opportunities, principally the expansion of the supply of electricity to meet increasing demand, and the opportunity to promote the environmentally and economically efficient consumption of abundant resources of local fossil fuel. However, the developer of a project will assume many significant risks. The risks include financial, political and regulatory risks. Fortunately, these risks are manageable. The Power Purchase Agreement is probably the most crucial part of a private power project, among other things, as it allocates the risks, defines the rights and obligations of the parties, and spells out the consequences of non-performance. Also, an Implementation Agreement between the project developer and the government may be necessary to induce private sector involvement. Finally, the experience of the independent power projects to date shows that the benefits clearly outweigh the risks.

Critical Issues in Power Project Financing

IEA Second International Conference On The Clean And Efficient Use Of Coal And Lignite: Its Role In Energy Environment And Life

I. Introduction

A. Private Power Projects Provide Unique Opportunities

B. Risks Can Be Great But Manageable

II. Risk Management Is Most Critical

A. Reluctance Of Lender To Take Commercial, Regulatory, Political Or Financial Risks

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VI. Conclusion

A. Risks Are Manageable

B. Rewards Are Bountiful

WORKSHOP A2

TECHNOLOGY OPTIONS: OVERVIEW

COAL TECHNOLOGY SELECTION METHODS AND TOOLS FOR NEW POWER GENERATION AND ENVIRONMENT/PERFORMANCE UPGRADING

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INTRODUCTION

Two worldwide needs are in apparent contradiction. One is the need to expand, through increased electrification, the industrial base and economic strength of all countries, particularly in the underdeveloped regions. The second is the need to maintain or improve environmental conditions, and to limit potentially harmful emissions from electric generating facilities and other industrial activities.

Ways to achieve both these priorities are the subject of this paper, which describes better and more efficient technologies for burning fossil fuels, particularly coal, in relatively environmentally benign ways and options for plant upgrading. In the United States great strides have been made in implementing clean coal technologies, many of which are now being demonstrated at commercial sizes by electric utilities. Further, new generating plants and upgraded older plants worldwide are increasingly likely to incorporate the latest designs in emissions control technologies, as well as thermal cycles and equipment that maximize plant efficiency. Additionally, plant upgrading, repowering, and refurbishment are frequently found to be very cost effective.

One factor that has emerged from the U.S. experience has profound implications for the future. The energy expended per unit of gross national product decreases as electricity assumes a greater fraction of overall energy usage. So electric power is a solution to, rather than a cause of, issues concurrent with increased economic development.

COAL-BASED POWER GENERATION AND THE ASIAN MARKET

Although the power generation capacity of Asian countries has expanded significantly in recent years, the installed capacity per capita in these countries (see Figure 1) tends to be an order of magnitude less than say the United States (where this value is 3000 MW/million people). However, added capacity plans in this part of the world are staggering. The markets in Asia and the Pacific Rim are expected to make up 45% of the world's orders for power generation equipment during the remainder of this decade. Table 1 shows that in these regions over 700 GW of installed capacity existed in 1992, but over 400 GW of new equipment (equivalent to almost 60% of this installed base) is expected to be on order by the end of the 1990s. These figures include orders for both new and replacement capacity.

Furthermore, it is forecast that the worldwide use of coal, which makes up 80% of the planet's fossil reserves, will double in the next 30 years. Figure 2 shows that for installation before the year 2000 some 160 GW of new coal-fired capacity is planned, committed, or under construction. Developments in selected countries in Asia are outlined below.

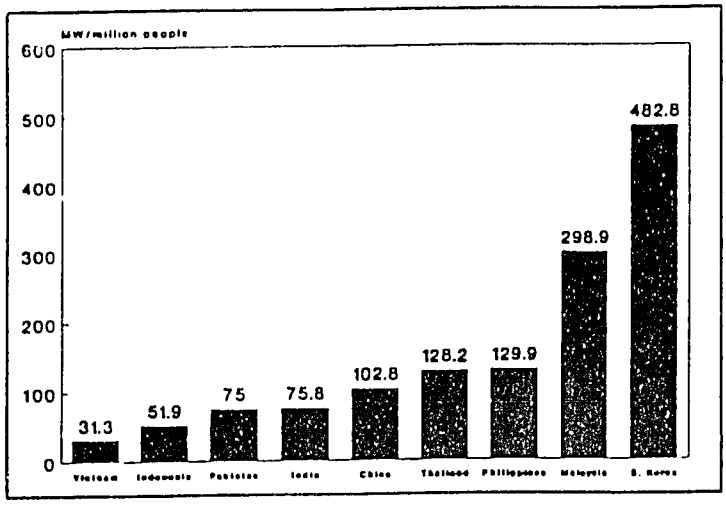

Figure 1. Many of these Asian countries have an installed capacity per capita one to two orders of magnitude less than that of the U.S. (Source: Power in Asia)

Table 1. Power Generating Equipment Order Forecasts (1)

Country/Area	1992 Installed Capacity (GW)	2000 Order Forecast (as percent installed capacity)
China	163	75-80
Japan	202	25-30
India/Bangladesh	76	50-55
Asia Pacific (w/o China)	166	70-75
Middle East/Central Asia	114	55-65

China

China currently has the largest expected MW growth in power generation in the world. Projections now show that China must add about 12-15 GW of capacity per year between now and the end of the decade to meet a planned installed capacity level of near 300 GW in the year 2000.

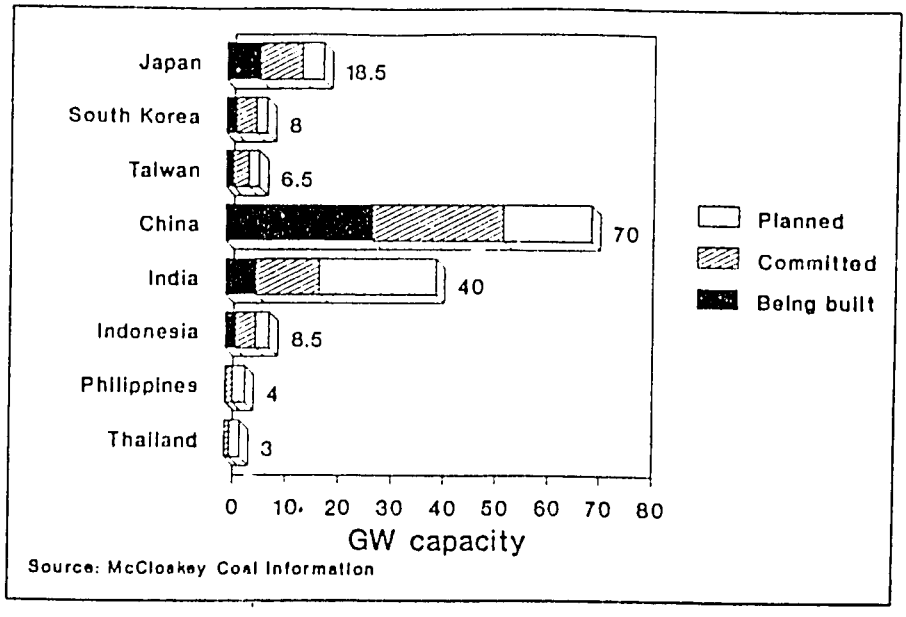

Figure 2. By the year 2000 about 160 GW of new coal-based power stations are planned, committed, or under construction in these Asian countries (2).

To meet this enormous addition in generating capability, China is expected to rely heavily on coal-based power generation. Current projections for the year 2000 show coal providing some 63% of China's installed capacity (and 72% of the kWh generated) with the remainder as follows: 30% hydro, 4% oil/gas, and 3% nuclear. EPRI recently participated in the U.S. Department of Energy-led electric power technology mission to China, which identified specific needs for performance and environmental upgrades of existing plants and opportunities for providing state-of-the-art clean coal technologies for new plants.

India

India's power system has an installed capacity of over 70 GW, with some 70% of its energy delivered from coal plants, 25% from hydro facilities, and 5% from gas, oil, and nuclear units. Some 35 GW of new capacity are expected to be installed by the year 2000. Most of this new capacity will utilize reserves of indigenous, low quality coal. This places India, along with countries such as China, Indonesia, Thailand, and Pakistan, in the very difficult situation of having to deal with severe environmental constraints and massive capital mobilization needs. The government of India is focussing on the following issues: rapid additions in generating capacity, an increase in private-sector participation, and aggressive life extension and performance upgrade programs for existing thermal steam plants.

Thailand

The current installed generating capacity in Thailand is almost 10 GW, including 5 GW of thermal, 2.4 GW hydro, 2.2 GW combustion turbine or combined cycle, and the rest diesel, wind, geothermal, and solar. Plans are to increase generating capacity by 12 GW over the next ten years. With very limited oil and gas reserves, added capacity is expected to come from indigenous lignite, imported bituminous coals, and possibly nuclear. Last year EPRI participated in the U.S. Department of Energy-led electric power technology mission to Thailand. Opportunities exist in Thailand for performance and environmental upgrades of existing plants and for providing clean coal technologies for new plants.

PRODUCTIVITY/PERFORMANCE UPGRADING OF EXISTING PLANTS

As fossil-steam units get older, degradations in availability and performance appear. Application of the latest advances in coal cleaning, performance optimization, heat rate improvement, boiler maintenance, plant diagnostics, materials, and repowering technology can enable many fossil plants to continue operation in a reliable and profitable manner. Some of these advances have been made possible by recent spectacular improvements in microprocessor technology.

Coal Cleaning

Precombustion coal cleaning provides the user with a low cost option for limited environmental control. Cleaning of coal to remove sulfur and ash is well established in the U.S. with more than 400 operating plants, mostly at the mine. Coal cleaning removes primarily pyritic sulfur (up to 70% SO_2 reduction is possible) and in the process increases the heating value of the coal, typically about 10% but occasionally 30% or higher (3). Additionally, if slagging is a limiting item, increased output may be possible, as at one station which increased generation from 730 to 779 MW (4).

The removal of organic sulfur, chemically part of the coal matrix, is more difficult, but may be possible using micro-organisms or through chemical methods. Research is underway in this area (5). For example, EPRI work has focused on perchloroethylene as a solvent to facilitate organic sulfur removal. Heavy metal trace elements can be removed also, conventional cleaning removing (typically) 30-80% of arsenic, mercury, lead, nickel, antimony, selenium, and chromium.

Coal Quality and Performance Optimization

In burning coal efficiently and economically, it is of prime importance to predict the effects of coal constituents on cost-related performance measures. In order for U.S. utilities to judge the impact of such decisions as coal cleaning, coal switching, scrubber additions, burner improvements, boiler tube replacements, pulverizer maintenance,

sootblower operation and so on, EPRI has produced the personal computer-based Coal Quality Impact Model (CQIM).

The CQIM is an excellent tool for determining the economics of power station operation, with or without coal cleaning, and with or without the addition of a flue gas desulfurization system. The CQIM tells a utility engineer or fuel purchaser what the quality of the coal does to heat rate, equipment reliability, maintenance needs, and the final cost of electricity.

Rapidly becoming indispensable for coal burning utilities (there are 184 users in the U.S. alone), it is available worldwide through EPRI's commercializer, Black and Veatch. Recently, it was used to study options for upgrading a Polish power station (6).

Heat Rate Improvement

Improvement of fossil plant heat rate is a major objective for most utilities. Four major reasons for improving heat rate are:

- Reduced Fuel Costs. Typically 70-80% of utility operating cost is for fuel. As more plants switch to low sulfur coal utilities will seek to minimize coal consumption as transportation costs increase.

- Increased Capacity. Improved efficiency can often be used to increase the MW output of the unit (for the same fuel input). Studies have shown a $1.8 billion advantage to U.S. utilities over 5 years if a one percentage point efficiency improvement can be applied in this way to baseload coal-fired power plants.

- Reduced Emissions. Plant emissions, including NO_x, SO_2, CO_2 and particulates are all reduced in proportion to heat rate as a consequence of burning less fuel per MW output.

- Reduced Cost of Emissions Control. Up to 40% of the cost of a new coal-fired unit is for environmental control equipment. As plant retrofits in this area continue, size (and hence cost) reductions can be realized by improved plant heat rate.

As an aid to improving heat rate, the on-line detection of deteriorating heat rate, called performance monitoring, is a rapidly growing technology in fossil plants. Since 1982, EPRI and Potomac Electric (PEPCo) have been developing and testing better instruments and sensors at the 575 MW Morgantown 2 unit. This coal-fired, supercritical unit is the site of one of the most advanced performance monitoring systems in the U.S.

One example of the work at Morgantown is the development of tools for boiler combustion optimization (7). Working with PEPCo, EPRI and its contractors

successfully introduced a boiler combustion optimization program called HEATRT. With this program and using both special instrumentation and standard sensors, utilities can tune boiler systems to improve efficiency and unit heat rate. To do so, utilities must have a means of methodically balancing many interdependent boiler parameters that govern unit performance. These include excess oxygen, coal fineness, unburned carbon, exit gas temperature, fan and pulverizer power, auxiliary steam, and reheat spray flows.

Reduced oxygen decreases SO_3 generation and may allow lower stack temperatures without increased pluggage or corrosion. Each temperature drop of 1°F in exit gas produces a heat rate saving of about 1 Btu/kWh. PEPCo estimates a possible reduction of 45°F, or 45 Btu/kWh in addition to a 15 Btu/kWh saving due to lower excess oxygen. The equipment covered by this computerized optimization procedure is shown in Figure 3. Once the set values of the parameters have been determined for a unit, an on-line performance monitor can track any perturbation of unit behavior.

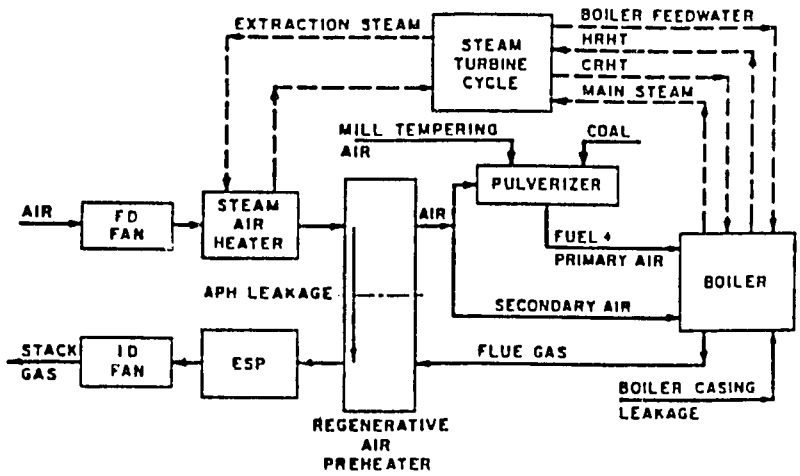

Figure 3. Fireside operating parameters are balanced for best performance using the EPRI boiler optimization program, HEATRT.

Boiler Maintenance

As with humans, ideas on plant aging mechanisms have changed over the years. Aging has been defined as accumulated wear due to the effects of creep, fatigue, erosion, and corrosion (8). A great deal is now known about the rate of aging that was not obvious in the 1950s and 1960s. For example, frequent starting and stopping of fossil units is much more punishing on plant equipment than constant steady-state, baseload operation. This includes not only the fairly obvious mechanical and thermal fatigue problems of material loading and unloading, but also the not-so-obvious effects of boiler tubing corrosion due to excessive infiltration of oxygen into the boiler water during downtime, or the increase of acid deposition in boiler back-end equipment at

part load operation. Of all failure mechanisms in coal-fired power plants, the most pervasive, and probably the most costly in terms of availability, are boiler tube failures.

EPRI has identified, and found solutions to 22 mechanisms of tube failure. In a recent project at several U.S. utilities, a determined attempt was made to reduce the unavailability caused by tube failures. Using EPRI prepared guidelines to reduce tube failures an average improvement in availability of about 2% was seen at the participating utilities. A total saving of more than $250 million has been identified and documented. If extended across the U.S. utility industry, an estimated benefit of more than $500 million per year is likely. Table 2 lists the leading causes of tube failures as seen by these twelve participating utilities.

Table 2. Leading Boiler Tube Failure Mechanisms

Rank	Mechanism
1	High-temperature creep
2	Flyash erosion
3	Short-term overheating
4	Sootblower erosion
5	Welding defects
6	Waterwall corrosion (fireside)
7	Corrosion fatigue
8	Falling slag
9	Thermal fatigue
10	Vibration

A computerized version of the guidelines, with nearly 200 copies now in use in the U.S., includes failure analyses, inspection and replacement techniques, and life estimation procedures. It is called the Boiler Maintenance Workstation (BMW). The BMW is one very successful example of a computer workstation which permits a utility to upgrade old plants. Recently, a group of U.S. utility users documented a saving of more than $200 million due to the use of the BMW.

Diagnostic Monitoring

Utilities will increasingly turn to a rapidly developing technology which permits older cycling units to operate without lengthy outages for major failures. This is on-line monitoring for mechanical diagnostics (9). As Figure 4 shows, work at EPRI in diagnostics covers all fossil plant equipment, the goal in most cases being to detect incipient damage in advance of major failure. If equipment damage can be handled by normal maintenance, the huge costs of a forced outage can be avoided.

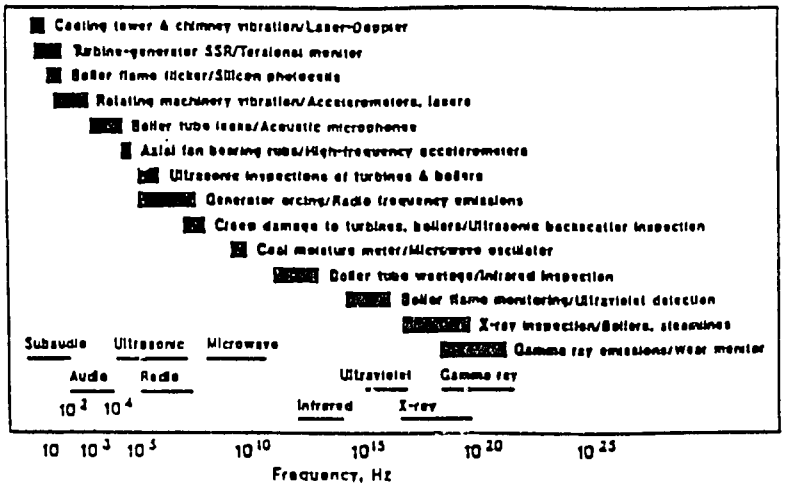

Figure 4. Diagnostic monitoring of fossil plant equipment covers the entire electro-magnetic spectrum. Signals range from a few Hz to the far end of the spectrum in the gamma ray band.

According to this chart, signals from equipment may be just a few Hz (as in chimney and cooling tower vibration) or can be in the ultrasonic bands or beyond to the infrared, ultraviolet, X-ray and gamma ray bands. Key elements of diagnostic monitoring are on-line sensors, data reduction software and microprocessor technology. Although much has been achieved in diagnostics, many opportunities remain in this field. Successful utilities of the future will be able to plan maintenance and upgrade activities based on day-to-day knowledge of machinery condition. Such a predictive maintenance strategy, based on a complete network of diagnostic monitors, has been developed at the EPRI Monitoring and Diagnostic Center located at Philadelphia Electric's Eddystone plant (see Figure 5).

Improved Materials

Working with the world's major suppliers of boilers, turbines and balance-of-plant equipment, EPRI has directed a re-assessment of materials and designs for coal-fired power plants. Particular attention is being given to temper embrittlement, creep and fatigue of headers and turbine rotors, boiler waterwall thermal stressing and superheater/reheater coal ash corrosion (10).

Improved materials for new fossil plants, and also for the retrofit of old ones, will be critical if optimum availability, efficiency and operability are required. Materials are available now that extend life, permit increases in steam temperature and pressure, and are fatigue-resistant to cycling operation (see Figure 6). Improved ferritic and austenitic materials exist for tubing and also for thick wall components. In the latter case, high chrome ferritic alloys have rupture strengths an order of magnitude greater than, for example, P22 (or 2¼Cr 1Mo).

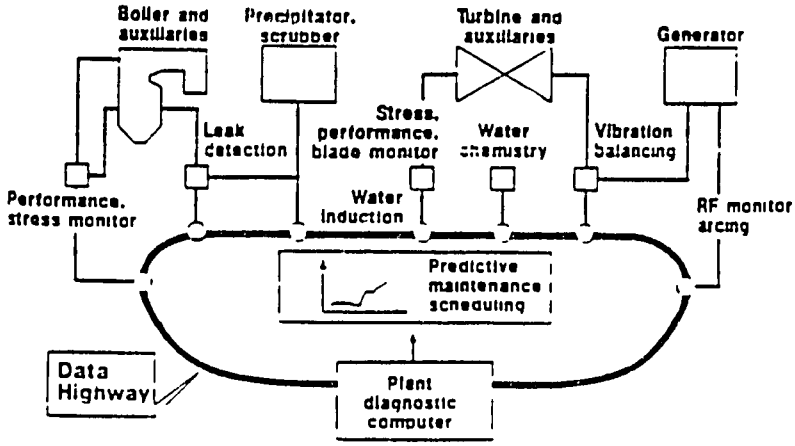

Figure 5. A data highway at Philadelphia Electric's Eddystone plant ties together separate monitoring systems for boiler, turbine, generator, environmental controls, and balance-of-plant equipment.

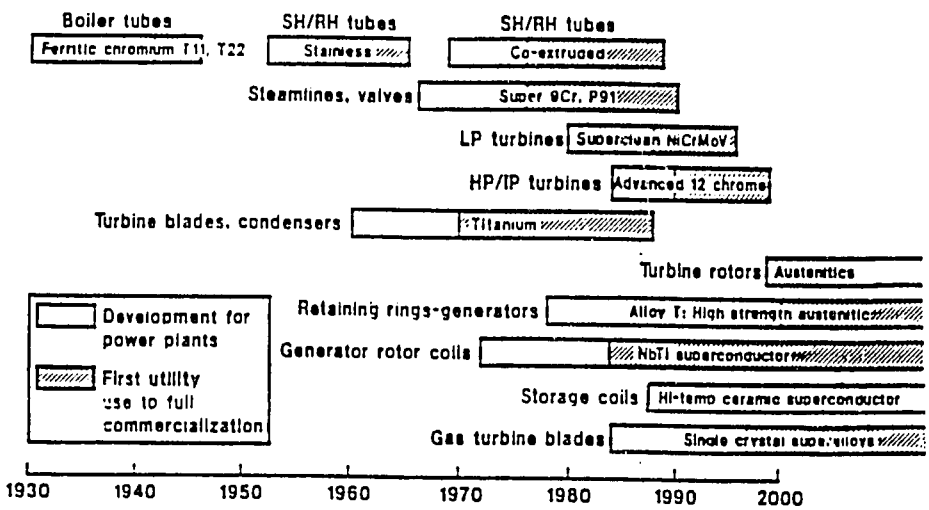

Figure 6. Improved materials are now available for fossil plants, including super-9-chrome steel (P91), which permits thinner sections and lower thermal stresses. It can be used for headers, steamlines, valve bodies, and turbine casings.

Of particular note are co-extruded tubing for superheaters, resistant to coal-ash corrosion; super-9-chrome steel (P91) for steam piping, valves, headers, casings; improved creep-resistant 12-chrome forgings for HP/IP turbines; and for LP turbines, "superclean" 3.5NiCrMoV rotors resistant to temper embrittlement.

EPRI is working closely with utilities in the U.S., Europe, and Japan to retrofit improved materials into existing units. This will permit the industry to quantify the benefits of the retrofit, and thus encourage widespread application of better technology to all aging generating capacity. Recent examples in the U.S. are superclean turbine rotors with Duke Power, super-9-chrome headers with Lower Colorado River Authority, and corrosion-resistant superheat and reheat tubing with Tennessee Valley Authority.

Repowering

Repowering is an attractive and cost-effective way to improve capacity factor and extend the life of a generating unit while adding capacity, improving heat rate, reducing emissions, and lowering heat rejection and water usage per kW generated. In some cases, repowering can make the difference between shutting down a unit, or making the unit economic.

The most common form of repowering replaces the original boiler with a heat recovery steam generator which is heated from combustion turbine exhaust gases. A less capital intensive option, though with lower efficiency gains, exhausts the gases into the original boiler windbox. Repowering with a fluidized bed boiler can significantly decrease emissions and can alleviate problems due to poor fuel. Recent U.S. examples of repowering are shown in Table 3.

Recent U.S. Utility Upgrades

In recent years, EPRI has worked with many utilities involved in plant upgrading. Table 4 summarizes some of the applications and cost-savings realized. References (11, 12) provide more details of these plant upgrades.

EMISSION CONTROL TECHNOLOGY FOR COAL PLANTS

When it is a matter of retrofitting an existing power plant, no two situations are identical: fuels, boiler configurations, even space available for new pollution control equipment, all play a role in the decision on how a utility will meet new emission reduction requirements. For example, a decision to install a sorbent injection technology rather than flue gas desulfurization (FGD) for SO_2 reduction may depend not only on the percentage reduction required but also on the space constraints of the site, and on the capacity factor of the plant (with a lower capacity factor, the lower capital cost of sorbent injection is advantageous compared to FGD).

Lime/Limestone Wet Scrubbing

Most utilities though have been selecting either wet or dry scrubbing systems for desulfurization (13). By 1991 the U.S. already had 155 FGD systems in operation on 69,000 MW at utility stations (see Table 5). U.S. FGD experience is now approaching 1000 unit years.

Table 3. Recent U.S. Utility Repowering Projects

Utility	Plant	Additions	Benefits
Glendale Public Service	Grayson	3 CTs 2 HRSGs	Added 75 MW Improved emissions Lowered heat rate to 9000 Btu/kWh
Southern California Edison	Terminal Island	7 CTs 7 HRSGs	Added 400 MW Lowered heat rate by 2200 Btu/kWh
Florida Power & Light	Lauderdale	4 CTs 4 HRSGs	Added 745 MW Lowered heat rate by 3000 Btu/KWh Improved capacity factor
PSI Energy	Wabash River	1 CT 1 HRSG gasifier	Added 180 MW Improved heat rate and emissions
Northern States Power	Black Dog	AFBC boiler	Added 45 MW Reduced SO_2 and NO_x emissions Added 25 yrs to lifetime
Montana-Dakota Utilities	Heskett	AFBC boiler	Added 5 MW Improved heat rate
Tri-State Generation & Transmission	Nucla	AFBC boiler 1 ST-G	Added 75 MW Improved heat rate 15% Reduced emissions Extended life 30 yrs

The dominant system is the wet limestone design, limestone being one quarter the cost of lime as a reagent. In this system (see Figure 7) the limestone is ground and mixed with water in a reagent preparation area. It is then conveyed to a spray tower called an absorber, as a slurry of 90% water and 10% solids, and sprayed into the flue gas stream. The SO_2 in the flue gas is absorbed in the slurry and collected in a reaction tank where it combines with the limestone to produce water and calcium sulfate or calcium sulfate crystals.

Table 4. Recent U.S. Utility Upgrades

Utility	Plant	Technology	Total Saving ($million)
PSI Energy	Gibson	Boiler tube failure correction, prevention, & control program	23
NYPA	Poletti	Adjustable speed drives	10
TVA	Gallatin	Corrosion-resistant reheater material	12
San Diego Gas & Electric	South Bay	Steam flow redistribution	0.3
LILCo	Barrett	Longer life (AL6XN) tubing for feedwater heaters	0.4
LILCo	Glenwood	Header-type feedwater heater	1.0
Lincoln Electric	Rokeby CT	Ice-based thermal energy storage system	1.5
Philadelphia Electric	Eddystone	Thermography predictive maintenance program	2

Table 5. U.S. Operating FGD Systems

<1 % sulfur coal	1 to 2.5 % sulfur coal	>2.5 % sulfur coal
85 systems 37,000 MW	31 systems 15,000 MW	39 systems 17,000 MW

A portion of the slurry is then pumped to a thickener where these solids/crystals settle out before going to a filter for final dewatering. Mist eliminators installed in the system ductwork at the spray tower outlet collect slurry/moisture entrained in the flue gas stream. Calcium sulfate is typically mixed with flyash (1:1) and lime (5%) and disposed of in a landfill. Various improvements can be made to this basic process including the use of additives for performance enhancement, and the use of a hydrocyclone for dewatering, replacing the thickener and leading to a saleable gypsum byproduct.

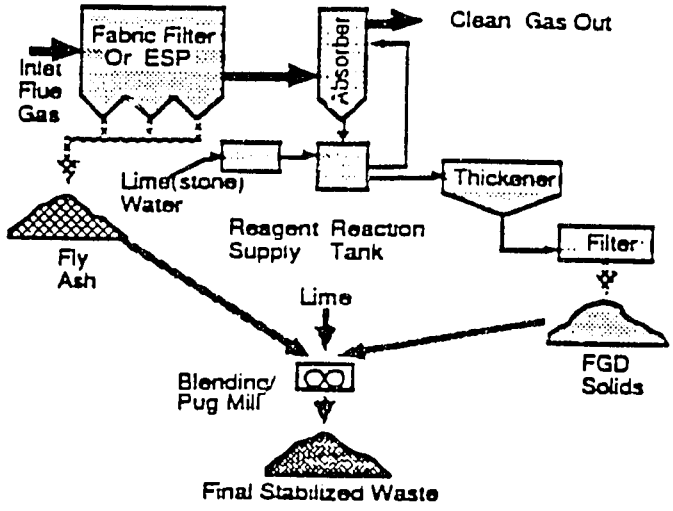

Figure 7. Conventional lime/limestone wet scrubbing is the dominant flue gas desulfurization system.

The Chiyoda-121 process (see Figure 8) reverses the classical spray scrubber and bubbles the gas through the liquid. This eliminates the need for spray pumps, nozzle headers, separate oxidation towers and thickeners. Bechtel has licensed this process in the U.S., the first commercial installation is at the University of Illinois on a heating boiler, and a DOE Clean Coal demonstration is underway. The waste can be sold as gypsum or disposed of in a gypsum stack.

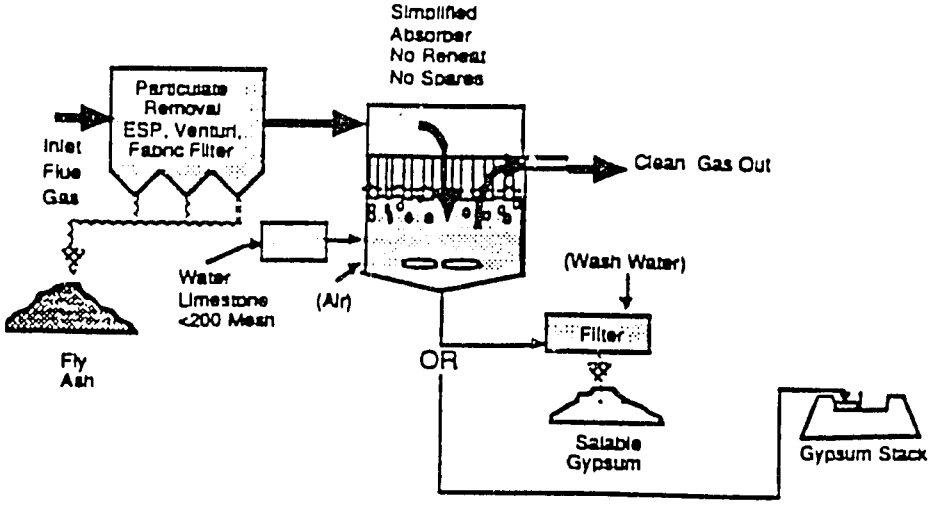

Figure 8. The Chiyoda-121 scrubber simplifies the conventional scrubbing process by bubbling the flue gas through the liquid, eliminating some equipment needs.

Spray Drying

Spray drying (see Figure 9) is the most advanced form of dry SO_2 control technology. Such systems tend to be less expensive than wet FGD but remove typically a smaller percentage of the sulfur (90% compared with 98%). They are used when burning low-sulfur coals and utilize fabric filters for particle collection, although recent tests have shown applicability to high-sulfur coals also.

Spray dryers use a calcium oxide reagent (quicklime) which when mixed with water, produces a calcium hydroxide slurry. This slurry is injected into the spray dryer where it is dried by the hot flue gas. As the drying occurs, the slurry reacts to collect SO_2. The dry product is collected at the bottom of the spray tower and in the downstream particulate removal device where further SO_2 removal may take place. It may then be recycled to the spray dryer to improve SO_2 removal and alkali utilization.

For small, older power plants with existing electrostatic precipitators (ESPs), the most cost effective retrofit spray dry configuration locates the spray dryer and fabric filter downstream of the ESP, separating in this manner the spray dryer and flyash waste streams. The flyash can then be sold commercially.

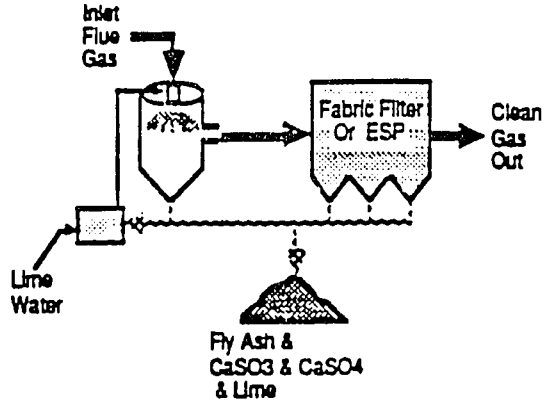

Figure 9. Spray dryers use a calcium oxide reagent mixed with water, which is dried by the flue gas. A dry product is collected in a fabric filter.

NO_x Control

For NO_x control (see Figure 10) the options can be described in three categories (14):

- Operational Changes. Reduced excess air or biased firing, including taking burners out of service.

- Hardware combustion modifications. Low NO_x burners, air staging, and fuel staging (reburning).

- Postcombustion modifications. Injection of NH_3 or urea into the convection pass, selective catalytic reduction (SCR), and wet or dry NO_x scrubbing (usually together with SO_2 scrubbing).

Low NO_x burners can reduce NO_x by 50%, and SCR by 80%, but the low NO_x burner option is much more cost effective in terms of cost per ton of NO_x removed. Reburning is intermediate in cost per removed ton and can reduce NO_x 50%, or 75% in conjunction with low NO_x burners.

To help in making control decisions, EPRI has developed a number of tools, mainly in the form of easy-to-use computer codes. Principal among these are FGDCOST (which compares the cost of different SO_2 control technologies applied to a specific plant); FGDPRISM (which simulates wet FGD process chemistry for application to performance, cost and reliability improvement); and NO_xPERT (which helps utilities select a NO_x reduction technology, again adapted to a specific plant configuration).

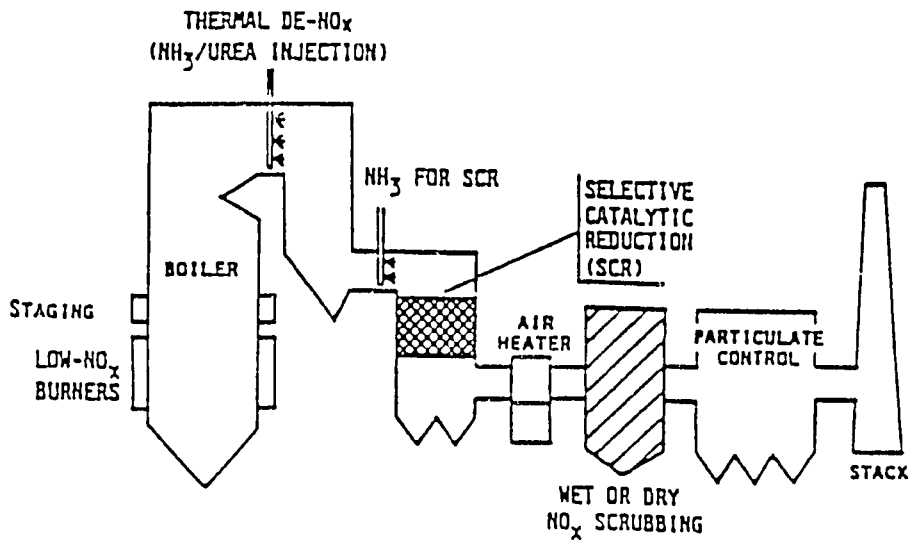

Figure 10. Control options for NO_x include operational, hardware, and post-combustion modifications.

NEW POWER GENERATION

The future for electric power generation is likely to be dominated by environmental control and thermal efficiency considerations. Several approaches for higher efficiency, cleaner power generation are under development in the U.S. and in many other

countries. Advances in coal-based steam plant technology and in natural gas-fired combined cycles are leading to cleaner, higher efficiency fossil power generation.

Updated Pulverized Coal Plants

There has been a perception that the pulverized-coal (PC) power plant has come to the end of its road, that advanced coal technologies will quite soon obsolete the PC plant with a scrubber, whose efficiency hovers around 35%. This perception is premature. There is good reason why the PC plant is still a primary choice for many utilities. First scrubbers have proved to be more reliable and effective than early plants indicated. Up to 99% SO_2 removal efficiency is possible. Second, the PC plant has the capability for much improved heat rate (about 8500 Btu/kWh) even with full FGD. Beyond these units, the PC-fired combined cycle with topping turbine (see Figure 11) has a projected heat rate of 7200 Btu/kWh, which includes full scrubbing capability. Third, the PC plant is a proven, reliable power source with unit capabilities demonstrated up to 1300 MW using a single-shaft steam turbine.

One plant, commercially available now, uses steam at 4500 psig and 1100°F, all ferritic materials for major boiler and turbine components, leading edge technology in environmental controls, and the latest techniques in waste heat utilization (15). It is modular, fuel flexible and designed for on-off cycling capability. Attributes include:

- 8500 Btu/kWh net heat rate
- 85% equivalent availability
- Low load capability to 15%
- Compliance with environmental regulations
- 24-month construction time from first concrete
- Less than $1400/kW capital cost
- Less than $50/kW-yr. non-fuel O&M

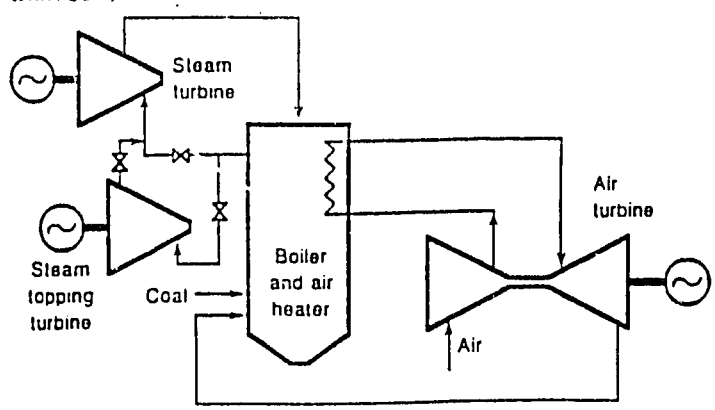

Figure 11. This pulverized coal combined cycle with topping steam turbine has a projected heat rate of 7200 Btu/kWh. The air turbine uses 1800°F air, or 2300°F air with supplemental firing. The topping turbine uses steam at 1300°F

Atmospheric Fluidized Bed Plants

Atmospheric fluidized bed boilers (see Figure 12) offer reductions in both SO_2 and NO_x and also permit the efficient combustion of low rank fuels. In the U.S. there are now over 150 operating units for power generation, and ten vendors of FBC boilers, four of which offer units up to 250 MW in size. The rapid growth in number of FBC units and capacity is shown in Figure 13. Three utility size FBC plants have recently been demonstrated as upgrades to existing PC-fired installations.

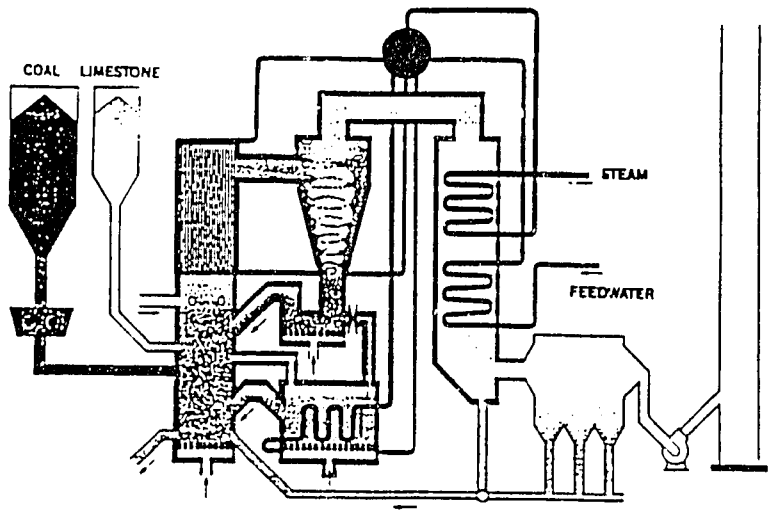

Figure 12. In a fluidized bed combustor, a coal/limestone mixture is burned in a suspended bed, fluidized by an underbed air supply. Sulfur reacts with the limestone to produce a solid waste of calcium sulfate. NO_x emissions are reduced due to low combustion temperatures (1500°F).

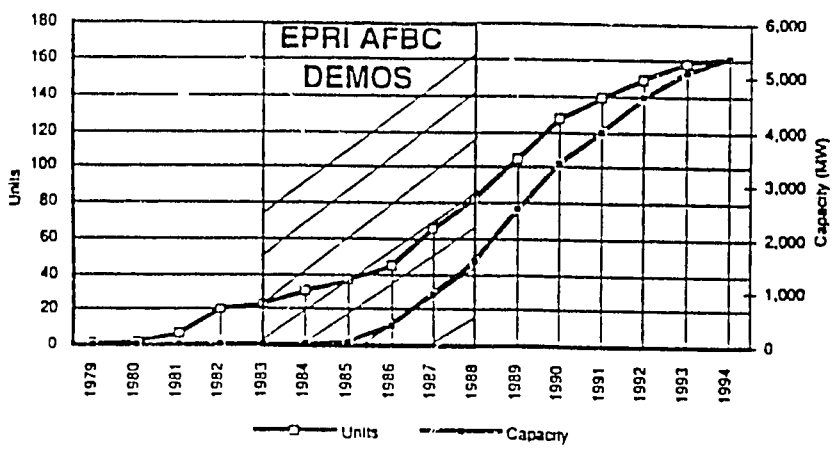

Figure 13. The growth in number and size of AFBC plants has been significant since the demonstration at 100+ MW sizes in U.S. utility plants.

The demonstration projects at TVA (Shawnee, 160 MW) and Northern States Power (Black Dog, 133 MW) are examples of successful bubbling-bed units. The Shawnee unit now routinely operates at 85-90% capacity factor having overcome initial fuel feed problems. The Black Dog unit has been dispatched recently in a daily cycling mode and has successfully fired a blend of coal and petroleum coke. The focus in the U.S. is now on circulating fluid bed (CFB) designs (16). The CFB project at Nucla in Colorado has been successful in demonstrating the technology at the 110 MW level and planned commercial plants have now reached 250 MW in size.

Most FBC units are being installed by independent power producers in the 50-100 MW size range, where the inherent SO_2 and NO_x advantages over the PC-plant have encouraged installations even in such traditional non-coal arenas as California. Pyropower alone had 18 CFB units in operation by 1990 and another 15 under construction (17).

Coal Technology Selection

New equipment, materials, and designs have been introduced that can now result in fossil plants with reduced costs and improved performance and operating characteristics. With technology options growing increasingly diverse, the screening and design process has been greatly complicated. EPRI is developing a series of software modules and a workstation that engineers, planners, and financial specialists can use to easily understand and evaluate these technology options and integrate them into the next generation of state-of-the-art power plants. The modules can also be used to retrofit new technologies in existing plants.

As shown in Table 6, EPRI has so far developed individual modules on pulverized coal plant technology and on combustion turbines and combined cycles. Each stand-alone module provides the user with complete details on a specific technology, including design, economics, construction schedules, and industry experience. Utilities can use these modules to screen technologies for specific sites. The modules are enhanced with interactive graphics and operate on IBM-compatible 386 personal computers equipped with Windows 3.1.

By 1995, EPRI will introduce a fully functional State-of-the-Art Power Plant (SOAPP) Workstation that can integrate all stand-alone modules to screen new technologies and then custom-design a conceptual site-specific state-of-the-art power plant. The interactive software workstation can be employed for pulverized coal, combustion turbine, combined-cycle, gasification-combined-cycle, or fluidized bed combustion plants. The resulting conceptual designs will include drawings, specifications, material and energy balances, costs, and schedules.

SEPRIL Services, an alliance between EPRI and Sargent & Lundy, offers technical consulting services in the Pacific Rim based on the use of SOAPP technology evaluation and assessment tools. SEPRIL can provide study and custom engineering services for evaluation of power generation technology alternatives, development of conceptual

plant designs for planning new generation projects, and evaluation of emission control technologies for retrofit on existing units.

Table 6. EPRI SOAPP Technology Modules

SOAPP Technology Module	Pulverized Coal	Combustion Turbine	Combined Cycle
Baghouses	x		
Electrostatic Precipitators	x		
Cycle Chemistry	x		
Feedwater Heaters	x		
Air Heaters	x		
Boiler Feedpumps	x		
Automatic Steam Bypass Systems	x		
Coal Blending	x		
Coal Cleaning	x		
Continuous Emission Monitoring	x		
Flue Gas Desulfurization	x		
Forced Oxidation Limestone FGD	x		
Inhibited Oxidation Limestone FGD	x		
Dry FGD	x		
Selective Catalytic Reduction	x	x	x
Selective Non-Catalytic Reduction	x		
Combustion Turbine NO_x Control		x	x
Combustion Turbine Selection		x	x
Fuel Systems		x	x
Inlet Air Conditioning		x	x
Inlet Air Filtration		x	x
Heat Recovery Steam Generators			x
Duct Burner Systems			x
Deaeration			x
Condensate Preheating			x
Bypass Stacks and Diverter Valves			x
Steam Turbine Selection			x
Wet Cooling Tower Systems			x

CONCLUSIONS

The future for electric power generation is likely to be dominated increasingly by environmental control needs. This will put an emphasis on the base efficiency of new generation, and on heat rate recovery for existing units.

Upgrading of older coal-fired plants is often a cost-effective method for increasing MW output, improving efficiency, and reducing emissions. Upgrading can range from simple coal cleaning, combustion optimization, or on-line diagnostics, to more extensive repowering and re-configuring options. Often it is possible to make a major combustion change, such as to fluid bed combustion or coal gasification, while retaining the majority of balance-of-plant equipment. Such approaches have led recently to U.S. utilities recovering lost MW, lost efficiency, or impaired availability for capital investments, modest by comparison with new plant construction.

The future for many developing nations is based on exploiting the opportunities offered by clean and efficient use of coal. This implies access to the range of new technologies now being tested at large scale in the U.S. and other developed nations. This strategy is both timely and prudent on a global basis. The world increasingly voices concerns related to carbon combustion, now on a scale many times that of yesterday. It is in the interests of governments, consumers, and suppliers of equipment to work towards a broad market for clean coal technologies.

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HIGHLY EFFICIENT PULVERIZED COAL-FIRED POWER PLANTS

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Abstract

Today the demands for modern power plant concepts are characterized by high efficiency, low investment costs and a high availability.

To fulfill the special needs of the customer regarding operation mode and site an engineering concept is developed for a 300 MW coal-fired power plant with both subcritical and supercritical design.

Both designs are compared with regard to efficiency, environmental impact, availability and costs.

The arrangement of turbine building and switchgear building is based on a modular concept reducing the engineering work and render a comparison of experience for each modul. This design concept allows an easy adaption to special needs of the customer.

1. Introduction

Today the demands for modern power plant concepts are characterized both by the high environmental awareness and the small amount of money which is at disposal. At the same time high efficiency, low emissions and low investment and operation costs are required combined with a high availability.

In addition there is also the request to operate a plant in base load mode at the beginning and later in daily shifts.

These requirements cannot be fulfilled by a standardized power plant concept following the boundary conditions of the respective site. But the power plant supplier must have a concept which can be easily adapted to the varying local conditions by planning and supply standards. Only thus an optimal price can be guaranteed. In the following such an engineering concept will be introduced by comparing a supercritical and a subcritical 300 MW coal-fired power plant.

2. Power Plant Efficiency

Especially during the last five years enormous steps in the development of efficiency increase of coal-fired power plants have been made (Picture 1). This was achieved by the measures shown in table 1.

Development of Design Parameters

	Seventies	End of Eighties	Nineties
Live Steam Pressure 1	bar 170 psig 2466	bar 250 psig 3626	bar 275 psig 3989
Live Steam Temperate 1	C 535 F 995	C 540 F 1004	C 582 F 1080
Reheat Temperature 1	C 535 F 995	C 560 F 1040	C 600 F 1112
Feedwater Temperature	C 250 F 482	C 270 F 518	C 300 F 572

TABLE 1

The first step to reach higher efficiency is to change from subcritical to supercritical steam conditions. This is accompanied by an increase in investment costs from 100 to 103-105%. To gain an efficiency above 45% (LHV) it is necessary to go to ultra supercritical steam conditions. These design parameters for the actual plants, specially in Europe and Japan, are only possible because of the development of new material e.g. P91/T91, Nf616.

The different fuels lead to different optimal steam conditions because of the design of the steam generator. The figures, shown in table 1, are the result of an optimization for hard coal, which can be bought on the world market.

3. Design and Operation Parameters of a 300 MW Coal-fired Power Plant

At ABB an optimized concept for a subcritical and supercritical 300 MW power plant has been successfully developed. Picture 2 and picture 3 show the heat balance diagrams of the plants. Table 2 compares the main design data and table 3 gives an overview of the main technical features.

Design Parameters for a 300 MW Power Plant

	Dimension	Subcritical Design		Supercritical Design	
Live Steam Pressure 1	bar psi	165	2400	250	3626
Live Steam Temperature 1	C / F	540	1004	540	1004
Reheat Temperature 1	C / F	540	1004	566	1051
Feedwater Temperature	C / F	261	502	208	550
Cooling Water Temperature	C / F	27	81	27	81
Heat Rate	Kj/kWh	7955		7522	

1 in front of turbine

TABLE 2

Features of 300 MW Power Plant

	Subritical Design	Supercritical Design
Steam Generator	Controlled Circulation	Once Trough
Steam Turbine	2 Casings (Combined HP/MP-Casing)	3 Casings
Feedwater Preheating	7 Preheaters	8 Preheaters
	2 HP Preheaters 1 FW Tank with Deaerator 4 LP Preheaters 4 LP Preheaters	3 HP Preheaters 1 separate Desuperheater 1 FW Tank with deaerator

TABLE 3

The subcritical unit is designed for conventional steam parameters; a boiler with controlled circulation is used. He feeds a turbine with a combined HP/MP-casing. For the supercritical design a 3-casing turbine brings clear advantages in efficiency.

Differences in Environmental Impact

	Dimension	Subcritical Design Design	Supercritical Design Design
Net Efficiency (LHV)	%	39,4	41,1
SG Efficiency (LHV)	%	93	93
Fuel Consumption	t/h	98,8	94,4
	t/a	874000	826000
Quantity of Ash	t/h	9,98	9,44
	t/a	87437	82694
Fuel Gas Emission	m3/h	843776	798400
	m3/h	1111	1051
Emissions			
CO2	t/a	2061000	1949000
SO2	t/a	17400	16540
Dust	t/a	360	350
Waste Heat	MW	761	730

Basis: 7680 h/a Full Load
1 Dust Emission 50 mg/m3

TABLE 4

Table 4 shows the technical operation data. The supercritical plant has an advantage in efficiency of 6%. This reduces the coal consumption and the environmental impact in the same range.

All these data are based on the coal analysis shown in table 5.

COAL ANALYSIS

(As received)

LHV	MJ/kg	25,7
Ash	%	10
Water	%	11
Volatile	%	30
Fixed Carbon	%	49
Sulfur	%	1

TABLE 5

4. Plant Design

To optimize technical design and costs we have developed component and arrangement concepts for both, sub- and supercritical unit, with a close look at standardization of engineering work and optimized availability.

Table 6 informs about the influence of redundancy on availability.

AVAILABILITY CALCULATION

Component	Component Capacity		Non-Availibility of One Component	Unit Non-Availibility Caused by the Failure of One Component	
	Design 1	Design 2		Design 1	Design 2
	%	%	%	%	%
Forced Draft Fan	2 x 50	1 x 100	0,0467	0,0467	0,0467
Induced Draft Fan	2 x 50	1 x 100	0,1298	0,1298	0,1298
Boiler Feedpumps	3 x 50	2 x 50	0,3028	0	0,212
Condensate Extraction Pumps	2 x 100	2 x 50	0,0825	0	0,0578
Primary Air Fan	2 x 50	1 x 100	0,0467	0,0467	0,0467
River Water Pumps	2 x 100	2 x 50	0,0311	0	0,0068
Intermediate Coolers	2 x 100	2 x 70	0,1438	0	0,0173
	TOTAL			0,2232	0,5171
	DIFFERENCE			0,2939	

TABLE 6

The consequences of the chosen solutions for the power plant costs are shown in a simplified way in table 8.

Price Relations

	Subcritical Design %	Supercritical Design %
Conventional Design	104	107
Advanced Design	100	103

TABLE 8

5. Arrangement Concept

Picture 4 shows a perspective view on the layout of a 300 MW coal-fired power plant with river water cooling. Both concepts, sub- and supercritical, are similar with regard to arrangement.
The site dimensions are approx. 400 x 500 m.

To reduce erection time to between 25 and 30 months the main buildings are arranged separately with a distance of approx. 5 m.

Turbine Building

The turbine building is divided into the turbo-group hall and the feedwater annex. (see Picture 5).

It has a full-size concrete foundation slab. The steelwork structure above ground level provides three operational levels at + 5,00 m / + 11,2 m (gratings) and turbine floor level + 17,0 m (concrete).

Two staircases are located outside in front of the turbo-group hall. A walkway on one end of the turbogroup hall enables direct access from the turbine floor to the control room in the switchgear building.

The components inside the turbine building are arranged in modular groups. The turbo-group with the condenser is installed in the middle of the turbogroup hall on a spring foundation on single supports. Picture 6 shows the arrangement for the subcritical, picture 7 for the supercritical design.

The oil room is located at + 11,2 m on the front site of the turbine. The HP-heaters are placed vertically in front of the oil room and turbine.

The switchgear room for generator exciter and the erection opening are arranged on the generator site.

The feedwater annex houses the feedwater tank at + 21,5 m and the feedwater pumps at + 5,0 m. The LP-heaters are arranged horizontally on the mezzanine level + 11,3 m. The HP-piping to and from the boiler and the HP-bypass-station are placed there.

The main condensate tank will be erected outside in front of the turbine hall.

Switchgear Building

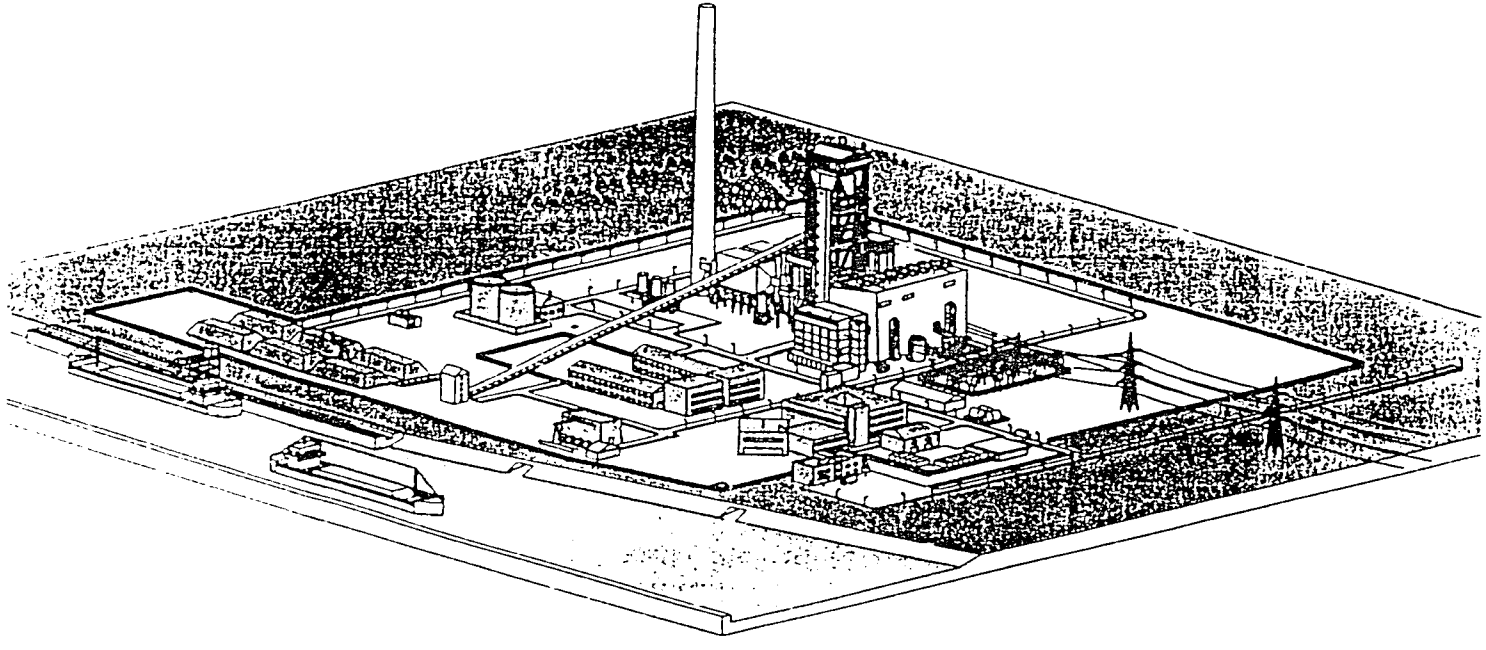
The switchgear building is a concrete building without basement. The air conditioning plant is housed on top of it in a steel structure.

6. Conclusions

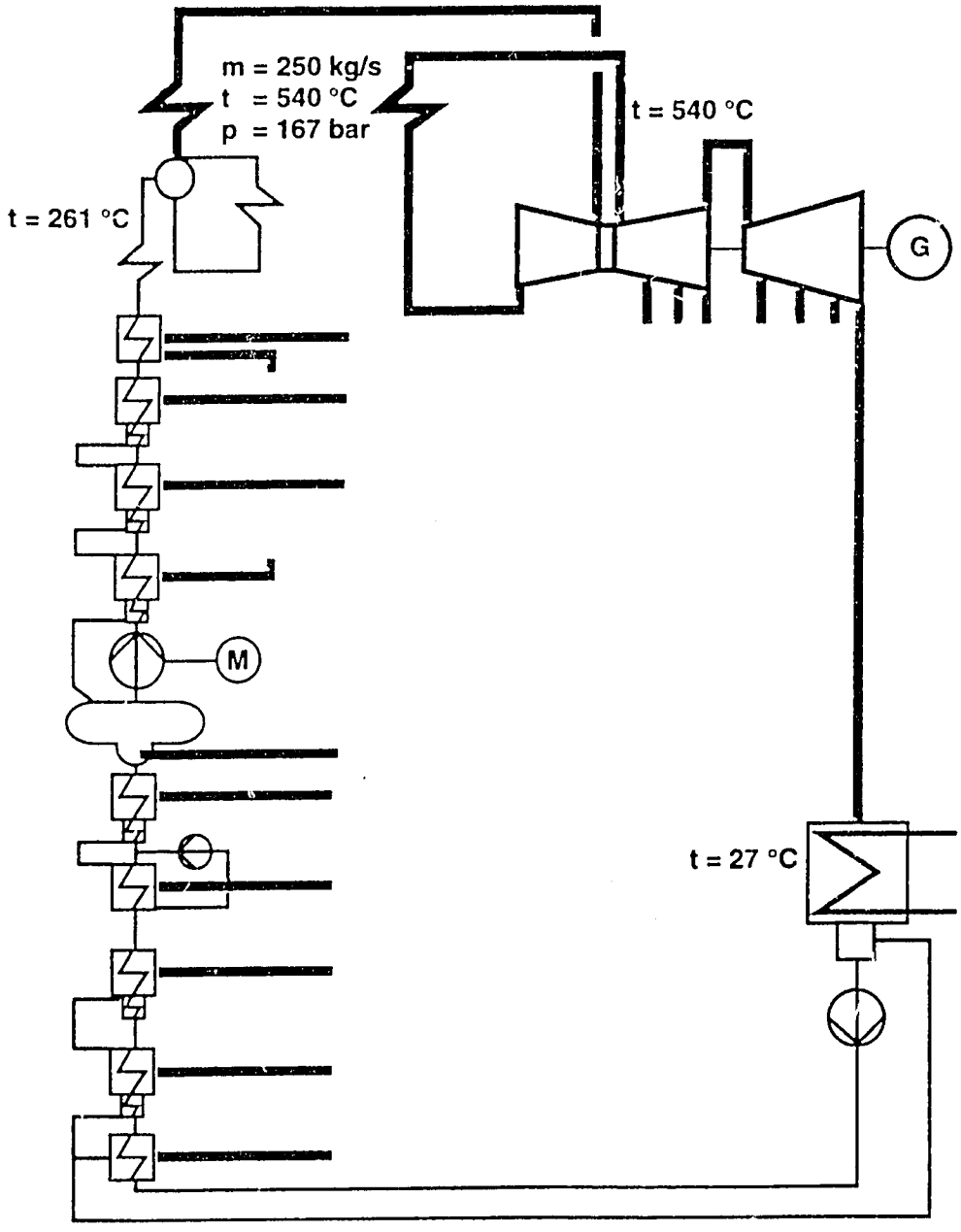
Both concepts, supercritical and subcritical design, give the possibility to optimize the plant for customers needs on the basis of preengineered solutions with a special regard to efficiency, environment, costs and operation mode.

300 MW Coal Fired Power Plant
Supercritical Design

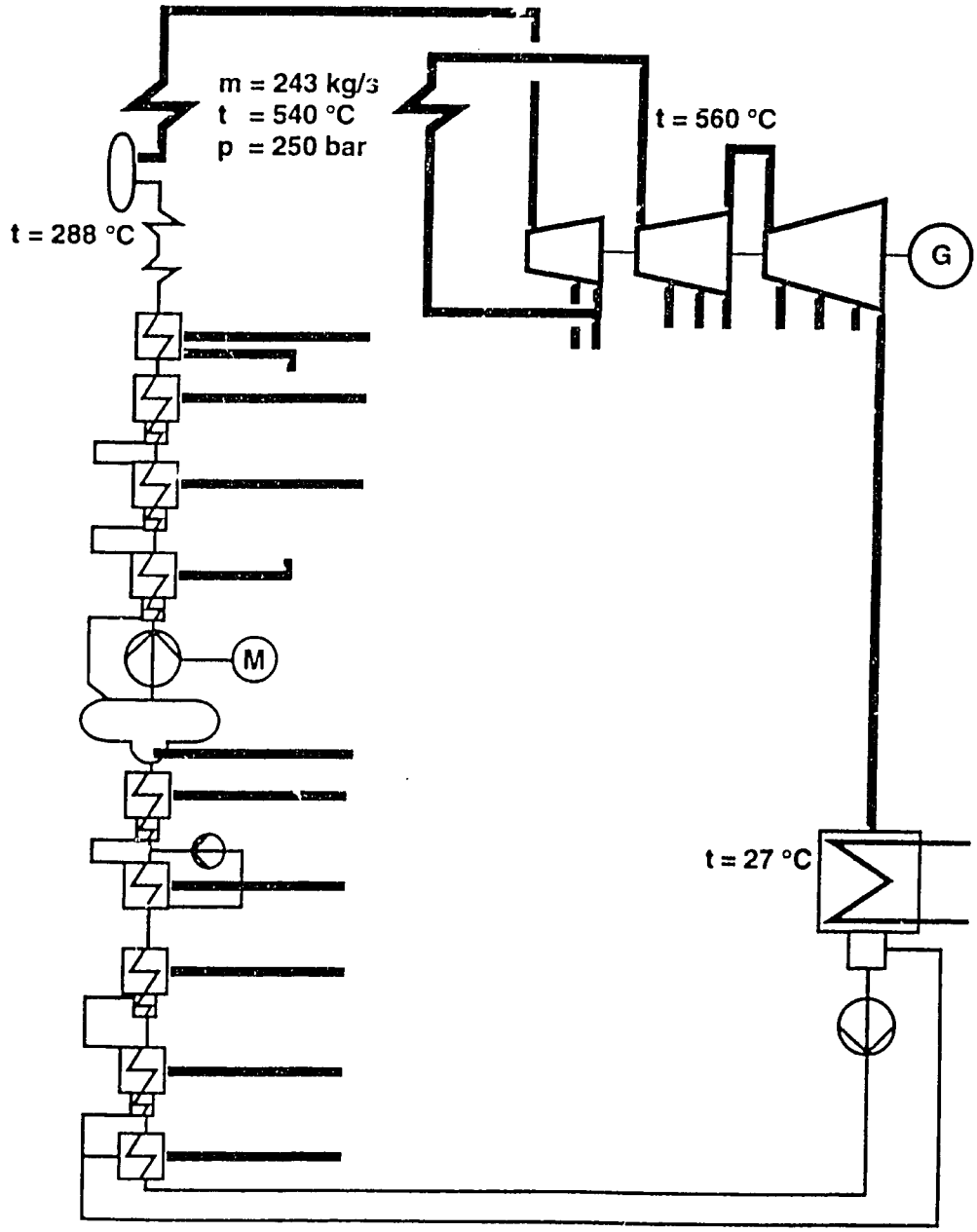
General Layout



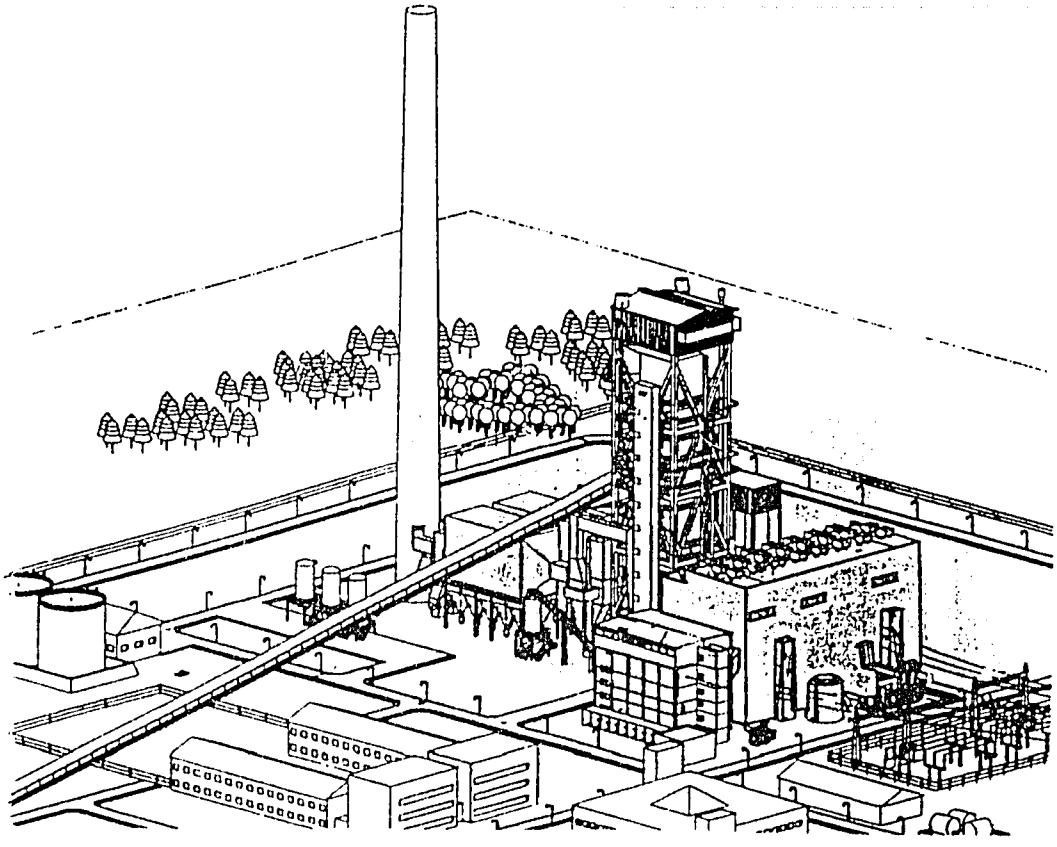
300 MW Coal-Fired Power Plant
Subcritical Design



300 MW Coal-Fired Power Plant
Supercritical Design

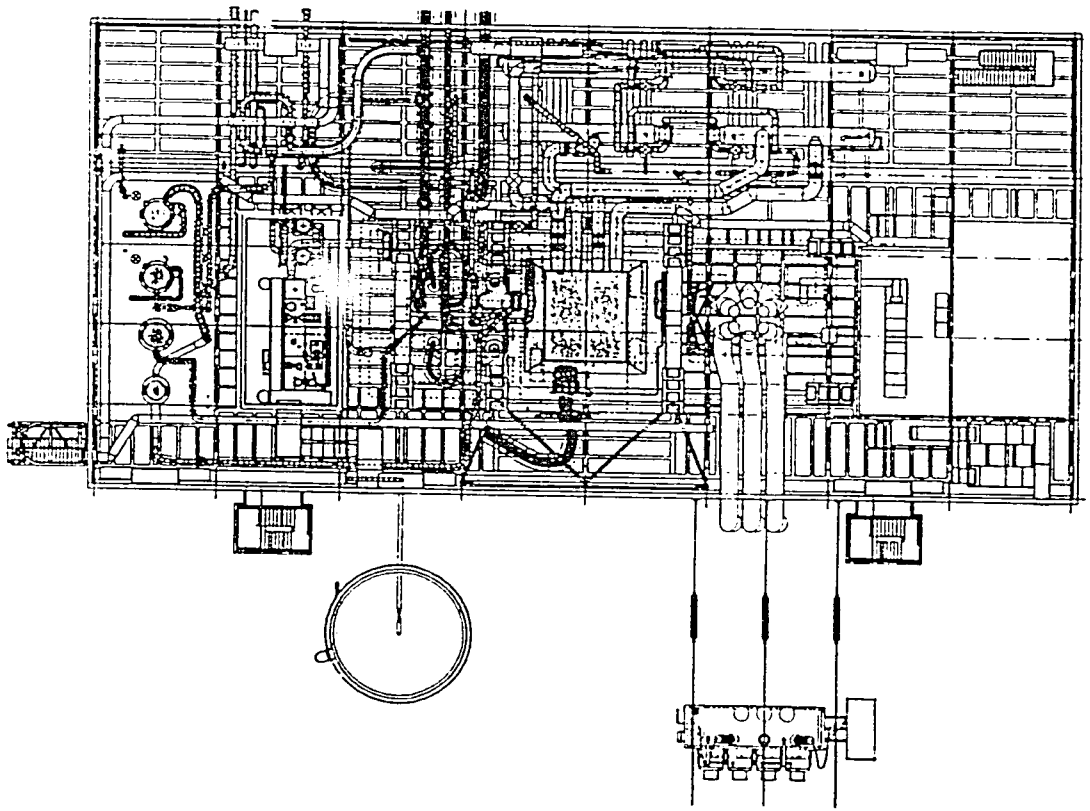


300 MW Coal Fired Power Plant
Supercritical Design
Main buildings

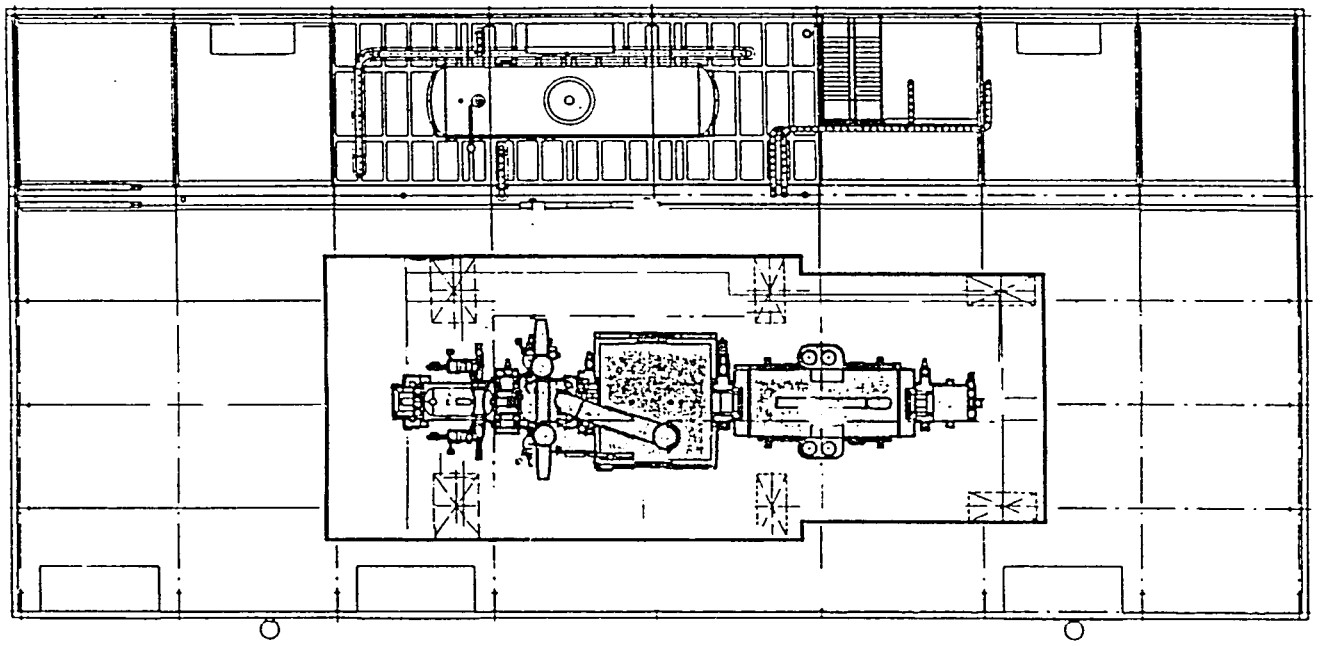


300 MW Coal Fired Power Plant
Supercritical Design

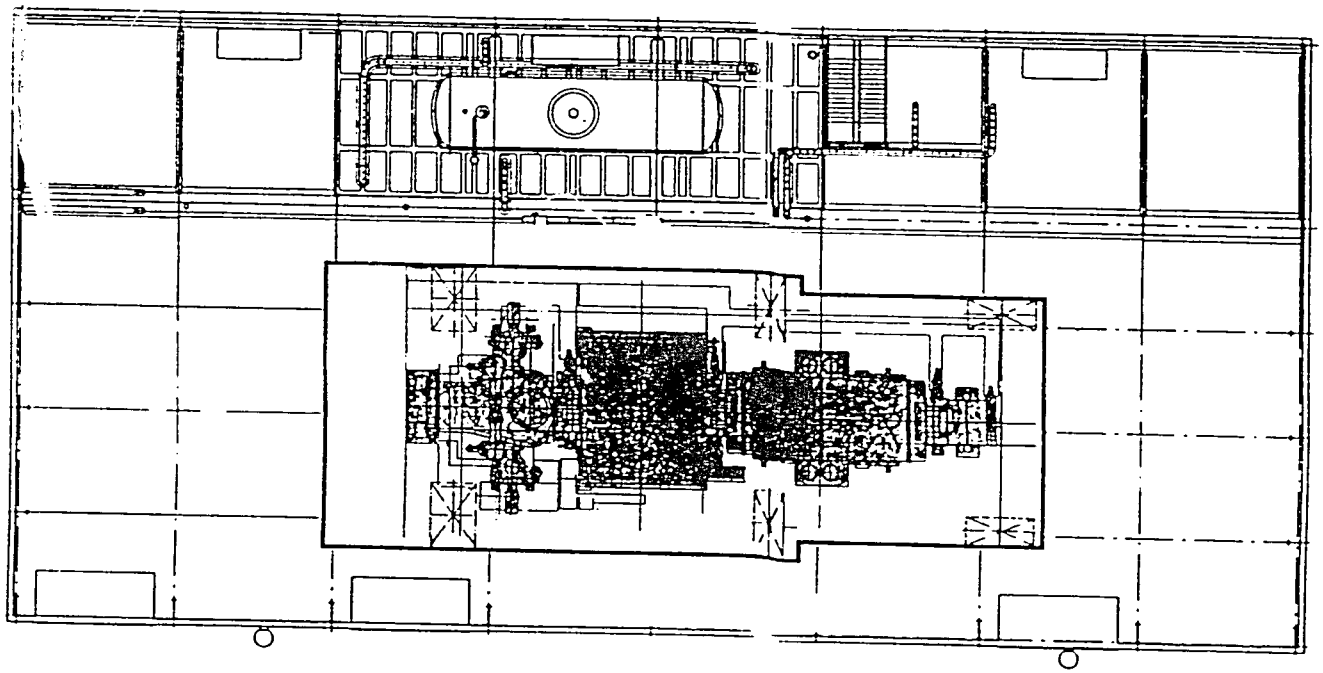
Turbine Building / Plan View +11m



300 MW Coal Fired Power Plant
Supercritical Design
Turbine Building



300 MW Coal Fired Power Plant
Subcritical Design
Turbine Building



Systematic Evaluation of Coal Utilization Technology Options for Developing Countries

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Over the past 15 years, we have seen an expansion of available clean coal or related technologies as a result of the needs of industrialized counties to address environmental and regulatory requirements. As these technologies emerged, their application to developing countries required an important and complex evaluation process. Not only is the number of available technologies continuing to increase, but the evaluation of their cost effective application has become highly specific to the challenges to be met in each country.

Stone & Webster through its worldwide expertise has developed a database and methodology to systematically evaluate the key characteristics of the technology options available and match them to the needs/requirements of the end user. In this paper, we discuss the significant factors which affect the technology selection, and the systematic process we suggest be followed as these technologies are evaluated for developing countries. The key aspects of these technologies are also discussed, including balancing their cost effectiveness with their suitability or ease of use in a developing country.

Introduction

New coal and lignite-fired projects in developing countries are confronted with a variety of technology options, whose evaluation and selection is driven by new constraints and opportunities unique to each country. Need for rapid economic growth is the major driver for these projects, tempered by changing environmental goals whose definition may not yet be clear. The sequence of analyzing, selecting, optimizing, and implementing technology for a coal or lignite-fired power plant must therefore address additional issues that reflect the unique economic, infrastructure, and

environmental conditions that form boundary conditions for the project. This process is enhanced through the use of state-of-the-art cost and performance computer characterizations combined with technical insights that support understanding of practical alternatives and their impacts.

Major technical and economic tradeoffs that must be resolved to optimize plant design include capital cost, O&M costs, availability, performance and environmental impact. Each of these groups of parameters competes with each other in the optimization process. Also, each of these is driven by local conditions such as financing ability, resources, planning goals, existing infrastructure and other conditions that will directly and indirectly affect the profitability of the project. Although this process appears to build on well known concepts, the implementation of a well-constructed optimization process within the context of a sequenced lump sum turnkey project can be very difficult.

The compatibility of various coal technologies must be compared to the needs of the developing country using criteria that go beyond the immediate scope of the project. Compatibility of fuel preparation, combustion, and emissions control technology with local conditions can impact the project in many ways.

Evaluation and Selection of New Power Project Configurations

Selecting and optimizing power generation plant designs in many developing/newly industrialized countries entails a process that must adapt to added constraints which represent the special opportunities and limitations characteristic of developing economies. This modified process is described conceptually in Figure 1, which highlights the sequence of decision-making as it responds to regional and local constraints and opportunities.

The need for power is driven by rapid industrial development and increasing standard of living that results in increased residential, commercial and industrial power load growth. Inadequacies of existing power generation and distribution systems provide a barrier to growth that is confronted by both private and government developers and planners. Some form of centralized planning generally drives the decision to add generation and transmission facilities. Often, these plans must address both economic and environmental targets, especially in areas that have undergone considerable industrial growth and suffered the resulting environmental and economic consequences. Specific environmental constraints may be imposed on the planning process if emission regulations, ambient air quality or other forms of regulations are implemented in an attempt to restore air and water quality, or at least to arrest further major deterioration. Often international financing sources, such as the World Bank, will require the use of state-of-the-art emission control systems to support general environmental planning goals.

The result is an established need for estimated blocks of power, that must be superimposed on a combination of first-order constraints including siting options, compatibility with existing and planned transmission grid characteristics and limitations, accessibility of fuels, and the environmental planning goals described above. Siting options are generally constrained by access to cooling water and makeup water, suitability for integration with the growing generation grid,

access to fuel delivery, and possibly environmental considerations. Site options can be developed through central planning or through the competitive process; in either case some intervention may be required to ensure that some degree of optimization takes place relative to these major criteria.

This paper focuses on the use of coal as the preferred fuel. Coal of varying ranges of quality is available as an indigenous fuel in many developing countries that promote its use as a way to improve strategic energy security and to promote local economic development. Those countries without usable indigenous coal have access to coal in the international market, which supports ship-based delivery to almost any coastal location.

Once major options and constraints are defined relative to site, fuel, transmission and environmental parameters, a second tier of regional constraints and opportunities can be applied before the selection process yields a specific site, size, technology and major plant characteristics. In many cases the largest economic driver in the selection of a site is the logistics of fuel supply. Coastal sites provide the best economics for large scale fuel delivery by ship, and may support once-through cooling systems that reduce plant cost and enhance plant performance. Inland sites require access to rail lines or navigable river systems for coal delivery as well as a makeup water source. Often, disposal of ash or flue gas desulfurization wastes requires bulk transport to disposal or reuse areas.

Optimum plant and unit sizes are determined primarily by economies of scale, transmission grid reliability considerations, ability to distribute and sell power from large single units and the relative costs of financing alternative cash flows. One common example is the comparison of 2x500MW coal-fired units versus 3x330 MW units. If built at the same time, the two larger units would provide the lowest cost project. However, the gradually increasing ability of the transmission network and reduced cost of financing associated with a sequenced three-unit station may result in a more cost-effective project.

Choice of technology is similarly driven by economics. Recent studies for international projects have shown that pulverized coal technology is generally more cost-effective for larger plant sizes (> 250 MW) because competing circulating fluidized bed (CFB) boiler technology is limited by maximum boiler sizes offered and becomes more expensive when multiple units are built. However, progressively larger CFB boilers are now being offered commercially based on successful operation of recent large CFB installations. This comparison must be looked at more carefully because of changes in commercial CFB offerings, and because of the influence of local labor costs, access to and costs of raw materials, costs of delivering fabricated components, and the impact of specific project economics and other requirements such as emissions control and waste disposal requirements.

Developing coal technologies, including coal gasification, pressurized fluid bed combustion (PFBC) and other advanced coal-based power cycles are in varying stages of development and represent added technical and economic risks to the project. However, some advanced coal power technologies may provide special benefits that best match unique needs of a developing economy. For example, gasification offers the potential for coproduction of chemicals such as fertilizers that may be critical to agricultural development. Some flue gas desulfurization systems

allow the production of byproduct gypsum that can be used in fast-growing commercial and residential construction industries. Even throwaway emission control systems such as spray-dryer systems can be adapted to produce materials that can be reused in construction aggregate or paving materials.

Selection of the most advantageous cooling system often hinges on the ability to design a cost-effective once-through cooling system in a way that minimizes impacts on ocean fishing resources. In many developing countries this is driven by commercial fishery activity rather than concern for specific aquatic species. Some innovative cooling designs may provide the opportunity to support aquaculture or fish-farming activity that takes advantage of the plant waste heat to promote selected biomass growth or support certain species that like warmer waters. Inland sites are more likely served by wet/dry cooling tower combinations that best satisfy the cost/performance tradeoffs peculiar to the project.

Specific local site and economic conditions must be addressed in the context of plant optimization. Plant design conditions are generally set based on power grid peaking patterns, local meteorology of the site, and relative fuel and capital cost drivers. Plant optimization addresses the conflicting forces illustrated in Figure 2, which shows that five major parameters affect the profitability of a project often in conflicting directions. Traditional results of these optimizations in industrialized countries may not be repeated in developing countries where plant design is driven by many different parameters, such as low construction labor costs, limited access to construction bulk materials of desired quality and long delivery routes for manufactured and fabricated items.

Plant availability is a critical parameter whose optimization must be considered relative to major plant design decisions, detailed requirements for the quality and redundancy of equipment, impacts on performance, and most of all - operations and maintenance planning. Developing power grids may be less concerned about reliability as economy, so the primary driver for availability may be the terms of the power sales contract for the project, rather than system-wide loss of load probability targets. Plant availability is a primary profit driver in private project ventures where power sales agreements heavily penalize unplanned interruptions in service and extended outages for overhauls and major repairs. O&M planning and execution is critical to maintaining and exceeding availability targets. However, O&M staffing and the quality and productivity of O&M labor may be heavily constrained by many local factors. For example, some developing countries attempt to maximize the use of local labor as part of their economic development strategy. However, local customs or culture may have a negative influence on O&M roles, such as custodial or maintenance functions. Taken together, such factors may result in design decisions that significantly impact costs and performance.

Evaluation and Selection Process Sequence - Retrofit or Repowering Project

Figure 1 presents asterisked (*) items relevant to a case that involves modifications to an existing power generation facility. Once economic and environmental goals indicate a need for upgrading, expanding or replacing an existing power plant, the identification of options and

constraints focuses on characteristics of the existing site and the condition and remaining useful life of existing equipment. Local environmental requirements may be a big driving force for upgrading the plant, and poor attention to operations and maintenance, as is characteristic in many developing countries, may limit the practical re-use of existing steam turbines and boilers.

Technology evaluation and selection for retrofit/repowering projects is therefore heavily influenced by the extent of re-use of existing equipment, combined with local economic and environmental constraints and opportunities. For example, cogeneration may be an attractive concept in the context of extensive local industrial and commercial development.

Optimization of plant design is driven by the same five major parameters highlighted in Figure 2 as described for new power generation facilities, perhaps with greater attention to shorter economic life and its impact on plant economies.

Integration of Cost, Performance, Availability, and Environmental Data

Following resolution of the complexities of evaluating and selecting plant sites, technology, size, cooling, and environmental controls, the task of optimization deals with traditional and unique tradeoffs that must be analyzed to achieve maximum profitability for a project. Figure 2 illustrates the competing forces of performance, availability, capital cost, O&M cost, and environmental (and economic) impacts. Each of these five parameters has some negative impact on some or all of the other four. For example, reducing O&M costs may increase capital cost through use of more expensive equipment and may reduce availability through longer planned and unplanned outages. Reducing emissions adds equipment that has a direct undesirable impact on all four other parameters.

A second tier of parameters is superimposed on these major tradeoff parameters to reflect local conditions and the effects of doing business in a developing country, as shown in Figure 3. Financing constraints, including currency interactions related to combinations of international sources of supply, may distort the decision process relative to tradeoffs involving capital cost and cash flow. O&M costs are driven by O&M planning as constrained by sources of local or imported skilled labor, cultural forces that may affect these occupations, and access to quality raw materials and manufactured parts. Availability considerations may be constrained by local and regional transmission grid development, subject to terms of power sales agreements that may pass through some risks and uncertainties. Local economic goals may impose certain requirements or preferences on the implementation phase of the project, limiting portions of construction work to local contractors and sources of bulk materials that may influence the schedule, quality of work, costs, and ultimate availability of the facility.

Superimposed on this network of tradeoffs is the need to identify and manage risks to the profitability of a specific project, and risks associated with rapid, uncoordinated development of power projects. New and complex technologies introduce substantial technical risks that may strain the abilities of available local technical expertise. Risk management techniques associated with lump sum contracting result in loss of control of many aspects of the optimization process

if contract terms and technical requirements inadvertently distort the design evolution of the project away from intended target conditions. The sequence of plant definition and procurement should build on well-established project approaches, but modified to incorporate levels of innovation and motivation that match the driving forces of the project, including the opportunities and constraints imposed by developing economies.

Stone & Webster has addressed these tradeoffs analytically by developing a *computerized database and models* that integrate the calculation of the five parameter groups highlighted in Figure 2 to calculate project economics for each combination of related assumptions. This is done through the use of a number of plant reference designs, capital cost estimates, O&M cost estimates, performance calculations, emissions calculations, and simplified availability calculations that are linked to a cash flow model. By linking these related calculations with a combination of algorithms and manual cross-referencing, tradeoffs can be quantified based on a well-defined set of assumptions and clear, proven calculation structures. The complexities of multiple currencies and the translation of cost data to various international locations represent important components that are required to analyze possible project configurations. By developing linked spreadsheet models for these calculations, it is possible to support tradeoff studies, sensitivity studies, and risk analyses at a comprehensive level.

Compatibility of Coal Technologies

By taking some of these local/regional driving forces that have direct and indirect impact on both technology selection and optimization, we can create a matrix that highlights some of the interactive factors that affect the compatibility of specific coal technologies with sites in developing countries. Figure 4 illustrates examples of this approach. This table shows a subjective interpretation of the relative compatibility of various coal preparation, combustion and environmental control technologies against selected general needs. This evaluation is presented only to illustrate the process, which would vary considerably within the specific context of a given site and country. The following examples illustrate some major compatibility factors:

Development of local natural resources is enhanced by all coal technologies through the development of the coal fuel cycle, use of supporting raw materials such as lime or limestone, and the development of construction raw material sources. Power grid reliability is improved through the use of modern power designs and through the development of indigenous coal and raw material sources. The use of complex plant designs, including emission control systems, may have some negative impact on plant availability. Local economic growth is enhanced further by larger projects and fuel cycle operations that maximize local investments. Training and technology transfer is enhanced for newer, developing technologies that may not be easily accessible other than through project experience. Dependence on foreign capital can be considered a negative compatibility, which is larger for more complex, capital intensive technologies. Air and water quality are protected by the use of environmental controls, although significant impacts will result from designs that avoid the more expensive emission control technologies. Production of solid waste may be very undesirable since it consumes land otherwise available for development and may have other environmental drawbacks. Useful

coproduction of chemicals, fertilizers, building materials and other byproducts could provide significant benefits to growing infrastructures.

Many of these compatibilities are subtle and complex, requiring in-depth understanding of the technology alternatives and their potential impacts. Use of structured cost and performance models can add clarity by establishing a quantitative basis for impacts to employment, resource development and consumption, and environmental impacts.

Regional energy planning should encourage consideration of developing clean coal technologies in a way that maximizes the likelihood that matching compatibilities can be recognized, and in a way that promotes balanced growth, transmission grid reliability, and environmental control. The basis for comparing and evaluating many emerging technologies is not obvious to project developers, who will tend towards proven, repetitive applications that minimize financial and technical risk. Only through considerable initiative, with the support of knowledgeable technology experts and the application of sophisticated analytical approaches will all important tradeoffs be addressed with the emphasis and weighting demanded by long-term planning needs. The translation of short and long-term energy, environmental and economic goals into development and procurement strategies requires careful consideration and merits application of the best expertise available. Unless properly translated, projects will evolve to serve the more immediate needs associated with conservative project development approaches that may preclude more attractive, and perhaps more risky, alternatives. The national benefits of such aggressive risk-taking could dramatically outweigh the short-term implications of these risks. These benefits, to be achieved, require a greater level of initiative, interaction, communication, and cooperation than has been experienced in the history of the power industry.

The interaction of central economic and power industry planners with technical experts and project developers is the greatest challenge to the implementation of new clean coal technologies in developing countries. The interface among these participants in the process is discussed in the paper entitled "International Collaboration and Partnering for Effective Selection, Demonstration, and On-going Use of Clean Coal Technologies" presented during Plenary Session I of this conference.

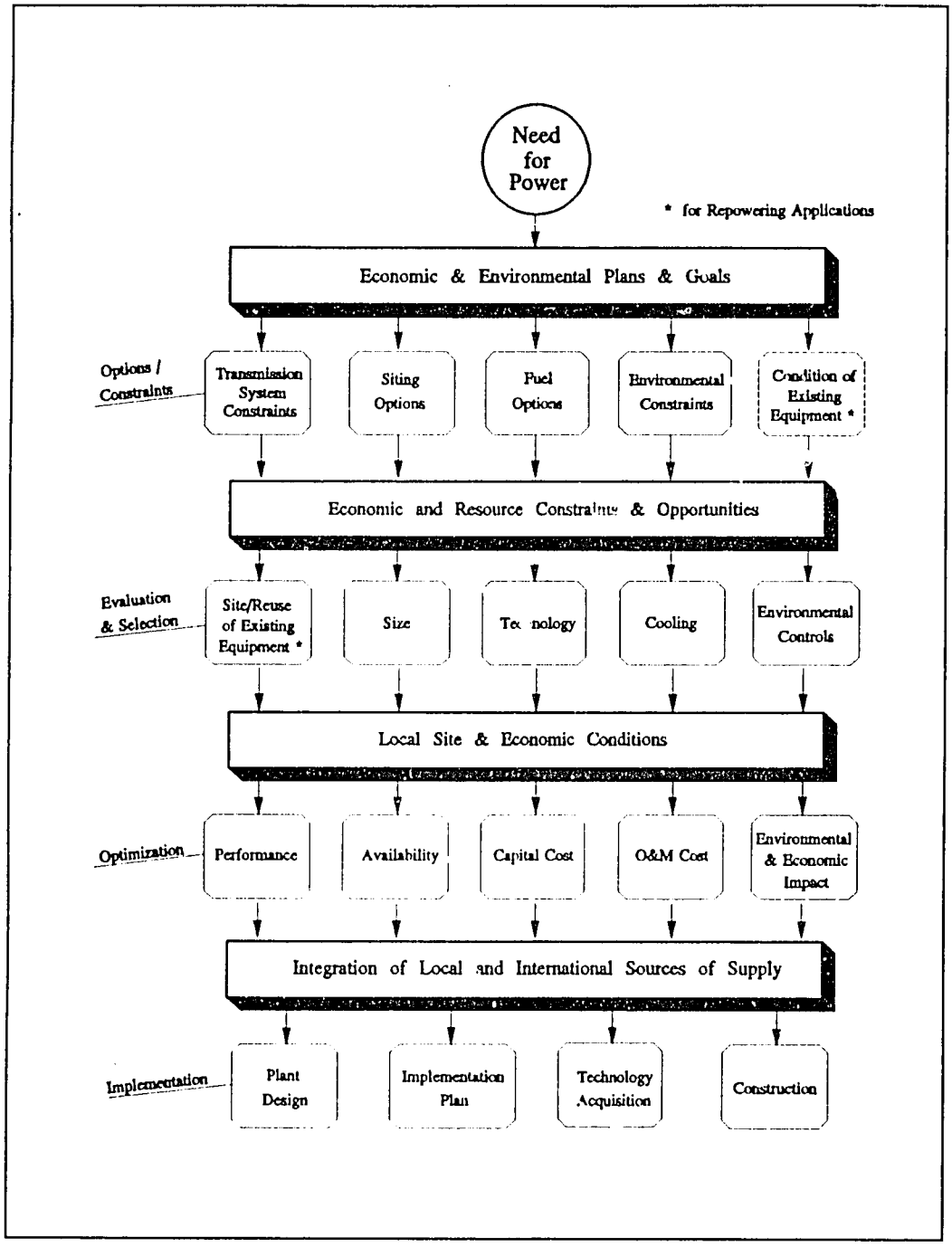

Figure 1 - Power Project Planning Sequence

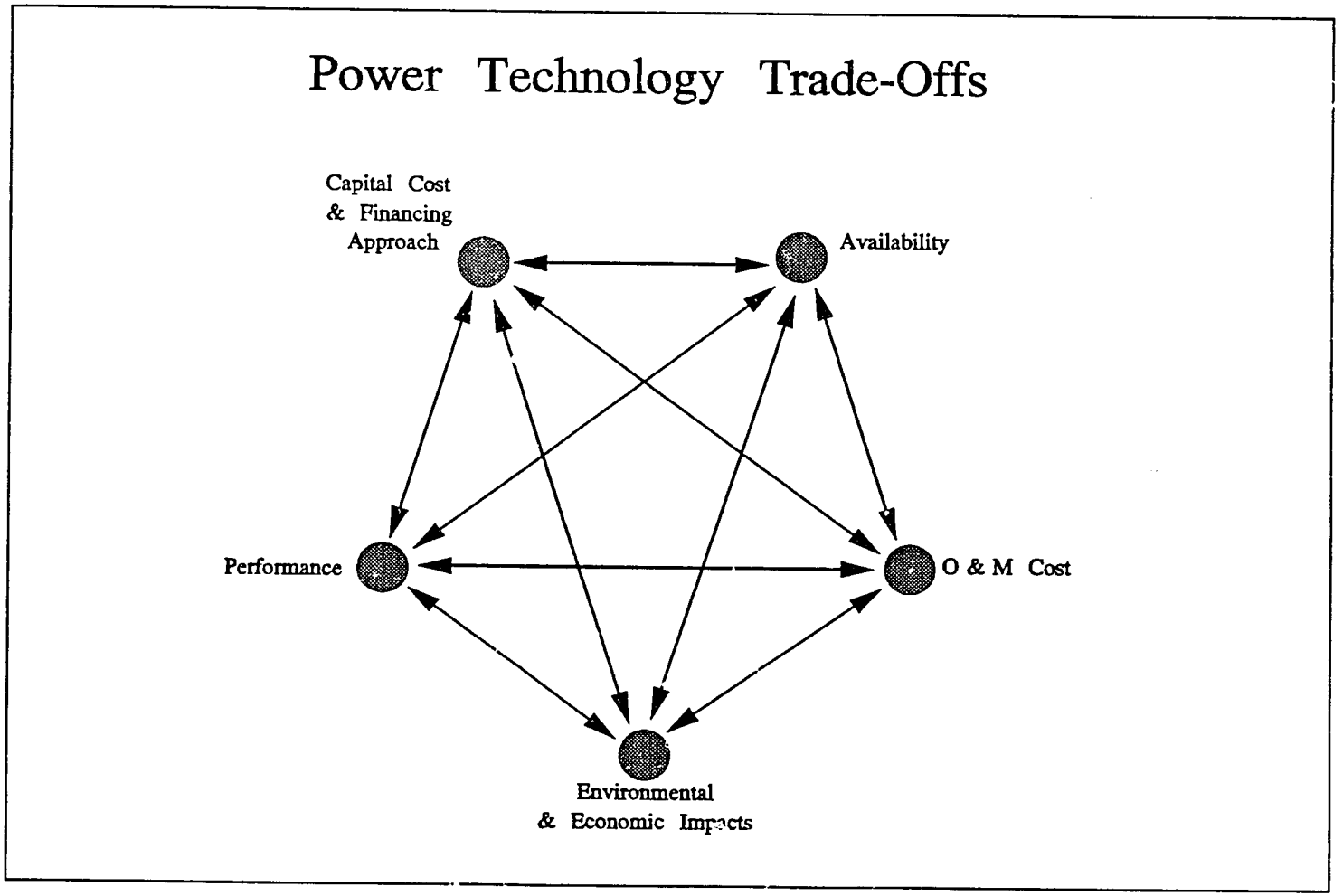

Figure 2 Each parameter interacts with all other parameters based on system, site, and project requirements.

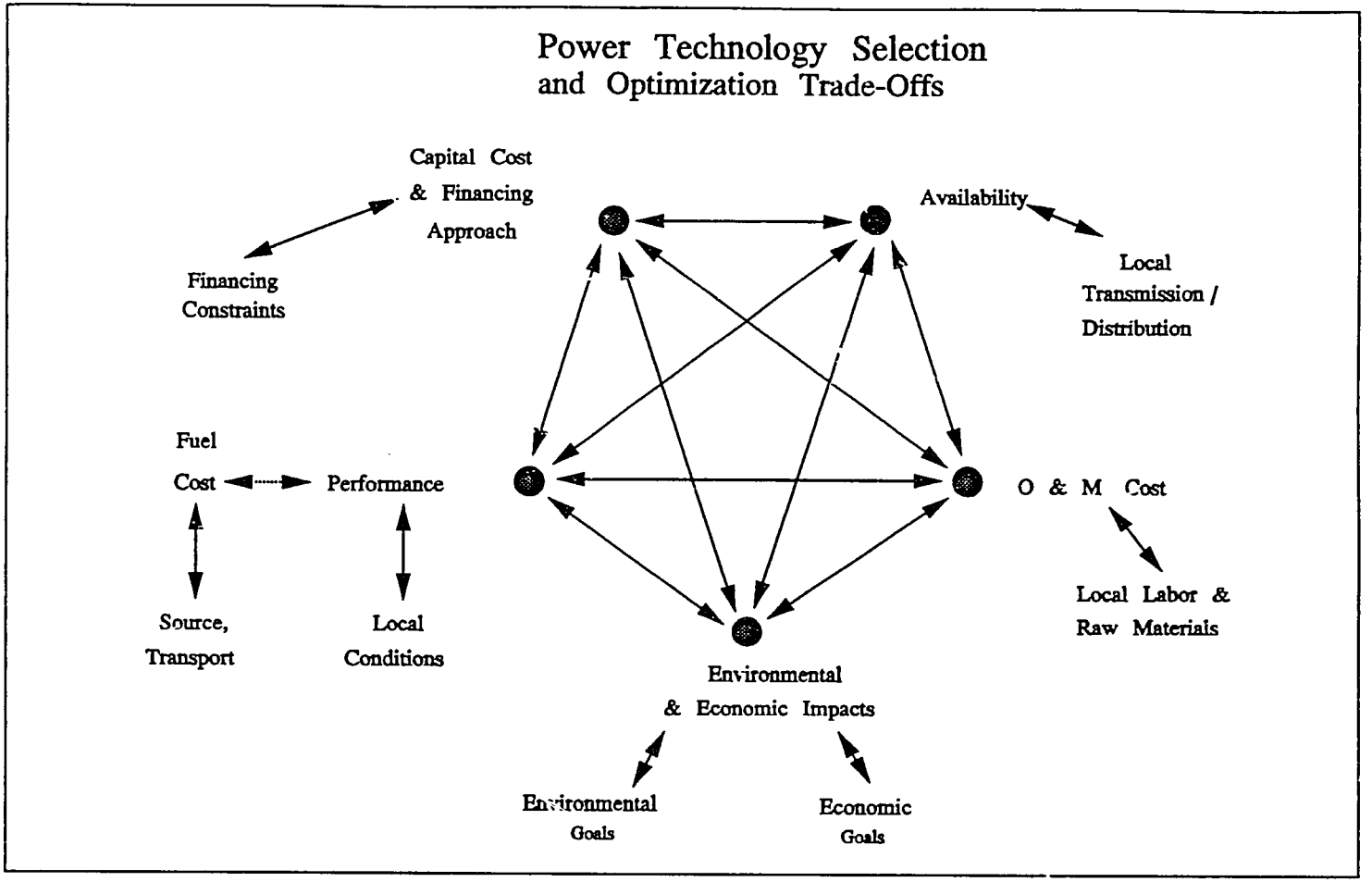

Figure 3 - Interactive Resolution of Trade-Offs Must Address Local Conditions and Use of Internation Technology & Sources of Supply

	Pre-Combustion			Combustion			Post-Combustion				
Needs: ↓	Mining	Cleaning	Slurry Fuels	PC	AFB	IGCC	FGD/ Gypsum	FGD Throw-Away	FGD Regen-erable	Spray Dryer	Duct Injec-tion
Development of Local Resources	+++	++	+	++	++	++	++	++	+	+	+
Improved Power Grid Reliability	++	–	– –	+	+	–	–	–	– –	–	– –
Economic Growth	+++	++	++	++	++	+++	+	–	++	–	–
Training & Technology Transfer	++	++	+++	++	++	+++	++	+	+++	++	++
Minimum Capital Investment	– –	– –	– – –	–	–	– –	– –	– –	– – –	– –	0
Improved Air Quality	–	+	++	0	+	++	++	++	++	++	+
Improved Water Quality	–	– –	– –	–	–	– –	– –	–	–	–	–
Minimum Solid Wastes	+	+	–	–	+	++	+	– –	+	– –	– –
Useful byproducts	++	+	+	0	0	+++	+++	0	+++	+	+
Chemicals									+++		

Figure 4 - Compatibility of Selected Coal Technology Options with Developing Country Needs

DEVELOPMENT OF COAL UTILISATION TECHNOLOGIES IN INDIA

BY: BC MISRA*, RK CHAKRABARTI**, CK BASU***

1.0 PREAMBLE

1.1 Energy is a key input for Economic growth. There is a close relationship between ENERGY CONSUMPTION & GDP Growth of a Nation. In other words it means between PRIMARY ENERGY SOURCE CONSUMPTION & GDP GROWTH. Viewing in global context India's per capita Energy consumption is abysmally low being only 208 Kg. of oil equivalent against 4952 of Industrial market economies and 314 of low income economics in 1986 (as per World Development Report 1988).

1.2 India's requirement of commercial energy is primarily met by FOSSIL FUEL i.e. COAL, LIGNITE, OIL & GAS. The contribution by indigenous production of COAL & LIGNITE, PETROLEUM PRODUCTS & NATURAL GAS, HYDEL & NUCLEAR in total commercial ENERGY of India is about 70%, 27%, 2.7% & 0.3% respectively. Except for oil the requirement of other fossil fuels is met primarily from indigenous production.

1.3 The energy consumption growth of the next decade is likely to be about 9% for power and 7% for coal for a GDP growth rate of 5 to 6%. The growth of coal production in India in the past 20 years since nationalisation of Coal Industry in 1973 has been impressive from about 78 million tonnes in 1973-74 to about 238 million tonnes in 1992-93 i.e. an increase of 160 million tonnes. The growth has been more impressive in 80's than in 70's. The 80's average annual growth rate is about 6.5% against the global corresponding average rate of about 2.3%.

1.4 The situation of reserves and production of Oil & Gas in Indian context is not a happy one. Currently, India has to import about 50% of its oil requirement. The reserves and production situation of coal is much better. The Indian coal resources at 193 billion tonnes though predominantly inferior and less than 1% of World reserves are going to last for about 100 years. Therefore, COAL is and is going to remain India's main source of *PRIMARY ENERGY* and we have to find ways & means to utilise it efficiently in an environmentally compatible manner for not only Gross Domestic Product (GDP) growth but also for improving the quality of life.

2. INDIAN COAL RESOURCES & QUALITY SCENARIO

A) Coal Resources

2.1 The estimated coal resources as on 1.1.1991 (down to a depth of 1200 metres) stood at 192 billion tonnes. These are categorised as below :

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*** SUPTDG. COAL TECHNOLOGIST, CMPDIL, RANCHI (INDIA)

Table - 1

(In million tonnes)

	Proved	Indicated	Inferred	Total
Coking	14,108	13,019	2,032	29,159
Non-coking	44,875	71,003	47,322	163,200
Total	58,983	84,022	49,354	192,359

2.2 Of these coal resources, the estimated resources down to a depth of 600 metres (considered workable) are of order of 174 billion tonnes i.e. 90%.

However, the above coal resources are predominantly of inferior quality and less than 1% of the world reserves.

C) Qualitywise Reserves

2.3 Qualitywise reserves of coal upto a depth of 600 metres classified as Superior, Intermediate & Inferior for non-coking (Steam) coal are given below :

	Superior Grade Ash% upto 24	Interme-diate Ash% 24 - 29	Inferior grade Ash% 29 - 50	Total Non-Coking Ash upto 50	Coking Ash% upto 40	G.Total
Billion tonnes	23.80	19.60	106.76	150.16	23.62	173.78
%age of total coal reserves	13.7	11.3	61.4	86.4	13.6	100.0

2.4 The above table shows that reserves of superior grade non-coking coals are limited being 13.7%. Intermediate grade non-coking coal reserves are also limited being 11.3%. The predominant non-coking coal reserves are of inferior grade being 61%. Coking coal reserves of 13.6% are also of predominantly low volatile and high ash .

3.0 COAL DEMAND SCENARIO

3.1 Actual demand (supply) in 1990-91 and further estimated demand scenario for next 20 years is as under :

(In million tonnes)

	1990-91 Actual	1996-97	1999-2000	2004-05	2009-10
Steel (incl. coke ovens)	30.05	41.50	43.20	45.00	45.00
Power Utilities	118.79	177.70	218.00	302.00	372.00
Cement	9.74	17.40	20.36	25.00	29.00
Others	53.56	78.60	104.44	143.00	184.00
Total	212.14	315.20	386.00	515.00	630.00

3.2 The share of power and other sectors is expected to grow as follows :

(In percentage)

	1990-91	1996-97	1999-2000	2004-05	2009-10
Power Sector	56	56	56	59	59
Other Sector	44	44	44	41	41

4.0 TECHNOLOGY DEVELOPMENT AREAS

From the foregoing discussions, it can be seen that major demand & demand growth is in Power Sector. Demand Growth in identified Cement Sector is also substantial. The limited available good and intermediate quality Non-coking (Steam) coal will have to be utilised by *HEAT INTENSIVE INDUSTRIES* which can not do without it. Therefore, Power, Cement and other industries alongwith Domestic Sector will have to depend on *INFERIOR COAL* only. Ways and means for efficient utilisation of this inferior coal in an environmentally compatible manner but economically have to be found. There is growth in Steel Sector (including Coke-ovens) too. Technologies for use of Low Volatile and High Ash Coking coals which are predominant in reserves are being tried besides adoption of technologies based on Non-coking coal.

All the above requires development of technologies with environmental compatibility and efficient energy utilisation for the above referred Sectors/Areas. The same have been briefly discussed below :

4.1 STEEL SECTOR

As has been discussed earlier, Coal reserves of India are, in general, of inferior quality and coking coal is no exception. For the production of Steel, certain specific quality parameters in the feed coal to coke are required to be maintained. Coal ash is one such important parameter. Due to difficult cleaning characteristics of Indian coals, its beneficiation to desired ash level requires adoption of improved beneficiation technology on which development activities are in progress in the country. Some of the advanced technologies like Spiral Concentrator, Column Flotation, Oleo Flotation, Oil Agglomeration, etc. are now in different stage of development. Some of them have been perfected in demonstration scale level prior to commercialisation. The above technologies were chosen for development under Indian context mainly due to the fact that Indian coals contain high near gravity materials and as such, calls for fine grinding to improve the yield of clean coal.

With a view to minimise dependence on coking coal for steel production, technologies like direct injection in Blast Furnace, adoption of Sponge Iron technology, Reduction melting technology based on non-coking coal are being adopted. For the production of non-coking coal with desired ash level, non-coking coal beneficiation for meeting the demand of Iron & Steel Sector is also coming up in a big way in the country.

4.2 CEMENT SECTOR

Production of Cement is one of the major energy consuming industries and as such, adoption of energy efficient process has become imperative under Indian context. Indian coals because of its high ash content calls for higher coal consumption for the purpose of clinker production. To reduce dependence on relatively superior grade coal and minimise consumption, the wet process of cement production is being phased out gradually from the country. The present trend in the area of cement production is adoption of dry process with precalcination where relatively inferior coals can be used for precalcination purpose and for the purpose of clinkering relatively superior coal is used. For the purpose of improving the productivity of Cement Plants and quality of the product, exercise is now in progress for establishing economics of beneficiating the feed coal to the Cement Industry.

4.3 DOMESTIC SECTOR

India with the population of about 860 millon needs huge energy for domestic purpose which comes from mainly non-commercial sources like Fire-Wood, Agricultural waste, Animal dungs, etc. There is urgent need to change this trend for maintainaing soil fertility. To this effect, use of coal based domestic fuel is essential and the subject has been dealt in details in another paper entitled *"Production of Coal Based Domestic Fuel : An Environmentally Friendly Technology"*.

4.4 POWER SECTOR

From the coal consumption pattern discussed in this paper, it is clear that power sector is the major consumer of coal in India. Being the major consumer of coal, Power Sector in India is to depend mostly on inferior grade coals with ash varying between 30-50%. Indian Power Plants upto the capacity of 500 MW unit based on pulverised coal combustion use such high ash coal. The problems associated in use of high ash coal mainly relate to erosion of boiler components and excessive use of oil support for boiler start-up and low load flame stabilisation. While the problem of erosion in boiler tubes is tackled by reducing flue gas velocity, installing suitable baffles in the flue gas path and by putting shields on tubes in critical erosion zones, the problem of flame stabilisation with oil support is being tackled through the use of low calorific value coal gas and adoption of direct ignition of pulverised coal developed in India.

Atmospheric Fluidised Bed Combustion (FBC) of coal for power generation has already reached commercial status in India and such boilers are capable of working with coals containing ash as high as 65% ash. Coal India Limited, itself has set up 2 Nos. of 2 x 10 MW A.F.B.C based captive power stations using coal washery rejects. Many more in pipe line. One CFBC Pilot Plant, for testing various high ash coals & washery rejects to enable design and construction of large size plants, is also operative.

In the area of Power generation, another technology now in advanced stage of development in India. is Coal Water Slurry Combustion (CWSC). The development of this technology will totally eliminate the problem of Oil/Gas support for the purpose of flame stabilisation in pulverised coal combustion.

Integrated gassification and combined cycle power generation is considered as the most environmental friendly technology with improved utilisation efficiency. The adoption of this technology is under active consideration in India. Indian coals being high in ash content, its gassification aspects have been investigated in details recently both in Pilot Plant and demonstration Plant scale to arrive at the optimum technology to be adopted for the purpose of gassification of such coals. The investigation carried out so far reveals that against the conventional thermal efficiency of only 33%, adoption of this technology may lead to a thermal efficiency of as high as 42%.

In the area of coal combustion, other development areas, where work is now in progress in India are Pressurised, Fluidised Bed Combustion, Oscilliatory Combustion & Magnete Hydrodynamic (MHD) System.

4.5 MISCELLANEOUS

The oil reserves over the world are depleting at a fast rate and as such, Coal is bound to become the primary feed material for the organic chemical industries. To face such a future situation, development activities in India are now in progress for the

production of oganic chemicals either from the coal tar or from coal based synthesis gas. Work is also in progress in this country for the direct hydrogenation of coal for the production of oil and chemicals.

5.0 CONCLUSION

Coal will continue to be the prime source of energy in India for the foreseeable future. Indian coal being of inferior quality, developmental activities are in progress for efficient utilisation of such coals in environmentally friendly manner with due regard for conservation of this non-renewable scarce source of energy. To achieve the above objective, developmental activities as well as adoption of improved technologies are being taken up on priority basis in this country.

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"COAL UTILIZATION IN CHINA: TECHNOLOGY OP

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Introduction

It is well known that China is the world's largest coal consumer and w
world's growth in coal utilization in the foreseeable future. Ho
appreciated that China's pattern of coal utilization by sector (electri
residential/commercial) differs drastically from that of other major c
For example, coal utilization in China's industrial sector is much
electric utility sector. Furthermore, direct coal combustion in China'
sector is extensive, currently about 200 million tons of coal per yea

Each sector in China uses coal technologies which are uniquely diffe
an analysis of coal utilization in China by sector, with special empha
coal technologies used in each sector. This analysis also includes
systems and new coal technologies which improve efficiency and r

Overview of Coal's Role in Energy, Environment, and Life in China

Coal dominates energy utilization, the environment, and life in China. Its energy role in China is much greater than in any other nation in the world. This is because of China's massive domestic resource of coal compared to its limited domestic resources of oil and natural gas. In addition, China represents one-fifth of the world's population at about 1.2 billion (10^9) people. This massive population combined with a quickly increasing standard of living leads to the largest growth in energy consumption and emissions in the world. For example, China is projected to surpass the United States as the largest emitter of CO_2 before 2025 [1].

China is facing the difficult task of maintaining a high economic growth rate that will be increasingly limited by energy supply and environmental problems. China's future is tied to improved energy technology and utilization. Currently, China is aggressively expanding its efforts in oil/natural gas exploration and production. If this does not produce massive new oil and gas reserves, it will become critical for China to greatly improve its coal utilization from an economic and environmental perspective. It must also be noted that the current practice of low subsidized (allocated) energy prices encourage waste and inefficiency [2].

Energy Overview

China is currently both the world's largest coal producer and consumer. More importantly, China represents most of the world's growth in coal utilization for the foreseeable future as shown in Figure 1.

Coal utilization in China is uniquely different from that in the United States and other major coal consumers. First, coal is 75% of China's total energy consumption, whereas in the United States, coal is only 24% of total energy consumption. Second, China consumes only 30% of its coal in electric utility boilers, whereas the United States consumes 87% of its total coal consumption in utility applications. The industrial sector is the major coal consumer in China, representing about 50% of the total coal consumed. Finally, about 20% of China's coal consumption is in the residential/commercial sector. Coal consumption in the residential/commercial and small industrial sectors represent much of the inefficiency and pollution of China's current coal utilization.

Environmental Overview

The dominance of coal utilization in China naturally creates environmental problems. Focus is usually brought on the air emissions associated with coal utilization. However, the land and water pollution associated with China's coal utilization is perhaps more serious as this stays concentrated in China, whereas air emissions are dissipated over the rest of the world. It is, therefore, useful to briefly review the problematic forms of emissions from China's coal use.

Solid Waste Emissions. Solid emissions result from coal cleaning (washing) waste and ash disposal. Coal cleaning wastes are the greater problem due to their reactivity and associated energy losses. Depending on the energy and sulfur content, coal cleaning waste leads to gob pile fires and mine acid (dilute sulfuric acid) water pollution, respectively.

Liquid Waste Emissions. Liquid wastes are associated with coal mining, coal cleaning, and the non-combustion uses of coal in China such as coke ovens. Coal mining and coal cleaning produce serious mine acid water pollution. This is a major problem because China has water shortages in many of the coal production areas. The many coke-based ammonia, town gas, and steel mills produce waste streams containing tar, benzene, and phenolic derivatives which are known carcinogens. These types of chemical and plant sites are also the historical cause of many of the current "Superfund" contaminated land sites in the United States.

Air Emissions. China has severe air pollution problems which are principally attributable to the combustion of coal. Most of the current concern and regulations relate to only ground level concentrations of particulates, SO_2, and NO_x. This promotes the use of tall stacks to better disperse air pollution, as was done in developed nations until the 1970s. Particulate air pollution is clearly the most serious air quality problem in China. This is principally from industrial and residential/commercial coal combustion due to poor combustion (excess soot), short stacks, and no particulate emission control.

In 1989 in China, it was reported that major northern cities had concentrations of total suspended particulate matter averaging 526 $\mu g/m^3$, and southern cities average 318 $\mu g/m^3$ (both annual averages). Wintertime levels of particulates are much higher due to direct coal combustion for residential heating. For perspective, the primary (health related) National Ambient Air Quality Standard in the United States for total suspended particulate matter is 50 $\mu g/m^3$.

The annual average concentrations in 1989 for SO_2 in China's northern and southern cities were reported to be 93 and 119 $\mu g/m^3$, respectively. The Primary Standard for SO_2 in the United States is 80 $\mu g/m^3$. Cities in the Shanxi province, where considerable amounts of coal are mined, had quite high concentrations of particulate matter and SO_2: Linfeng had values of 828 and 356 $\mu g/m^3$ for the two pollutants; Taiyuan had values of 783 and 409 $\mu g/m^3$. Since low sulfur coal is generally used, the ground level SO_2 emissions problem is primarily due to the use of short stacks.

Reported concentrations of NO_x do not indicate as severe a problem as particulate matter and SO_2. Only one Chinese city was reported to have an annual NO_x concentration exceeding the United States standard. However, NO_x concentrations will increase in the future as transportation fuel use (I.C. engines) expands.

Electric Utility Sector

Electric utility power generation is of greatest interest to both the Chinese and the international coal technology community. China's rapid economic growth and rising standard of living are being limited by chronic electric power shortages. China's 1991 reported electric utility power generation installed capacity was 151 GW, of which 77% was coal, 18% hydro, and 5% oil. More importantly, by 2000 the installed capacity is estimated to grow to about 300 GW. This currently requires the capacity addition of about 10-12 GW per year, of which 70-80% is coal-based. In addition, during the "ninth" five-year plan (1995 to 2000), capacity additions are projected to reach 17-20 GW per year.

This enormous growth in coal-fired utility power plants in China provides the current market for the vendors of large coal-fired power plant technology. The market for large coal-fired utility power plants in the developed nations is bleak due to excess capacity of baseload coal and nuclear power plants. Deregulation and laws that require electric utilities to purchase industrial cogenerated electricity at a fair price has consumed the limited need for new base-load capacity. Most of the remaining electric generation capacity addition requirements are currently for peaking and cycling load where new coal units are not competitive. In addition, coal-based power is not competitive at this time with natural gas-based combined cycle power plants in most developed nations because of low natural gas prices. Therefore, western vendors of traditional coal-fired utility power plants must rely on projects in Southeast Asia (including India) for the next few years.

The enormous growth in coal-fired utility power plants in China is also well timed for the Western developers of Independent Power Producer (IPP) projects. The deregulation and resulting competition in electric power generation in developed nations represents the greatest change in the world energy business since the oil price/supply shocks of the 1970s [3]. Non-utility electric power generators now supply over half of the new capacity in the United States and represent most of the growth in total electricity generation as illustrated in Figure 2. The overwhelming success of deregulated power generation in developed nations has lead the World Bank to encourage the same change in developing nations [4]. As a result, about 67.5 GW of electric power generation capacity is now being solicited for IPP ownership or build-own-operate-transfer (BOOT) in China. The capital and construction/operating expertise of IPPs from developed nations will be invaluable to China. The biggest challenge of IPPs in China will be financing and terms of payment.

China is currently building "world class" 300-600 MW pulverized coal (PC) power plants. Only a few key components need to be imported. These plants are about 35% efficient (HHV) and have low NO_x burners, electrostatic precipitators (ESP), and tall stacks. Like Australia, most power plants in China do not have flue gas desulfurization (FGD) systems. This is because, as in Australia, most of the coals in China are low sulfur. In the future, FGD systems are likely for power plants using the few high sulfur coals mined in China. These coals are generally located in Southern China. The economics of FGD (Yuan per ton sulfur recovered) will favor the use of FGD for only high sulfur coals, high removal efficiency systems, and production of byproducts that are in short supply in China [5]. Converting air pollution into

solid waste pollution is the last thing China needs. FGD systems will increase capital and operating costs while reducing efficiency. It is unrealistic to expect China to add FGD systems to power plants while many developed nations continue to build coal-fired power plants without FGD systems.

In the future, the Chinese electric utility industry will want to build coal-fired power plants based on advanced technologies such as atmospheric circulating fluidized bed combustion (CFBC), pressurized fluidized bed combustion (PFBC), and coal gasification combined cycle (CGCC). All three technologies offer higher efficiency and lower emissions than the current Chinese coal-fired power plants. Fluidized bed systems (combustion and gasification) have added advantages for use in China due to the high ash and variability of Chinese coals. In addition, the low sulfur content of most Chinese coals greatly reduces the solid waste disposal problems of fluidized bed systems. However, all three advanced coal technologies also require technology transfer, additional imported components, higher capital cost, and the highest quality construction, operation, and maintenance. The future success of these advanced coal-fired power plant technologies in China will be greatly enhanced by the presence of IPP and BOOT.

Industrial Sector

Industrial sector coal use in China is generally of less interest to the international coal technology community. However, that reflects a basic lack of understanding of this market. Industrial sector coal use in China is perhaps more important than utility sector use because of the following [6]:

- Industrial coal use in China is currently about 550 million tons per year and is likely to grow at a rate equal to utility growth in coal consumption (tons per year increase).

- Industrial coal use in China represents the largest source of air pollution. The ground level particulate emissions from industrial boilers are much worse than that from utility boilers due to poorer combustion, lack of particulate control, and short stacks.

- Industrial cogeneration is a "win-win" situation. Industrial cogeneration has the potential of much higher efficiency than that of the most advanced power plant. Furthermore, it can be done with simple domestic technology as well as with advanced coal technology

- Many parts of the industrial sector in China are experienced with international trade and technology licensing.

- However, the greatest advantage of the Chinese industrial sector is the availability of "hard currency." This makes IPP and BOOT financing and terms of payment much easier than for utility projects.

The dominant industrial coal use in China is in firing relatively small stoker boilers. These boilers are very inefficient: principally due to the poor and constantly varying quality of coal. It is common to find coals with 50% fines and 25% ash being burned in these stoker boilers. This naturally leads to high carbon losses as soot since stoker boilers cannot effectively burn large amounts of coal fines. This situation can be greatly improved at low cost by developing and encouraging "stoker grade" coal. Specifically, low cost screening systems could be added at mines to segregate coarse coal for use in the many small industrial stoker boilers and fines for use in a few large PC boilers. In addition, cyclone char recycle systems and low cost baghouse systems could be added to existing stoker boilers.

New industrial boilers clearly favor the use of CFBC boilers because of fines content, coal variability, and low sulfur content. There is also the highly successful experience of the numerous CFBC boilers for industrial cogeneration in the United States. Licensed CFBC boilers are already being built in the industrial sector in China. SFA Pacific's FBC database shows a total of 19 licensed CFBC units in 10 Chinese locations with a total steam generation capacity of 2,700 tons per hour. These units are based on Ahlstrom/Pyropower and Riley/Deutsche Babcock licensed CFBC technologies.

Longer-term, coal gasification will be even better for industrial cogeneration in China. Coal gasification would enable large central facilities to transport coal-derived fuel gas via pipeline to various small combustion turbine based cogenerators. This is better than steam turbine based cogeneration due to the much higher electric power to cogeneration steam ratio of combustion turbines [3]. This is important since effective cogeneration is usually cogeneration "heat host" limited. Converting an existing cogeneration heat host steam requirement from a steam turbine only system to a system that includes combustion turbines can increase electric generation by a factor of 5. Coal gasification also has other benefits including:

- Much lower emissions and better recovery of sulfur (sulfur is currently in short supply in China).

- Allows the economical development of very small commercial cogeneration systems based on internal combustion engines (for office buildings and large residential apartment buildings).

- Co-production of valuable industrial fuel gas and chemical synthesis gas.

Texaco already has several coal gasification projects in China's industrial sector based on its coal gasification process in conjunction with combustion turbine based cogeneration, industrial fuel gas, and synthesis gas chemicals [7]. The industrial use of coal gasification will greatly expand as China converts from an oil exporter to an oil importer and the "allocated" domestic oil supply/pricing system is phased out.

In the distant future, China faces a difficult situation regarding crude oil utilization. The rapidly increasing use of liquid transportation fuels will force China to become a major oil importer. A first step in alleviation of this problem is conversion of oil-fired boilers to coal. This is enhanced by coal technologies such as coal water mixtures (CWM), slagging combustors, and low technology coal gasification systems (gas producers). The replaced fuel oil can be converted to high value light distillates (diesel and gasoline) by cost-effective heavy oil conversion technologies commercialized by the international oil refining community [8].

There are also many other innovative ways to utilize domestic coal to improve China's petroleum position. Coal-based steam generation and CO_2 will be required for enhanced oil recovery. Advanced coal technologies can also be required in oil refineries to increase liquid product yield substantially [9]. This would likely involve direct coal combustion for refinery utilities, coal gasification for refinery fuel gas and synthesis gas, coal/residual oil coprocessing, and indirect coal liquefaction.

Residential and Commercial Sector

Per ton of coal consumed, the residential and commercial sector represents the most severe pollution problem in China. The large increase of ground level emissions in China's northern cities during the winter is principally due to residential heating by direct coal combustion. This coal combustion is of even lower efficiency, produces higher emissions, and has lower stacks than industrial coal boilers. There are great opportunities for improvement considering that direct coal use in China's residential and commercial sector is about 200 million tons per year.

China has made great strides in improving the quality and quantity of residential and commercial energy. Innovative anthracite briquettes have been developed for cooking. Liquefied petroleum gas (LPG) and town gas are also available in many of the major cities. The town gas is usually produced from coal via coke ovens and sometimes vertical retorts. However, the principal energy product of coke ovens is the coke, not the coke oven gas. The capital cost of coke ovens is very high per unit of town gas produced. In addition, metallurgical grade coals required for coke ovens are of very high quality and are in short supply due to critical expansions required in China's steel industry.

Large industries and some municipal electric utilities are also developing cogeneration/hot water district heating systems in the major northern cities of China for wintertime heating. However, the capital cost of district heating infrastructure is very high. Even worse, the electric power output drops to about one-half when the power plant steam turbine generators are converted from condensing to back pressure or steam extraction operation, which is required for district heating.

Town gas and district heating energy supplies will continue to increase as the allocated energy supply/price system in China is phased out. The current low (allocated) town gas prices make coke ovens the only economical source of town gas because the large revenues of valuable merchant coke sales is used to subsidize the small town gas sales revenues. Increasing town

gas and district heating energy prices to reasonable levels will spur interest in the electric utility and industrial sectors. Furthermore, premium residential energy supplies by the utility and industrial sectors will be based on high efficiency and low emission technology coal use.

There is significant potential in China for integrated steel mills and oil refineries to sell their existing methane-rich internal fuel gas as town gas. Direct coal combustion and low technology coal gasification processes can be used to replace the existing steel mill coke oven gas and the oil refinery "refinery gas." Longer-term, extensive coal-based town gas facilities will be required unless large natural gas reserves are discovered and developed.

There is better potential for electric power generators to supply district heating once they receive a reasonable price for the hot water. However, continued electric power shortages in China will favor district heating based on combustion turbines. This is because the drop in electric output when cogenerating hot water is minimal for combustion turbine-based power generation. However, since combustion turbines require a clean fuel gas, this application must wait for long-term development of CGCC or improved town gas supplies.

As mentioned previously, expanded coal-based town gas will be required longer-term unless large domestic natural gas reserves are discovered and developed. As with natural gas in developed nations, town gas allows low emission and high efficiency energy use in the residential and commercial sector. This will require modern coal gasification systems that maximize the direct methane production. This clearly favors oxygen-blown, high pressure systems based on moving-bed or fluidized-bed coal gasification processes.

Summary

Considering that China represents one-fifth of the world's population, the dramatic improvement in living standards in much of China over the last 15 years is one of the greatest economic achievements of the twentieth century. Much of China's impressive economic growth has been based on export of crude oil and consumer products. However, as already discussed, China's crude oil position is quickly eroding. Also, the consumer products are based on labor-intensive manufacturing where the key issues are low wages and ample electric supplies.

China has now reached a critical point in its economic development. The massive populations in the rural areas of China will begin to share more of the increasing standard of living. Furthermore, the people in the major cities and Southeastern China, which already have the higher standard of living, will use automobiles increasingly in place of over-crowded buses, and motorcycles in place of bicycles. Finally, housing and infrastructure in China will continue to improve overall. This will greatly increase per capita energy consumption.

Simply stated, if China's per capita fossil fuel consumption increased from its current level (about 27 million Btu per person per year) to the same as Canada (about 270 million Btu per person per year) China's fossil fuel requirements would increase by a factor of 10 and the total world fossil fuel requirements would more than double. For both worldwide environmental

and energy supply reasons, it is essential that China utilize the cleanest and most efficient coal technologies. In other words, it is in the best interest of the developed nations to make sure that China has access to the coal technologies that increase efficiency and reduce pollution.

If China continues to rely on coal as its principal source of energy, coal technologies and applications must be pursued that differ from those used in developed nations. Coal is generally used only in large central power stations in most developed nations. However, this is because the residential/commercial and industrial sectors use mostly natural gas and oil. The lack of domestic natural gas and oil make the industrial and residential/commercial sectors the largest coal consumers--and polluters in China.

Advanced coal-based power plant technologies are attractive for China due to persistent power shortages. They also have efficiency advantages over older existing power plants. However, this has little impact on overall efficiency and environmental emissions in China. Advanced coal-based technologies also represent increased capital costs, key technology transfer, increased imports of components, and improved operation and maintenance. Furthermore, the most advanced stand-alone power plant is only about one-half as efficient as modern industrial and commercial cogeneration systems. Industrial and utility cogeneration must be encouraged by offering attractive prices for this higher efficiency source of electricity and hot water, regardless of the supplier or consumer. The same applies for town gas, natural gas, and coal bed methane.

Short-term, atmospheric circulating fluidized bed combustion is the coal technology of greatest need in China because of the properties of the local coals and the large use of coal in small inefficient industrial boilers. In addition, continued improvement in the coal allocation and pricing policy will discourage the mining and addition of rock with coal merely to increase tonnage during mining and will encourage the availability of "stoker grade" coal.

Long-term, modern coal gasification is strategic to China's energy and environmental future. This is the only coal technology that meets the long-term requirement for all the important energy needs and sectors: electric power generation, cogeneration, town gas, and premium liquid transportation fuels.

The markets for coal technology in China are vast and expanding rapidly. At the same time, the developed nations' need for their own improved coal technologies is currently dormant. This creates a unique opportunity for both China and the international coal technology community to work together. Challenges exist regarding technology transfer, financing, and terms of payment [10]. However, these issues can be resolved if the focus is kept on the fact that China's approach to coal utilization will dramatically affect the energy and environmental future of the entire world.

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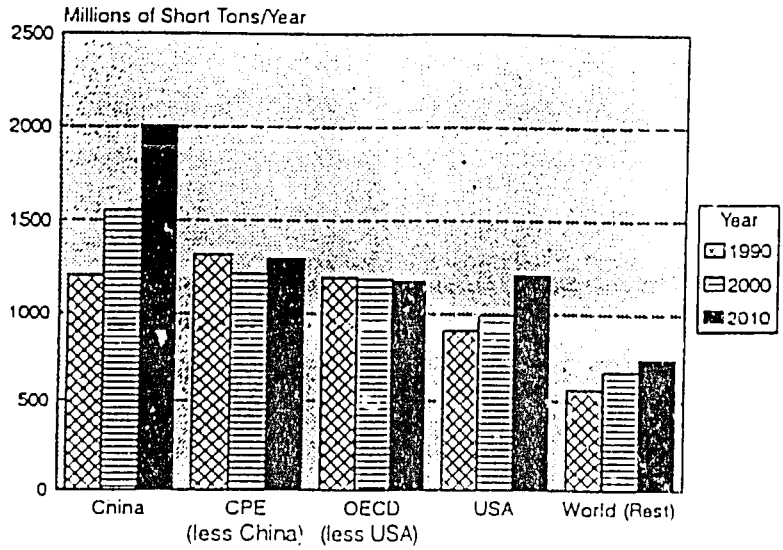
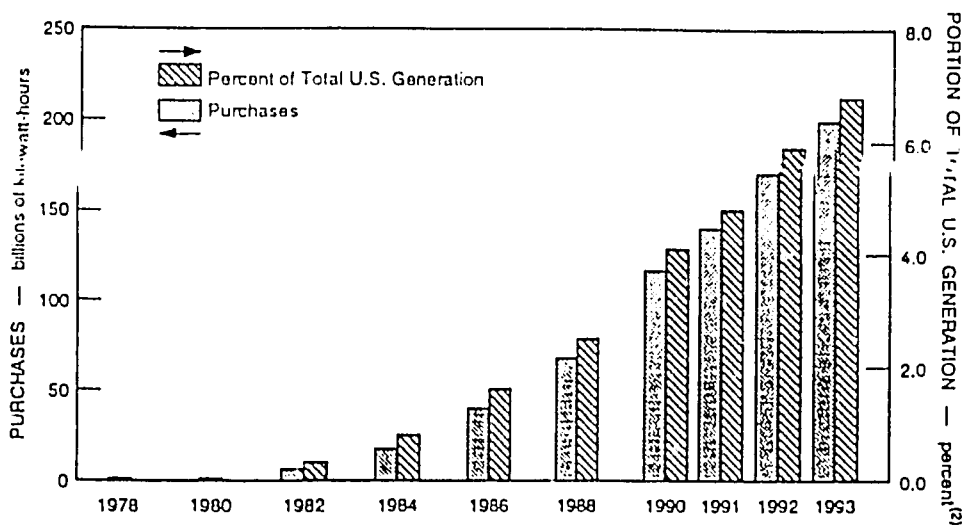
Figure 1
World Coal Consumption



Source: Modified by SFA Pacific, Inc. from EIA/International Energy Outlook, 1992; Reference 10

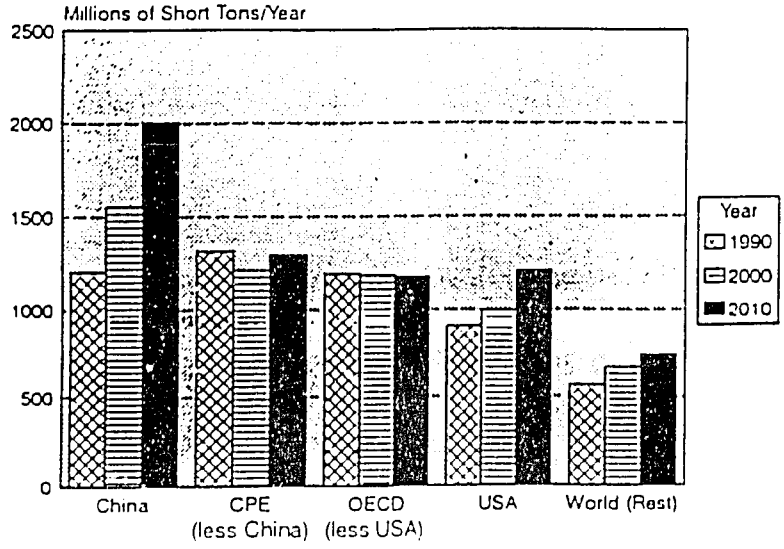
Figure 2
Electricity Purchased from Non-Utility Power Producers
by Electric Utilities in the U.S.[1]
(billion (10^9) kilowatt-hours)



[1] Total non-utility power producer generation is approximately 50% larger than these figures
[2] SFA Pacific, Inc. estimate

Source: Modified by SFA Pacific, Inc. from EIA/Annual Energy Review, 1992; Reference 7

Figure 1
World Coal Consumption



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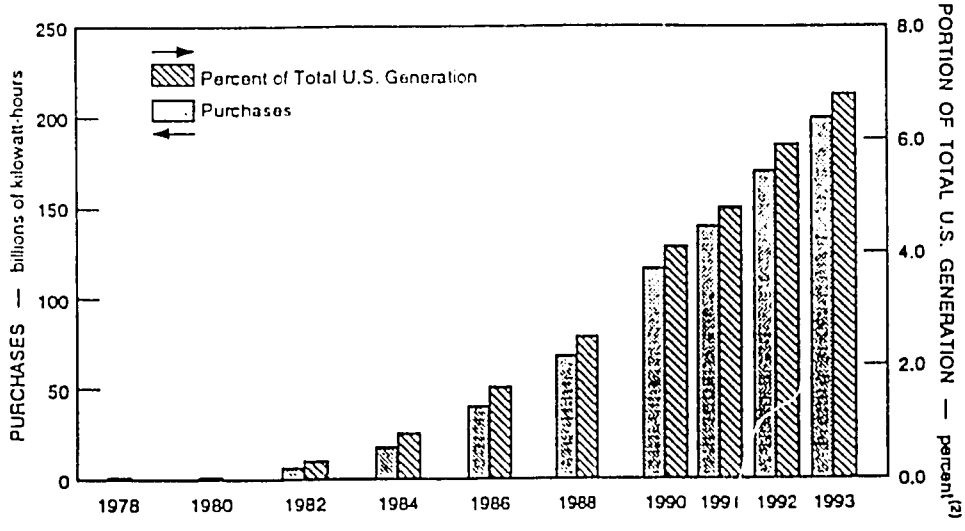

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DEVELOPMENT AND OPTION OF RETROFIT AND NEW TECHNOLOGIES FOR LOW-RANK COAL

G.Moumdjian; Bulgaria

ABSTRACT

Many countries in South-Eastern Europe, including Bulgaria, on the basis of economic reasons and aiming at relative independence on external energy resources have developed PCF technologies for low-rank coal utilization with caloricity reaching 1100 kcal/kg A^d=38%, W^r=55% , S=2% (for Bulgaria).

The gained technological successes in Bulgaria during the last 20 years coincided in time with the dynamically changing ecological requirements in the industrialized countries. In the period 1980-1993 these requirements gained international and global dimensions.

The impossibility of the operating low-rank coal utilization technologies to satisfy the new criteria is unfortunately connected with the scientific, economical and technical unpreparedness for commercial application of Retrofit technologies or commissioning of new ones.

The analysis of the problem regarding the emissions values and CO_2 reduction through reducing the low-rank (steam) coal consumption leads to some alternatives of compromise.
energy consumption restructuring, improvement the energy efficiency in resources-end user system, transition to combined heat and power production and application of cleaning-up technologies distributed along the whole track fuel-exhaust gases.

CO_2 and emissions values reduction are also connected with decision concerning the change of coal quality.

The analysis of the development rate of retrofit and new technologies for LRC, unfortunately, does not give possibilities to make a drastic turn for a period of 10-15 years in relation to the emission indices of the energy technologies.

The absence of acceptable technological and economic possibilities for improvement of the ecological indices of those technologies can be balanced partially too, applying an appropriate control of the load of the set of power production capacities in operation.

PRODUCTION OF COAL BASED DOMESTIC FUEL:AN ENVIRONMENTALLY FRIENDLY TECHNOLOGY

BY : BC MISRA, RK CHAKRABARTI** & CK BASU****

1.0 INTRODUCTION

India, with only 22% of the global land area is accommodating 16% of the global population. The Energy scenario is still more bleak with only 0.8% of coal reserve and 0.6% of oil reserve of the world and most of the coal reserve being of inferior quality. Still, in Indian context, the recoverable coal reserve has a life of 100 years at an annual recovery of 500 million tonnes (mt) compared to only 24 years in case of crude oil at the current rate of production of about 30 mt. Hence, our emphasis is on the utilisation of coal to the extent possible to meet our energy need. In fact, in our country, the trend of production of primary commercial energy indicates a considerable rise in the recent past to match with the industrial activity in the country. The trend of production is shown in Table-1.

TABLE - 1

TREND OF PRODUCTION OF PRIMARY COMMERCIAL ENERGY

Energy form	PRODUCTION				
	1950-51	1960-61	1970-71	1980-81	1990-91
Coal in mt	33.00	55.67	72.95	114.01	211.73
Lignite in mt	-	0.05	3.39	4.8	14.07
Crude Oil in mt	0.26	0.45	6.82	10.51	33.02
Natural Gas in million m^3	-	-	1445	2358	17998
Hydro Power in B Kwh	2.52	7.84	25.25	46.54	71.54
Nuclear Power in B Kwh	-	-	2.42	3.00	6.24

From the table, it is evident that production of coal has increased from meagre 33 million tonnes in 1950-51 to 211 million tonnes in 1990-91. In comparison, the production figures of other fuels are quite low. This indicates the emphasis on usage of coal as the source of energy. Sectoral consumption/demand of coal in India is shown in the Table-2.

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** GENERAL MANAGER (COAL TECHNOLOGY), CMPDIL, RANCHI (INDIA)
*** SUPTDG. COAL TECHNOLOGIST, CMPDIL, RANCHI (INDIA)

TABLE - 2

SECTORAL CONSUMPTION/DEMAND OF COAL IN INDIA

Sector	1955-56	1965-66	1973-74	1984-85	1989-90	1993-94 proposed
Steel (including Coke-Ovens)	3.40	11.70	13.78	25.33	28.37	35.00
Steel (DR)	-	-	-	-	-	1.60
Power (Utilities)	3.16	10.50	16.64 (1.26)	61.98 (2.25)	133.00 (2.12)	157.10 (2.90)
Railways	13.35	16.80	13.92	9.52	5.73	3.60
Cement	-	-	3.65	7.07	8.74	13.10
Fertilizers	13.78	-	-	3.89	3.97	3.70
Brick & other Industries	-	13.90	22.27 (1.08)	26.17 (1.33)	34.55	31.00 (0.025)
Captive Power	-	-	-	-	-	15.40 (2.65)
Soft-Coke/LTC	-	3.60	4.65	2.24	1.30	4.10 (0.20)
Export	1.78	0.80	0.62	0.11	0.16	0.20
Colliery Consumption	-	2.80	2.77	4.02	3.47	4.00
Total	35.47	60.10	75.53 (2.34)	140.33 (3.58)	219.79 (2.12)	268.80 (6.00)

N.B. : *The figures in the brackets indicate consumption of middlings.*

This table gives us a fair idea of the pattern of coal use in India. One point to note here is that consumption of domestic sector, i.e. for production of Soft-coke/LTC is very meagre. This does not indicate that the demand of domestic fuel is so low. In fact, this indicates production which is far behind the actual demand. The current domestic energy consumption is of the order of 270 million tonnes of coal equivalent with following break-up :

Fuel	Quantity (in million tonnes) (Coal equivalent/year)
Soft-coke/Semi-coke	2.2
Liquified Petroleum Gas	13.3
Kerosene	32.0
Coal Briquette	1.8
Raw Coal	3.0
Other Non-commercial fuels	217.7
Total	270.0

It is evident from the figures that commercial fuels constitute only around 20% of the total energy consumed and the rest 80% comes from non-commercial sources like Fire-Wood, Agricultural products, Animal dugs etc. It has been estimated that at present annually about 118 million tonne of Fire-Wood and 78.7 million tonnes of Animal dung are used as domestic fu... This is likely to increase to 135 mt & 91.5 mt per year respectively by 1999-2000 according to National Council of Applied Economic Research (NCAER). Such massive and increasing use of non-commercial fuels is bound to lead to disastrous consequences on the environmental front particularly the use of Fire-Wood resulting in deforestation. This will not only affect ecological balance by way of deforestation but will also affect soil fertility due to diversion of animal dung from its more gainful use as organic manure with serious consequences. Substitution of non-commercial by commercial fuel for domestic use is, therefore, a must. With limited resources and production of oil in India, there is no other way but to take recourse to Coal based domestic fuel to avoid an ecological disaster. It has been estimated that each million tonne coal based fuel can replace about 2.6 mt of Fire-Wood or 6.25 mt of dry animal dung.

Emphasis has, therefore, been given on development and adoption of technologies for production of coal based environmetal friendly domestic fuels. This paper deals with some such technologies. The issue of replacing non-commercial fuels take Fire-Wood & Animal dung is of relevance to other developing countries of Asia & Pacific region too. The technologies developed in India for environmental friendly domestic fuel based on coal can be of relevance to other countries and the region also.

2.0 TECHNOLOGIES

The technologies developed or adopted have been identified keeping in view various segments of our population. The technologies discussed here are :

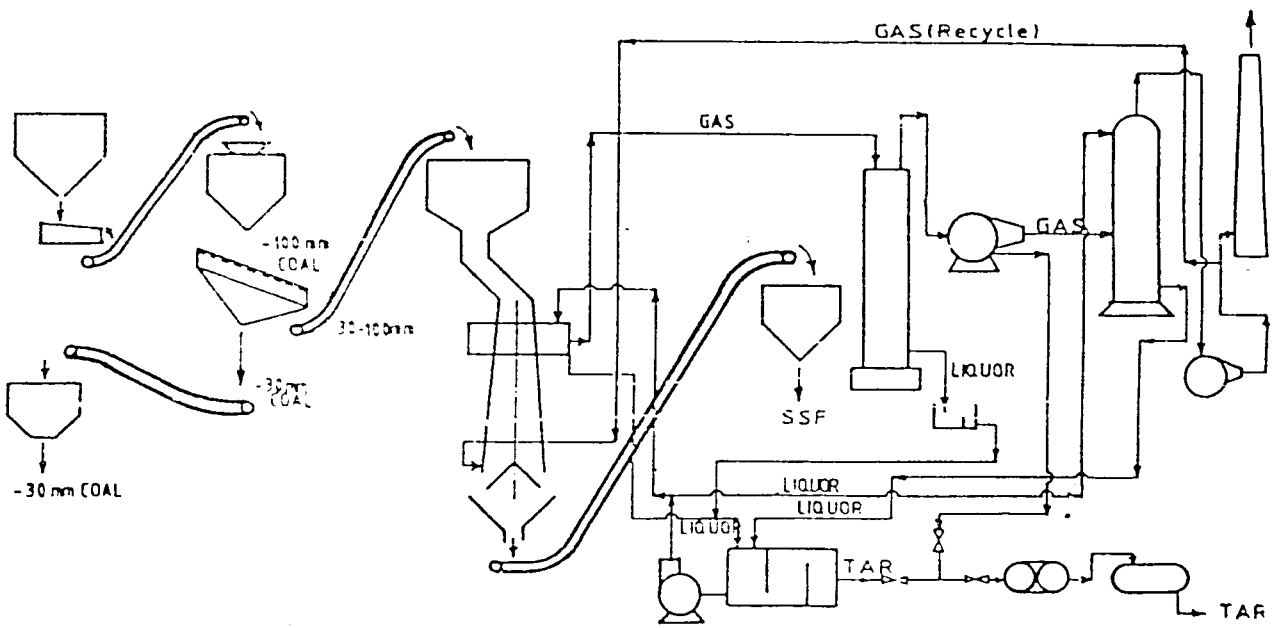
- Special Smokeless Fuel (SSF)
- Coal Agglomerate
- Coal Briquette
- Fuel Gas & Semi-coke - *Adopted*

2.1 SPECIAL SMOKELESS FUEL (SSF)

Out of the various technologies developed, use of coal as environmental friendly domestic fuel. *SPECIAL SMOKELESS FUEL* (SSF) technology deserves a special position for reasons of ease of manufacturing, suitability for wide ranging coal quality (ash range upto 42%) and low cost with least air pollution particularly for particulate matter, SO_2 & also NO_x.

Conventional domestic fuel in India other than petroleum products and non-commercial energy sources has been *SOFT COKE*, produced through conventional openstack burning of lump caking coal, and thereafter quenching it with water. This does not provide total and consistent devolatilisation and is also wasteful processd from

SCHEMATIC FLOW SHEET FOR SSF PLANT



energy conservation point of view. Thus, Soft-Coke does not give pollution free burning in domestic use and is not adequately environmetal friendly either at the user's end or at the production end where profuse smoke emission takes place in a concentrated area.

Special-Smokeless Fuel is a mechanised process of converting raw coal even non-caking into consistent quality smokeless domestic fuel under controlled burning in retorts specially designed for the purpose with controlled air feed, control of temperature, residence time, etc. The volatiles are not allowed into the atmosphere but suitably trapped and converted into tar for other use. Energy wasting in burning is also checked through better heat exchange between outgoing gasses and the coal and also by water quenching of the final product under controlled conditions.

The technology has been developed and patented by sustained efforts, pilot plant/demonstration plant over a period of time. Coals earlier not being considered suitable for domestic fuel particularly high ash (upto 42% ash) non-coking coal have been successfully utilised. Numerous small scale (100 tonnes per day) plant using such coals have come up and are providing much needed domestic fuel.

With expertise developed in this sphere over a period of time and with testing and pilot/demonstration plant facilities available with us, we can undertake testing of all type of coals and finding out ways & means to make them suitable for Environmental friendly domestic fuel and thereafter plan and design & construct such plant in any country based on its requirements.

A schematic flow diagram of the process is shown in the enclosed figure. Steam coal is fed into a crusher to size it below 100mm. The product from the crusher is fed on a screen on 30mm apperture. The -30mm fraction is screened out and the 30-100mm fraction is fed to the service bunker over the retort. The retort is the main item of development. It is a shallow depth vertical retort made of refractory bricks and refractory arches. The sized coal fed at the top gravitates down the retort, counter current with the rising gas generated out of devolatilisation and partial combustion and gets devolatilised through exchange of heat with the rising gas before being discharged as hot coke through the bottom of the retort. The heat of devolatilisation is obtained on partial combustion of volatiles in the coal and to some extent its fixed carbon. The gas leaving the retort is subjected to spraying and cooling before it passes through expansion vessel, exhauster and venturi scrubber where bulk of the tar contained in the gas is separated out. The tar free gas is then partially recycled back to the retort for improving the productivity and yield of tar, the balance gas is vented to the atmosphere. The vented gas is almost clean having virtually no fuel value and does not cause any pollution. The hot coke coming out of the retorts is quenched with water and conveyed to the product storage for despatch.

The technology has got several advantages like :

- Minimisation of air pollution
- Recovery of Bye-product tar
- Consistent quality product
- Low capital investment
- Utilisation of low grade coals
- Low cost fuel

The merit of the technology is established by the fact that within a span of 5 years, already 35 plants have gone into commercial production and many more are in various stages of implementation in India. These plants are mostly of 100 tonnes per day production capacity. One Plant of about 500 tonnes per day coal tnroughput capacity is nearing completion. The broad basic information, coal quality limits, product quality etc. of a 100 tonnes per day plant are as follows :

Limits of Coal Quality :

Ash Percentage	Upto 42
Volatile Percentage	Above 14
Caking Index	Upto 12
Size range	30-100mm

Product Quality limits : (dependant on Raw coal quality)

Ash Percentage	< 50
Volatile Percentage	< 10
Sized coal throughput/day	120 tonnes
Yield of Coke	About 78% of the Feed (dependant on coal quality)
Yield of Tar	About 1.0% to 2.5% (dependant on coal quality)
Space requirement for the Plant	About 2 Acres
Water requirement per day	$60m^3$

2.2 COAL AGGLOMERATE

While SSF is meant for Urban & Semi-urban population, a cheaper fuel, coal agglomerate has been developed for weaker section of rural population. This fuel is made out of low grade/rank coal fines/slack. The coal is finely ground, mixed with required quantity of proper binder and agglomerated in a disc pelletiser. The raw/green agglomerates, thus, produced are dried in a continuous drier, heated with hot flue gas. The dried product is ready for use. The success of the process lies in proper grinding

of the coal to required size, proper mixing and proper agglomeration. The product gives a little smoke if burnt as such in a domestic appliance. Suitable devolatalising technique and equipment for making it perfectly smokeles and weather resistant fuel has also been developed and patented. The manufacturer of the product has the choice to market as such or after devolatilisation thus offering product as per need and capability of the consumers. This type of domestic fuel and the small plant required for it has special significance for weaker section of population in non-urban areas.

2.3 COAL BRIQUETTE

Briquetting of coal using binders is an established practice. For making it smokeless, it has to be carbonised. In India, briquette carbonisers, so long in use, were of low productivity and pollute the air in the atmosphere. Recently, a briquette carboniser with high productivity and air polution control has been developed and patented by CMPDIL. Unlike the conventional carbonisers, this is continuous vertical type. The height and slope of the carboniser has been fixed in such a way that breakage of the briquettes is minimum. The system has been designed in such a way that the tar laden gas is not released into the atmosphere. The dried briquettes are fed from the top and the carbonised briquettes are discharged from the bottom, quenched with water and sent for storage.

2.4 FUEL GAS & SEMI-COKE

A commercial plant of Low Temperature Carbonisation (LTC) *(Adopted Technology)* of coal has been set-up near Calcutta to produce fuel gas and solid domestic fuel known as Semi-coke. The target consumer is urban population as well as small industries. The plant is based on Woodall-Duckham Technology. In this process, sized coal is devolatilised in externally heated continuous vertical retorts. The walls of the retorts are made of silica brick for facilitating condition of heat from the adjascent flue chambers where producer gas generated out of the coal is burnt with pre-heated air. Since the system is externally heated, the gas produced out of devolatilisation of the coal is of medium calarific value. The gas is detarred, its pressure boosted and supplied into gas pipelines for distribution to the consumers. The solid product coming out of the retorts is called Semi-coke (commercially termed CIL coke). This is a consistent quality uniformly sized solid domestic fuel. The feed coal to the system is of good quality and so the Semi-coke produced. This Semi-coke is also being used for commercial purposes.

The Dankuni Plant is of 1500 tonnes per day sized coal throughput capacity. It produces around 1000 tonnes of Semi-coke, 0.5 Nm^3 of fuel gas and 72 tonnes of tar per day. Provision is there for fractionating the tar. The product pattern from the plant is as under :

i) Semi-Coke	351450 tonne per year
ii) Gas	186.8×10^6 Nm^3/year

iii) Tar Product

a)	Neutral Oil	13000 tonne/year
b)	Pitch	11000 tonne/year
c)	Phenol	430 tonne/year
d)	O-Cresol	190 tonne/year
e)	M-P-Cresol	400 tonne/year
f)	Xylenols	600 tonne/year
g)	HBTA	520 tonne/year

iv) Other Products

a)	Sulphur	580 tonne/year
b)	Calcium Carbonate	5620 tonne/year
c)	Ammonium Sulphate	5500 tonne/year
d)	Coal Fines	83780 tonne/year

3.0 CONCLUSION

Non-commercial sources of Energy particularly Fire-Wood, Agricultural wastes, Animal dung being the main source of domestic fuel in India and other developing countries deforestation and deprivation of soil of organic manure/nutrients is proceeding at a pace that may lead to an environmental situation totally upsetting the natural ECO-BALANCE resulting in disastrous situation. This is further accentuated by rising population and increasing domestic fuel demand. In developing non-oil rich countries, coal is the only commercial fuel which can replace and reduce consumption of forest products and animal waste. But coal has its problems too of causing air pollution and is not a welcome fuel as such for domestic use.

But now after prolonged work suitable technologies have been developed to produce acceptable quality coal based domestic fuel in an environmental friendly way utilising any variety and size of coal. These technologies developed can be applied on small and medium scale with comparatively less skill and capital. These technologies with small plants spread over the various consumption centres have become popular in India.

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COAL TECHNOLOGIES

TECHNOLOGY OPTIONS. OVERVIEW

COAL TECHNOLOGY FOR DEVELOPING COUNTRIES

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1.COAL-PRIMARY ENERGY SOURCE FOR DEVELOPING COUNTRIES.

Generally,developing countries have been defined according to the per capita energy consumption under 1.0 toe.This paper also approaches the former centrally planned economies of Eastern Europe,for which this parameter is high, but for which the high energy intensity values (toe/1000$) exceed by far the corresponding values of OECD countries.

From a total world consumption of coal for energy the former USSR and Eastern Europe and respectively Asia have 406,respectively 793 millions toe of 2186 millions toe.The quantity of coal used in Latin America and Africa (South Africa excepted) are least.

Over 60% of the world's coal resources are found in developing countries,50% in China only,the former Soviet Union having 13%.

The developing countries' installed energy capacity is estimated at 470 GW/year;also,the countries with over three quarters of world's population are responsibly only for less than one quarter of all fossil fuel-based emissions;they require energy intensive groth,then the project level of 855 GW per year should be achieved by the year 2000 (1).

Developing and emerging countries coal-fired power plants summary for 1990 (2) is shown in table 1. For a worldwide total of 97 exajoules of primary energy provided by coal developing and emerging countries represent 56 exajoules .

Asia. High-growth economies and the subsequent rapid rise in the electric capacity demand establishes Asia as the world's most significant market for new power project opportunities.It is difficult to generalise about a continent as vast as Asia.From the electricity supply and power generation standpoint the most representative are China,India and Southeast Rim countries:Thailand,Malaysia and Indonesia.China and India will heavily rely on coal accounting for over 70% of additions in China and almost 60% in India.The South-East Rim countries project using coal to fuel 32% of their capacity additions through the end of the decade (3).

China coal demand projection shows an increasing from 716.8 Mtce in 1990 to 992 Mtce in 2000 and 1536 Mtce in 2020 (4).Indian coal demand for power utilities projections shows an increase from 110 mil.t in 1989-1990 to 218 mil.t in 1999-2000 (5). In 1992,in Indonesia, domestic coal use for power generation was 5.3 mil.t from a total coal production of 23.0 mil.t.At present,the total coal-fired electricity generating capacity is 1925 MW but about 11.860 MW is planned to be installed by 1999, requiring respectively about 28.4 mil.t of coal per year (6). Israel,a country which has no coal resources,adopted in 1975 the strategy according to which all new power plants should be based on coal:actually,more than 50% of electricity is coal produced (7).

Former Soviet Union.At present Russia accounts for around 60% of the former Soviet Union's production and almost all of the remaining 40% is nearly equally shared between Ukraine and Kazakhstan (8). In 1991 in Russia the total amounts of coal used in power stations was over 130 mil.t (9).Projections are to stop electricity production decrease reaching the 1990 production level by 1995-1997 and to provide its growth up to 1.2-1.5 trln kWh by the years 2000-2010 (8).

Eastern Europe.Most of the Central and Eastern Europe countries (former planned economies) have coal resources, but much of this coal is rather low-rank and low-grade (Poland excepted). The largest quantity of coal is used for electricity generation,but its share in the utilities varies between wide limits: 95% in Poland, 60% in the Czech Republic and Slovack Republic and around 30% in Romania,Hungaria and Bulgaria (10,11). In Latvia, whose 92% of the energy resources are imported, the existing power plants use gas and heavy oil,but the new power plants are designed on imported coal. In order to overcome their national economy crisis, not only Latvia but also Estonia and Lithuania must solve coal supply problems with the Western countries help (12).

Africa. About 75% of the total estimated reserves of Africa are in the Republic of South Africa (RSA).Coal consumption for power generation represents 73 mil. t/year, respectively 40 % of the total coal consumption by market sector. Given that 1991 RSA's annual coal sales were 179 mil.t representing more than 90 % of the coal produced on the African continent (13).

Latin American and Caribbean Region . The Latin American and Caribbean Region's coal reserves are 38 % of its total fossil fuels. The countries having the greatest coal resources (for example Columbia and Venezuela) have good-quality reserves with low-sulphur and ash contents. During 1980 - 1986 the Region's coal consumption for electricity generation increased , but between 1987 - 1991 consumption fell to 4 % due to the oil prices decrease and the economic recession. The Region's coal consumption is about 1 % of the world total. In 1991, coal consumption barely contributed with 3 % of the total amount of energy sources responsible for CO2 emission (14).

2. NECESITY TO APPLY CLEAN COAL TECHNOLOGIES (CCTs) IN DEVELOPING AND EMERGING COUNTRIES

Developing and emerging countries found themselves in different situations : countries which have great coal resources and export coal (China.South-Africa. Russia.Poland) , countries which have only limited sources and of low-rank quality (Romania. Hungaria.Czech Republic. Bulgaria) and countries which have not their own coal sources and import coal (Israel. Latvia).

But the statistics and the predictions show that almost all developing economies look for coal to provide much of the increased electricity. Coal used for power generation pollute air . water and soil . Air pollution generates two damaging effects: acid rains. due to SOx and NOx emissions and contribute to the climatic change due to the greenhouse effect caused by CO_2 emissions. Also. there are two difficult problems to solve : the first having immediately consequences and the second being very dangerous in the future.

The first problem - acid rains - causing lake acidification . forest damage. human health damage . etc. is very accute in Europe.In Asia. Latin America and Caribbean Region acid rains has accured only in the largest cities and mainly because of the oil products consumption.

The second problem - combustion coal contribution to the greenhouse global warming effect - remain a problem in the future. but with most important consequences for the whole planet.Replacement of non-efficent coal-fire power plants by new CCTs over the next 40 years can have a dramatic effect on both energy efficienty for power generation and impact on the environment. (2)

3. CLEAN COAL TECHNOLOGIES

There is only one possibility to change the black and dirty image of coal : to apply the CCTs. The criteria which have determined to choose CCTs are the emission reduction . efficiency. fuel flexibility and costs.

There are a lot of reports which have extensively dealt with technical. environmental and economic details at CCTs (15.16.17.18).

Depending on the stading which this technologies is applied. CCT can be classified in :
- precombustion - coal cleaning (CC):
- during combustion : circulating fluidized bed combustion (CFBC) and pressurized fluidized bed combustion (PFBC):
- postcombustion : advanced pulverized-coal combustion with flue gas desulphurisation (PC + FGD) (and de - NOx):
- conversion : integrated gasification combined cycle (IGCC).

There is also hybrid cycles - as topping cycles which try the combination of other technologies to obtain more advantages. (18) Cycles based on fuel cells and magnetohydrodynamics (MHD) will be used on long term.The major candidates will clearly be PFBC.IGCC and more advanced PC plants.

Coal cleaning (CC) (24.21.19.20).

CC removes primarily pyritic sulphur (up to 70% SO2 reduction can be possible) and ash content.increasing the heating value of coal with 10 to 30 percent.Conventional coal preparation plants generally use methods developed at least 40 years ago. There is no large scale activity in low-rank coals and lignites until now.

The decision to implement this type of strategy to the utilities is essentially dependent upon the savings achieved by coal cleaning.The factors which determine these savings are:
* coal cleaning costs depend on the cleaning plant capital costs. cleaning plant operation and maintenance,the value of lower-quality coal disorded in the cleaning process:
* market difference between the prices of good-quality coal (similar with those obtained after cleaning) and the low-quality coal which is cleaned:
* the benefits obtained by the reducing size of coal handling and ash handling equipment (capital and maintenance costs):
* the benefits obtained by the boiler efficiency increase:
* savings due to:less expensive flue gas processing equipment use (reagent quantity reduction.amount of solid waste requiring disposal reduction.

Clean coal process efficiency depends on the coal characteristics quality :the amount . nature and size of mineral matter. the relative proportions of pyritic and organic sulphur.the size distribution of the coal. coal oxidation. the porozity of particles.

Circulating Fluidized Bed Combustion (CFBC) (21.22.23)

The main advantage of CFBC sistems are : the ability to burn low-grade fuels with minimal preparation. the in-bed sulphur absorbtion capability and the low combustion temerature which inhibits NOx formation. The SO2 reduction is about 90 %. sulphur being eliminated as gypsum (dry. granular waste). NOx are 60 ÷ 80 lower than in case of PC systems. CFBC plant efficiency is comparable to those of PC plants - about 36 %.

The producing electricity costs by CFBC plants is comparative to those of PC plants and have the advantage of pollution control and a high fuel flexibility degree. The largest CFBC units in operation have electrical outputs of about 150 MW. although units of up to about 250 MW are under construction.

Pressurized Fluidized Bed System (PCFC) (15.16.23)

The low combustion temperature inhibits NOx production and operation under pressure enhances sulphur retention when limestone (or equivalent) is added to the PFB. The succesful operation of the gas turbine depends on the cleaning of the exhaust gas from the PFBC to avoid the errosion and corrosion of the turbine blades. SO2 reduction is about 95 % , and NOx concentration are with over 90 % lower than the PC systems. PFBC efficiency is up to 45 % (first commercial - 40 %) . The "first generation" PFBC is in commercial operation.

Advanced pulverized coal with flue gas desulphurization (PC + FGD) (and de-NOx) (24.25.26.27)

Improvement of PC efficiency was obtained by the use of supercritical pressure (up to 350 bar), double reheat and steam temperatures of the order 560 - 650 °C. These conditions mean that materials are required to operate close to their designed limits. Efficiency is 42-45 % . Emissions control is made by using low-NOx burners and by installing flue gas desulphurization (FGD) and selective catalytic reduction (SCR) equipments. The most used FGD-system is wet scrubbers , followed by spray dryers and which are large commercial available. Combined NOx/SO2 control processes offer the potential to reduce SO2 and NOx emissions for less than the combined costs of SCR and conventional FGD. Most processes are under a developing stage and are not commercially available, although several processes have been applied to low sulphur coal-fired boilers.

Integrated Coal Gasification Combined Cycle (IGCC) (28.29)

IGCC is promoted as a "very clean " technology. SO2 reduction is of 99 % and NOx reduction is over 90 % lower than PC systems. Plant efficiency is up to 47 % (first commercial 42 %) Different from other CCTs , the quantities of solid waste are very reduced and the sulphur is eliminated as elemental sulphur.Particulate emission is very reduced due to clean-up before gas turbine. The technology is not yet commercial available, the existing plants being of demonstrative-type.This year a demonstrative plant is to be started up at Buggenum (The Netherlands), having 253 MW net capacity, 43 % net efficiency, 98 % desulphurization efficiency, max. 95 g/GJ NOx emission.

Significant improvements are expected in the performance of coal-based electric power generation system until the beginning of the 21st century.

4. OPTIONS FOR CCT IN DEVELOPING AND EMERGING COUNTRIES

The policies which have to be adopted in order to diminish the environmental damages caused by the fossil fuels use are known all over the world:

* old plant retrofitting aiming to high-efficiency and low-emission processes:
* regulations for emissions reduction:
* strict regulations for the new constructions emissions:
* tariff policies ment to stimulate energy savings and severe penalties for energy waste and emissions increase, as well:
* electric energy demand reduction by demand-side management:
* wastes recycling.

Adopting the proper strategies meant to carry out these policies is determined by certain factors which are specific for each country: the macro-economic development, environment, social factor and the maturity degree of certain technologies.

Generally, the PC power plants is the technology used at present. The absolute majority of the PC power plants have no emission control equipment other than some particulate removal system. In upgrading power plants, developing countries start from a lower technical base than that of the developed economies. For the existing power plants there are three possibilities : retrofitting, repowering and replacement.

A number of existing PC power plants must be modified to enhance their life ,to improve their performances and to reduce their emissions. Depending on what plant components need replacement, the rehabilitation may or may not involve repowering. Retrofitting with de-SOx and de-NOx equipment will occur in cases where the existing power plants are in good shape.

Plants that were built in the early 1950s use about 25 to 30 % more fuel than today's modern plants to produce a KWh electricity. In these cases a decision must be taken whether it is preferable to repower or to replace them.

It is obvious that the option for a suitable alternative is difficult to make because it depends on the real conditions of each country. The steps that a country should undertake are: option identification, costs estimation and financial sources identification as well. EPRI and other companies have developed comprehensive computer programs for help utilities in making decisions in retrofitting the existent power plants(20). The last models created by EPRI:CCCM (Coal Cleaning Cost Model),FGD COST (Flue Gas Desulphurisation Cost),COIM (Coal Quality Impact Model) are used as tools for the control technologies selection (26,27).

Asia Option for different CCT in rehabilitation, retrofitting and modernisation of existing plants or in new power plants construction for Asian countries are determined also by the Asian Development Bank position. The Bank's influence on environmental conditions is conveyed by a combination of its comprehensive environmental revue and assessment of projects at all stages within the project cycle. They are five key environmental issues asociated with coal-fired generations: resettlement of population from the plant side and its related social issues: air pollution:

thermal pollution by cooling and process water, water pollution caused by liquid affluents discharge and ash disposal (30).

Being a big coal consumption country, China pays great attention to environmental protection. Special investment will be made for dust control and desulphurisation . More coal will be washed , the percentage for coal gasification will be increased. The Chinese government gives favorable conditions on production arrangement and tax for foreign investors (4,30).

In India, studies carried out by the National Productivity Council show that FBC retrofitting on conventional boilers can result in thermal efficiency and restore the old units to the designed outputs. Almost 10,000 vintage boilers need to be replaced or retrofitted with efficient combustion systems. It has been also made a feasibility study for IGCC power generation in a 600 MW plants on Indian coals by means of a joint Indo-US collaborative project. On the other hand, the R & D works carried out by the National Environmental Engineering Research Institute - NEERI - in the area of coal cleaning have evaluated two reactor systems for microbial desulphurisation of coal containing pyritic sulphur (5) .

Former Soviet Union In Russia, the Part of the State Scientific and Technical Programme "Ecologically Clean Power Generation " is involved in creating ecologically clean thermal power plants fired by low-grade solid fuel. R & D activity aimed at substantial production of harmful emission: NOx and SO2 up to 200-300 mg/cu.m.particulate matter - 50 mg/cu.m. no water pollution, 80 % ash. As a result,there are four projects under work now on commercial and two demo plants. The technology which must be prouved is : wet limestone desulphurisation with production of gypsum. NOx reduction by use of low-NOx swirl burner in combination with reburning system and selective catalytic reduction.CFBC (110 MWe unit), IGCC (120 MW unit), entrained-flow, oxygen-blown dry coal dust gasification.IGCC (250 MW demo pressurized fluidised bed air-blown gasification),PCFB to fire low-grade coals and 200 MW demo power plant based on slagging fixed bed gasifier (9).

Eastern Europe Almost all East European countries foresee desulphurisation programmes using mostly wet limestone methode. In Poland,four project are already under way. Poland, which has the best coal resources of all East European countries, is the most ambitios inconsidering the new CCT like PFBC and IGCC (10). Czech Republic and Slovakia take into account either to change the fuel or use FGD: for further repowering of olds plants CFBC may be used, but for further reconstruction of electricity generating systems IGCC is not excluded (31). A contract has already been signed for the supply of a PFBC plant produced by ABB Carbon to the Czech utility MST. This will be a PHS plant that produces 60 MWe , 100 MW heat to the district heating grid and also 10 MW process steam to a neighbouring industry. A number of other project are under discussion (16).

The Hungarian power generation community is very reserved and cautious in choosing the new appropriate advanced technology as IGCC and PFBC, but considers that the quality of the Hungarian coal should be compatible with the introduction of CFBC. The old age and the small size of the plants make FGD retrofitting economically viable only in the case of the 800 MW lignite-fired plants:the planned technology is a limestone forced oxydation scrubbing with removal efficiency over 96 % (10).

Africa Today the parastatal power utility Eskom on the largest electricity undertakings in the world, supplies 97 % of RSA's annual consumption. Developments in boiler dessign linked to advanced characterisation studies have led to the extensive use with maximum efficiency of the low-grade coals.

Eskom's future power plants will probably be lokated near the coal reserves of the Eastern Transvaal Highveld. Plants to be built in the following 5-10 years will probably follow the 6x600 MW current set patterns:but those to be built later are likely to be smaller and will involve the IGCC route.The older power stations are quite amendable to IGCC repowering (13).

The Latin and Caribbean's RegionThe Latin American and Caribbean's present and future coal consumption has not appreciable environmental effects. The technologies for using coal to efficiently generate electricity and with appropriate pollution controls are well known.but the Latin American and Caribbean region should not be pressured into applying the same pollution control measures currently used in developed countries (14).

And now, please allow me to present some aspects on Romania's coal technology.

Romania, an East European country having 362.000 sq km area and about 23 millions people, passes through a transition period toward the market economy, and economic decline is one of its effects. The electricity consumption fell from 9.500 MW in 1989 to 6.700 MW in 1992, projections being that in the year 2000 it is likely to reach the 1989 consumption level. The present installed capacity of RENEL's (Romanian Electricity Authority) power plants is 20.500 MW (out of which 8.500 MW from coal) is higher than the demand. Coal ensures about 25 % of the primary energy resources , heavy oil and natural gas.about 50 % and the rest is hydropower plants generated electricity.

Coal is burned in PC boilers without FGD .The coal demand is 90 % covered by the countries reserves of whom 80 % are lignites. Romanian lignite reserves are of low-grade quality: moisture 40%, ash moisture free 42%, low heat power 7MJ/kg, sulphur 1%. The 1989 lignite consumption was 11.800 mill.tcc and fell to 7.700 mill.tcc in 1992. Coal is expected to increasingly contribute to the primary energy sources.

At present, in Romania there is no in force regulation for power boilers emission standards but norms aiming at the pollutants concentration reduction starting with 1992.

The Least Costs Development Study (financed by ECE-PHARE) made by foreign consultant and appraised by RENEL and the Feasibility Study for 11 representative thermal power plants (financed by the World Bank) have contributed to establish RENEL's strategy on long and short term. By the year 2000, investments for new coal fire capacities will be very reduced. On the other hand, old power plants retrofitting for efficiency improvement and air emissions reductions will be required.

Due to the high ash and water content in Romanian's coal, large quantities of raw coal are required in order to generate energy. The SO_2 quantity released in the air upon a 1 tcc burning is of 90 kg SO_2 in case of a coal type with 1% medium sulphur content. The situation becomes more worrying when using a lignite system with 2-3 % sulphur content, which correspond to 180-270 kg SO_2 relased upon a 1 tcc burning.
We develop our own studies on primary measures meant to reduce NOx and to apply the FGD technology. There are also concerns for the achivement of a coal gasification technology in view of IGCC, as well as of a fluidished bed combustion technology. But experiments have been carried out on small size pilot facilities and it is difficult to assume that own research without international cooperation might lead to technologies economically competitive to the Western ones.

The present scarcity of funds is the reason why no CCTs application technology is under way. Romania is likely, however, to follow the option of other East European countries for the implementation of FGD systems in order to observe the emission regulations. Moreover, if this is done in the next few years when there are hopes for IGCC and PFBC developement with lower cost, chances are that the FGD retrofitting would be less profitable than the repowering by means of IGCC or PFBC. But the financial, not the technical considerations are determining for the technology choice by the decision making factors, regardless of a country's geographic position.

5. OBSTACLES FOR CLEAN COAL TECHNOLOGIES APPLIED IN DEVELOPING COUNTRIES. POSSIBLE SOLUTIONS

The most important obstacles for implementing CCTs in developing and emerging economies are due to their inadequate financial structures, to difficulties in obtaining currency profits for the invested capital, to rudimentary schemes for generation costs to the long-term stability of the business and to political climate. (32). Some of these obstacles and their possible solutions for encouraging CCT introduction in developing countries are further on presented:

1.Lack of financing determined by:

* perceive "CCTs as riskier than conventional technologies":
* the lack of information in a form usable by the Key Decision-makers:
* country risk:
* perceive "CCTs costs as higher than conventional technologies costs".

Possible solutions:

* establish a concessional financial facility having local and regional environmental benefits by supporting the incremental cost of CCTs over conventional technologies:
* create basic financing structure including lenders and sponsors by:
    * elimination of country risk:
    * manageable commercial risk:
    * government involvement:
    * public financial agencies involvement:
    * maximum support by the contractor and operator:
    * shorter loan term:
    * cooperative effort between public and private sector:
    * finding mechanisms to promote the financing of certain CCTs demonstration projects in developing countries:
    * institutional, legal, fiscal, financial and regulatory framework conditions creating in order to introduce long-term investments.

2.Lack of information and know-how

Possible solutions:

* disseminate information on energy efficient and environmentally acceptable technologies about: performance, environmental impacts, suitability to specific fuels, state-of-the-art technologies, costs and expected technology development:
* disseminate information in developing countries to: Electric Utility Executives, Government Officials, Electric Power Research Institutes, Electric Power Planners, Multilateral Bank Officials and Commercial Bank Officials:
* disseminate a technical guide on How to Specify and Evaluate CCTs power plants:
* disseminate of know-how regarding specification, design, manufacturing and operation of CCTs plants:
* CCTs assesment and technology selection Methodologies:
* facilities for participation of developing countries R&D organisations to the demonstrative CCTs project.

3.Lack of appropriate environmental standards and regulations due to:
    * impossibility to observe these norms in the present plants operation state:
    * lack of procurement funds for emissions control

instrumentation:
* lack of funds for the plants retrofitting.

Possibies solution:

* facilities for environmental standards and regulations to encourage CCTs use in developing and emerging countries.

4.Policy disincentives

Possible solutions:

* facilities for the developing countries Government Power Corporation which updates an energy policy in order to encourage CCTs:

* prices which reflect costs including environmental costs as much as identifiable:
* subsidies removing, including those for fuels, labour, capital or others:
* encouraging competition in energy and energy trade among regions and throughout the world:
* stepping up of government support for R&D to new and cleaner energy technologies but not under the market distorting subsidies form.

6. DEVELOPING COUNTRIES NEED FOR A SUSTAINABLE DEVELOPMENT SHOULD BECOME A REALITY

Sulphur dioxide emissions can readily be eliminated by using advanced control technologies. Short-term solutions like retrofitting old technologies with scrubbers do not make for sound environmental policy in the long term.

If coal is to remain a viable energy source in a world concerned on the human and ecological consequences of the global climate change, the imperative of higher efficiency technologies becomes more critical.

Due to the current estimates of the relatively high costs of greenhouse gas controls,many countries will postpone this problem dealing until better information is available or will adopt only those measures that make sense for other reasons.

The most promissing near-term options include PFBC and IGCC systems, estimated to reduce CO_2 emissions by up to 20 % as against the existing PC power plants. At present, the estimated costs for PFBC and IGCC range from slightly lower to perhaps 10 or 20 % higher than PC plants with FGD (33).

Mitigations costs increase rapidly depending on the greenhouse gas emission reduction levels.Over a longer term, a variety of advanced coal technology options hold promise for substantially reducing CO_2 emissions from coal use at costs comparable to the less efficient technology now in use.

A lot of developing and emerging countries have their own R&D activities but it is hard to believe that they could develop in a short period, only by their own work, CCTs in commercial stage to be competitive with those found in the developed countries.

In case that the developing countries will be offered the possibility to procure technologies considered new in that country, but becoming morally worn out in a near future, will be an inconvenient not only for the respective country, but for the whole world.

There are two aspects to be taken into consideration when applying CCTs in developing and emerging countries:
* the pollutant emissions do not take into consideration the countries frontiers, therefore the caused damages are almost always irreversible;
* the well-known saying "I am too poor to buy cheap " should be taken also into consideration because it fits almost everywhere.
If in other fields of concern the acces limitation to advanced technologies is normal, in that of CCTs, which is a technology that integrates energy and environment, these obstacles should be removed.

Developing countries need co-operation in identifying and developing economically viable and environmentelly sound coal technologies following the specific conditions of each country.

International financial institutions and other assistance programmes should provide additional funding required to increase energy supply through environmentally sound technologies and efficient energy use.

The idea to establish an International Electric Power Development Institute to work with developing countries, multilateral banks, multilateral and bilateral agencies is to be appreciate.(32)
International co-operation should include new forms of scientific and research partnership between developed and developing countries.

Developed countries must agree on ways and means to facilitate the transfer of these technologies to developing and emerging countries and to assist them in applying these new solutions.

The international bodies financing programmes for CCTs implementation into developing and emerging countries should develope a policy that would stimulate international co-operation towards technological transfer and will support the electricity producers from these countries understand the requirement to choose the most environmental-friendly coal and lignite utilisation technology.

To promote the concept of substainable development in order to realise the linkages between development in environment in the

coal area energy.the financial resources for an increased scientific and technological co-operation is by all means required.

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Table 1-Developing and Emerging Countries Coal Fired Power Plant Summary for the Year 1990 (source : Gouse W. and other, 1993)

Region country	Capacity MW	Coal MTCE /Yr	Production TWH	Total Coal MTCE /Yr	Total Coal EXAS /Yr	Efficiency %	Coal to Power %
1	2	3	4	5	6	7	8
ASIA							
China	68.000	194.0	450.0	731.0	21.45	28.5	27
India	42.750	93.4	172.0	172.0	5.05	22.6	54
Indonesia	1.730	3.7	7.0	3.8	0.11	23.1	95
Israel	1.400	2.9	7.0	3.4	0.10	29.3	86
North Koreea	4.500	10.0	21.0	50.0	1.47	25.8	20
Malaysia	600	0.7	1.5	1.5	0.04	27.1	45
Philippines	405	0.9	2.0	1.9	0.06	27.3	47
Thailand	1.185	3.3	6.8	3.6	0.11	25.6	91
Subtotal	120.570	308.9	667.3	967.2	28.39	26.5	32
CSI (CRSS)	95.000	202.0	433.0	530.0	15.55	26.3	35
EUROPE							
Bulgaria	4.869	9.6	20.0	22.0	0.65	25.5	44
Czech.+ Slov.	9.180	16.3	40.0	58.0	1.70	30.1	28
Hungary	2.412	3.7	7.4	10.4	0.31	24.5	36
Poland	22.865	54.0	134.0	138.0	4.05	30.4	39
Romania	7.631	9.0	22.0	32.0	0.94	30.0	28
Yugoslavia	8.850	18.8	43.0	27.0	0.79	28.1	70
Subtotal	55.807	111.4	266.4	287.4	8.44	29.3	39
AFRICA							
Botswana	170	0.4	0.6				
Marocco	885	1.4	3.2	1.5	0.04	27.8	94
South Africa	29.843	64.9	129.5	90.0	2.24	24.5	72
Zimbabwe	1.280	2.3	3.5	5.0	0.15	18.8	45
Subtotal	32.178	69.0	136.8	96.5	2.83	24.3	72
LATIN AMERICA and CARIBBEAN REGION							
Argentina	840	1.0	1.6	1.6	0.05	20.0	61
Brazil	1.080	3.5	3.5	14.6	0.43	12.4	24
Chile	894	1.5	3.0	3.4	0.10	25.0	43
Colombia	579	1.2	2.0	3.4	0.10	19.8	36
Dom. Rep.	125	0.3	0.4	4.9	0.14	18.9	5
Mexico	1.900	4.0	6.7	7.5	0.22	20.4	54
Subtotal	5.436	11.5	17.2	35.4	1.04	18.4	32
TOTALS	308.991	702.8	1.520.7	1.916.5	56.25	26.5	37
WORLD TOTALS	898.964	1.796.8	4.180.1	3.312.0	97.17	28.5	54

MTCE/Yr-metric tones of coal equivalent per year (1TCE=29.34 GJ)
EXAS/Yr-exajoules per year.

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ON THE CLEAN AND EFFICIENT USE OF COAL AND LIGNITE

ITS ROLE IN ENERGY,ENVIRONMENT AND LIFE

TECHNOLOGY OPTIONS FOR INDUSTRIAL, COMMERCIAL AND RESIDENTIAL APPLICATIONS

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1. INTRODUCTION

Coal remains the principal primary energy source in China and features strongly in many other Asian countries. In both the UK and China usage for power production dominates but significant amounts of solid fuel are supplied to other markets. In the UK, British Coal currently supply about 12 million tonnes per annum to industrial and domestic markets whereas in China, albeit with a much higher population, the figure for industrial boiler use alone is estimated at around 350 million tonnes. In the case of the UK this represents about 13% of British Coal's sales but would be more than double this in China. The pattern is similar in East European and CIS countries with significant quantities of coal being consumed in factories, commercial premises and homes.

There is increasing concern, worldwide, of the pollution that can be caused in coal utilisation processes. Such pollution is exacerbated in some countries by the use of low quality, high ash and high sulphur coals and further made worse by inefficient plant and lack of clean coal technologies. International concern about coal use and the environment tends to concentrate on the transboundary pollution that comes from burning such fuels in power stations. However, local concern is as likely to be focused on health problems related to domestic and industrial burning in urban areas.

In the UK severe problems with coal related urban pollution in the years following the second World War led to the passing of the Clean Air Acts of 1956 and 1968 This in turn triggered development of a range of smokeless fuels and improved appliances for domestic use so that urban pollution in the UK has long been associated primarily with the automobile rather than with coal. These clean technologies are likely to be suitable for use in other countries, certainly for hard coals, and with some adaptation for low rank coals.

Also in the UK industrial coal burning has been developed to meet increasingly fierce competition from oil and gas. In the late 1970's and early 1980's a large programme was undertaken to produce industrial appliances, including coal and ash handling equipment, which begin to match oil and gas for cleanliness and convenience in use. There is now over a decade of experience of installing such equipment in customers' premises. Again, adaptation of these designs is appropriate for use in other countries.

Significant benefits in all of this development for the industrial and domestic sectors are the high efficiencies attainable with modern designs. In the domestic sector a fully enclosed boiler providing hot water and central heating can approach 75% thermal efficiency (GCV basis). In industry steam raising at efficiencies of over 80% (GCV basis) would be expected. Such high efficiencies not only help considerably to reduce pollution, they will also become increasingly significant to householders and industrialists as economic pricing of fuels becomes prevalent in China, CIS and Eastern Europe.

Details of these developments and comments on their application are made in the following sections and perhaps as important are the intentions to make them available in other countries.

2. DOMESTIC HEATING EQUIPMENT

British Coal, in association with manufacturers in the UK, has for over 40 years been developing improved fuels and equipment for heating domestic buildings. Much of this work has been carried out at the Coal Research Establishment (CRE). The aim has been to provide fuels and appliances that improve efficiencies and reduce emissions at affordable prices. It has made a significant contribution to the elimination of 'smogs' in our cities.

Two approaches were followed; viz (a) new "smokeless" fuels that could be burnt in conventional appliances, and (b) new appliances that would burn bituminous coal "smokelessly". "Smokeless" can be taken to mean producing less than one tenth of the smoke which would be produced by burning a UK bituminous coal on a traditional open fire.

2.1 Smokeless Fuel Manufacture

Conventional methods involve low and high temperature carbonizations of coal at between 400 and 700°C and at about 1000°C respectively. There can be operational and environmental problems carrying out such carbonization in conventional ovens and retorts at these temperatures and advice should be sought to preempt such problems.

As the result of increased mechanisation of coal production in the UK, there was greater availability of small-sized, low rank bituminous coals. CRE was instrumental in developing processes for producing smokeless briquettes from these coals which are low swelling and high in volatile content. The fine coal is first carbonised in a fluidised bed reactor to render it smokeless, and then briquetted in a high temperature extrusion press to enable it to be used in domestic heating appliances. The process is based on the phenomena that the temperature (430°C), when the coal becomes smokeless, is also the temperature at which the coal exhibits its maximum plasticity and so is most amenable to briquetting. The heat for the carbonization stage is provided by combustion of a small amount of the fuel in the bed with the fluidising air. Extrusion or roll presses can be used for the briquetting step. The product is sufficiently reactive to burn on conventional open fires.

CRE has had significant involvement with other processes for producing fuels often better suited to more efficient domestic appliances such as described in the ensuing section. By way of example, an environmentally benign process was developed by CRE in the 1980's mainly to use naturally smokeless anthracite fines for which there were no ready markets. The process involves briquetting with molasses as a binder and hardening (curing) the product at about 250°C to give strong, weather-resistant compacts. The method can be readily adapted to use other binders, eg starch, lignin, depending upon local availability.

2.2 Conventional Combustion Appliances

Along with developments in smokeless fuel production, CRE has made many significant advances in the design of domestic combustion appliances: including achieving greater efficiencies[1]. It recognised the fundamental design difficulty of the common open grate domestic fire. Air, which is required to burn the coal on the grate, is supplied from below.

As the coal heats up, the volatile tars and gas are released and swept away from the embers of the fire to regions of lower temperature. Consequently, these volatiles are incompletely burnt and are emitted from the flue as smoke.

This effect is particularly marked immediately after refuelling of the fire, when maximum smoke emissions occur. As a consequence, such simple appliance require a smokeless fuel with a low volatile matter content in order to burn 'smokelessly'; eg naturally - occurring anthracite, some low volatile steam coals and suitable manufactured fuels. Naturally smokeless fuels suffer a disadvantage of low reactivity which make them less suitable for burning on open fires. Such appliances, when incorporated into a hot water and home heating system can result in thermal efficiency of 75%. Consequently, new types of appliance have been developed which overcome this problem yet take advantage of their natural smokelessness; viz a range of gravity feed, or magazine boilers (Figure 1).

This not only benefits the household with lower fuel bills, but is environmentally beneficial as it reduces the amount of pollution per useful unit of energy extracted from the coal.

2.3 Smoke Reducing Appliances

The principal approach to obtaining smokeless combustion of high volatile coals at the domestic scale has been the adoption of "down-burning" designs (Figure 2). In this way, the volatile tars and gases, formed when the coal is heated, are drawn through the embers of the fire and are virtually "consumed" in the process. Refinements to the air distribution, which provides primary and secondary air, improve the control of the combustion conditions and significantly increase the overall efficiency of combustion.

This type of appliance reduces smoke emission by some 90% compared to a conventional open fire when burning high volatile bituminous coals, and would also effectively reduce smoke emission from lower rank coals such as lignite and brown coal. Such appliances can be designed as dry stoves or boilers for hot water and central heating.

Another CRE development has been the application of underfeed stoker technology to small coal burning appliances (Figure 3) in the range 13-45 kW (thermal). To enable this to be achieved on the small scale necessary for domestic applications, the coal needs to be free burning, have a fairly high calorific value, low ash and to be sized within the range 6-25 mm. It is fed to the retort by a screw together with air from a fan. Combustion occurs in a small zone, and a high temperature is maintained by a hot arch or plate above the retort. Ash falls over the edge of the retort into a collecting box from which it may be removed manually or automatically.

These appliances combine low smoke emissions with high amenity value, in part due to their excellent turndown capability (30:1) and response time to full output of a few seconds. Their automatic coal feed and ash removal makes them suitable for unattended operation. These stokers are most suitable for independent boiler providing central heating for large houses: boiler efficiencies are over 70%.

3. COMMERCIAL HEATING EQUIPMENT

For a heat requirement of up to about 3 MW (eg for light industrial or commercial buildings) a number of boiler designs have been developed by CRE, which are capable of high efficiencies (78-84%), and virtually smoke and grit free operation at moderate capital cost[1]. The degree of automation depends on user requirements, but such boilers can be operated largely unattended when they are fitted with suitable controls, electrical ignition, and mechanical coal and ash handling.

The same efficient, clean burning, underfeed stoker technology, as can be used for large domestic boilers, has been used for appliances with capacities of up to 300 kW. Typical sites for such equipment include schools, offices, fire stations etc. These slightly larger stokers can tolerate lower calorific value and higher ash fuels.

Another development has been the manufacture of self-contained "Energy Capsules" which utilise these boilers in transportable packages. One version is assembled from prefabricated components clad with glass fibre panels. Another uses a modified cargo container to accommodate two 150 kW boilers with a 12 tonne coal bunker and an integral chimney (Figure 4). This whole package can be readily transported to site and made operational as soon as water and electrical connections are made.

Above 300 kW there are a range of large conventional underfeed stokers available. These feed the coal automatically and burn it under thermostatic control. The ash is removed manually, typically taking 15 minutes twice or three times per day. These boilers are low in capital cost, and can be used to burn a wide range of low ash coals.

Several small automatic reciprocating grate stokers are also available (Figure 5). The coal is fed onto the grate where it is progressively burnt out as it travels along the moving grate which reciprocates in order to advance the fuel bed progressively so that ash is discharged at the far end of the grate. These stokers are an improvement on the conventional underfeed design; they can easily include automatic ash removal, but they are more expensive. Figure 5 shows schematically an integrated 1 MW coal fired appliance which operates at very high efficiency, minimal stack emissions and with good amenity. This particular design operates at a relatively low combustion intensity with low air velocities through the firebed. This feature would provide advantages when operating with low grade, high ash coals.

4. INDUSTRIAL HEATING EQUIPMENT

In the 1960's and 70's the coal industry in the UK was faced with competition from cheap oil and, later, natural gas. R&D efforts at the CRE were redoubled to develop coal-firing technologies which were more efficient, cleaner, more reliable with improved coal and ash handling facilities, and also environmentally acceptable. Attention was directed towards both improving conventional combustion equipment and developing new systems, notably based on fluidised bed combustion (FBC)[2].

4.1 Stoker Firing

Stoker firing is the most common coal combustion technique. Recent developments in stoker-fired equipment, used in industrial boilers particularly below 10 MW_t capacity, have been aimed at improving the intensity of combustion, their reliability, ease of operation, and their adaptability to a wide range of fuels. Such improvements have been made for the underfeed stoker (already described), the drop tube stoker, coking stoker, and the chain and travelling grate stokers.

For example, graded coal is dropped onto a static grate of a drop-tube stoker where it burns at high temperature, forming a layer of ash which is removed manually. Following collaborative development work with a UK manufacturer, tipping grates have been designed which periodically drop this ash for subsequent removal.

In its various forms the moving grate stoker is used for firing boilers with outputs of 2 MW_t up to over 70 MW_t. Essentially, the grate is a continuous mat of bars and amenable to burning a wide range of coals. Lump coal is fed onto these bars where it burns progressively as the grate moves forward, discharging ash from the rear end. A new development enables ignition to be initiated electrically and is particularly applicable when intermittent use is made of the system as, for example, in the horticultural industry.

Increasing concern for the environment over recent years has led to considerable effort being spent on researching methods of reducing the emission of gaseous pollutants (particularly NOx and SO_2) for coal fired boiler plant. Whilst coal fired stoker equipment generally gives low NOx emissions, a number of different methods of SO_2 removal have been demonstrated. However such systems are not widely used at the present time in the UK, primarily due to the cost of the equipment when compared to the cost of importing coal with an inherently low sulphur content. Using a limestone sorbent, studies at CRE have shown that sulphur capture is relatively ineffective if limestone is fed directly onto the fuel bed. More suitable conditions exist immediately above the fuel bed in the furnace when the combustion gas temperatures are below 1200°C. The injection of fine sorbent (<100μm) into this region can achieve 40-60% SO_2 removal.

Alternatively, a dry sorbent, which would normally be lime, may be injected into the cool flue gases leaving the boiler (in-duct injection). It can be more effective in terms of sulphur capture than in-furnace sorbent injection provided the flue gases are humidified and there is a close approach (<10°C) to saturation temperature. Typically, SO_2 removal is 40-80%. Semi-dry or spray dry systems are principally for use on large industrial boilers. The sorbent slurry, typically lime, is sprayed into the flue gas as it passes through a reactor vessel. The SO_2 is removed as the slurry dries, typically achieving 60-80% capture.

4.2 Pulverised Fuel Firing

Most modern, large coal-fired power stations and some large industrial boilers are designed to burn pulverised fuel (pf). The coal is ground to a powder (about 75% <75 μm) using

pulverising mills. It is then transported by preheated combustion air to the burners installed at the corners or on the walls of the boiler.

Pf combustion has not generally been a success on small industrial boilers though much work has been carried out on burning finer grades of pf in an attempt to increase flame intensity. For example, microfine pulverised fuel firing has been introduced into the UK in recent years. In this case, the pf is milled to less than 40μm. It burns with an intensity almost matching that of heavy fuel oil. Another approach is based on a burner which burns only oil or gas for up to about 30% boiler heat input. Beyond that, combustion of pf is initiated and increased progressively so that pf is providing 70% of the heat at full load. However, the higher capital costs associated with milling and fly ash collection equipment have tended to make them relatively uncompetitive for smaller boilers.

CRE has evaluated and demonstrated the use of coal-water mixtures (CWM) to fire industrial boilers. CWM is made from finely ground coal mixed with water in the ratio of about 70% coal to 30% water (by weight). The size distribution of the coal powder is important as it influences the 'coal loading' of the CWM, this being dependent on the proportion of very fine particles present. Generally, additives in the form of dispersants and/or stabilisers (up to 1% of each) are needed to ensure that the CWM has acceptable viscosity for pumping and handling purposes, and to ensure it remains stable over extended periods.

An advantage of CWM is its convenience and safety in storage and handling. Also, these fuels can be made from coals which have been 'deep' cleaned (known as beneficiation) to produce low sulphur and ash contents. To achieve this, they need to be finely ground and processed in a wet state. Thus, they are ideally suited for making into CWMs. Their combustion characteristics are good and they can be used as substitutes for heavy and light fuel oils.

Post combustion techniques, such as the in-duct injection and spray dry systems used with stoker-fired boilers, can also be applied to smaller pf plant. Normally, wet flue gas scrubbing (FGD) is selected only for larger utility scale plant. Although they operate with SO_2 removal efficiencies of around 90%, they involve much more complex plant; they are generally only cost effective at the large scale.

NOx emissions tend to be high with flame combustion but there are a large number of combustion modification techniques available which can reduce these emissions by up to 50%. The general principle employed is to change the distribution of fuel and air so that fuel rich conditions, inhibiting NOx production are present in the early stages of combustion. Sufficient air is then introduced to ensure complete combustion downstream of this zone. This staging may be done within the burners themselves or within the furnace. In the latter case, the lower rows of burners are operated under fuel rich conditions with the upper burners or ports supplying the remaining air.

With a conventional pf burner, flame temperatures can exceed 1600°C and sulphur capture by feeding limestone with the coal is ineffective. Two alternatives have been developed; viz sorbent addition into the furnace above the burners where the gas temperatures have dropped

to below 1200°C, and sorbent injection at the periphery of 'low NOx' burners. By either method, sulphur dioxide reductions of up to around 50% can be achieved.

4.3 Fluidised Bed Combustion

In parallel with work on improving conventional firing equipment, CRE has undertaken a large development programme for applying FBC to a wide range of industrial boiler and furnace applications[3]. The incentive has been the lower combustion temperatures than in other systems: this offers the potential for low NOx emissions and effective capture of sulphur by direct feeding of limestone to the fluidised bed. Also, it offers the prospect of much greater fuel flexibility with the capability of burning efficiently a wide range of coal types and quality, together with industrial wastes.

CRE concentrated on developing low cost, 'shallow' bubbling FBC designs in collaboration with a number of equipment manufacturers. Over 100 units have been built giving an overall thermal capacity of about 1200 MW_t. These include watertube, composite and locomotive boilers, and horizontal and vertical shell boilers together with furnaces for providing hot gas at up to 1600°C for direct contact drying applications (including mineral dryers, calciners) and clean hot air (food and plasterboard drying).

In these designs lump coal is simply fed by gravity onto the surface of a shallow bubbling bed (generally <400 mm depth before fluidisation) which consists largely of silica-sand and residual coal ash particles of about millimetre size. Shallow beds are used in order to reduce costs by minimising furnace height and fan power requirements. They also enable simple and effective load control for boilers through the use of carefully designed 'in-bed' tube arrangements.

The simplest applications of FBC are for hot gas furnaces and calciners. They account for some 50 units and about 400 MW_t of installed thermal capacity in the UK. A further 35 units (215 MW_t) have been sold into several European countries and in Asia licences have been taken up in Korea, India and Japan. These furnaces operate with high excess air and produce an uncleaned gas containing fly ash (Figure 6). However, they are low in cost and are suitable for drying a wide range of materials, including coal, sand, limestone, roadstone and clay for cement manufacture. Unit sizes range from 2 to 40 MW_t output.

Shell boilers may have vertical or horizontal configurations, although the latter are more difficult to develop because of problems in matching the fluidised bed requirements to the dimensions of a horizontal fire tube (in UK limited to 1.8m diameter). On the other hand, vertical shell designs are particularly suitable as the fluidised bed can occupy the base of the firetube. However, because British Standards restrict the diameter of firetubes, thermal outputs are limited to about 4 MW_t.

Shallow fluidised bed firing has also been applied to conventional watertube boiler construction to provide packaged boiler units. Examples include a 15 MW twin bed boiler unit supplying combined heat and power to a dyeworks (Figure 7) and a single bed design, rated at 7.5 MW, burning coal and wool washings (grease sludge) at a textile factory.

Another manufacturer has adopted a once through coil boiler to fluidised bed firing. Four boilers of this design have been installed at a sugar manufacturer's works. These boilers can operate on heavy fuel oil, as well as on coal.

Boilers of composite design incorporate a watertube wall combustion chamber with a conventional shell and tube heat exchanger for cooling the flue gases. Such designs followed initial development work by CRE and demonstration of a 8.5 MW double-ended locomotive type boiler. Several alternative designs are available commercially and units installed range from 1 MW hot water boilers to steam raising boilers of 21 MW capacity (Figure 8). The larger boilers are capable often of burning industrial wastes; they incorporate bed cleaning facilities to allow the use of lower grade coals which have a significant shale content. Also, these larger beds may be fed with limestone for controlling SO_2 emissions.

As a further development of FBC systems, CRE has developed a twin bed design which comprises two adjacent beds (Figure 9). One acts as a pyrolyser with the other as a combustor: these beds are connected by transfer ports. Coal is fed to the pyrolyser where it is devolatilised and a fuel gas is produced. The devolatilised 'coke' then passes through the transfer ports to the combustion bed where combustion is completed. The design does not incorporate in-bed tubes: rather the combustor bed temperature is controlled through operation at high excess air. The off-gases from the two beds are combined to produce a fuel gas; the oxygen in the combustor off-gas being used to burn the fuel gas. Because this is a form of staged combustion, nitrogen oxide emissions are low. Sulphur dioxide emission can be controlled by feeding limestone with the coal. This pyrolyser-combustor principle has been applied to industrial boiler plant and for generating high temperature gases for furnace operation.

5. COAL AND ASH HANDLING EQUIPMENT

To facilitate the introduction of clean coal-fired technologies, it is important to ensure that the coal and ash are handled in an acceptable manner[7]. Traditionally, coal-firing has been a manually-intensive practice, with the operators (stokers) manually feeding coal, and removing ash from boilers and furnaces. With cleaner combustion systems becoming available, more accurate control systems are needed to maximise efficiencies and minimise pollutant emissions. It is therefore important to develop improved coal and ash handling equipment.

Coal delivery to a user site can be by tipper, conveyor, pneumatic or container lorry. These methods give increasing levels of convenience for site reception. A container vehicle can deliver a 20 tonne coal container. It gives a rapid turn-round time but does require special site facilities. The pneumatic lorry offers a convenient delivery method by its ability to transport coal direct to a storage hopper up to 40 metres away. The conveyor lorry has on-board facilities allowing it to deliver coal to a storage hopper up to 3 metres high. However, the tipper lorry provides the most economic method in terms of operating and maintenance costs and is available in most countries.

Special covered reception hoppers at ground level have been developed for use with tipper lorry deliveries. They avoid the need for relatively expensive underground storage. Two

types are available. The first is in the form of a large 'drive-in' hopper which is loaded from the lorry. The coal can then be emptied into the site pneumatic conveying facility by raising one end of the hopper by means of hydraulic jacks. In the second type, the floor or the hopper is designed to transfer coal mechanically either by a belt conveyor or by a reciprocating bar method (Figure 10).

Space constraints at coal storage user sites (particularly open stockpiles) has led to the application of vertical silos of up to 1000 tonne capacity. Silos may be of concrete stave, steel or plastic construction. Care is taken in the designs to ensure their safe use in terms of structural stability and avoiding spontaneous combustion of stored coal. Coal is removed from silos by gravity discharge or by screw conveyor. Figure 11 is a schematic diagram of a silo structure suitable for use with industrial grades of coal.

On-site pneumatic conveying systems are available. They are lower cost, offer greater reliability, design flexibility and cleanliness than conventional mechanical systems such as bucket elevators, en-masse conveyors etc. Two types of pneumatic system have been developed; viz 'lean phase' and 'dense phase' depending on the solids to conveying air mass ratio ($<20:1$ and $>40:1$ respectively) and the means of air supply.

A 'dense phase' feeder is suitable for handling lump coal. It comprises a pressure vessel of up to 50 kg capacity located at the base of a silo or bunker, which gravity fills through a special valve. When full, the valve closes and the vessel is pressurised up to about 4 bar; this causes the coal to be 'extruded' into and forced along the conveying pipe in the form of an aerated slug. The sequence is repeated until the reception hopper is full.

A lean phase 'suction nozzle' system uses a fan or blower to transfer coal, from stock to a feed hopper, through 125 mm diameter pipework at rates of up to 15 tonne/hr (Figure 12). In one development the pick-up nozzle can traverse and clear automatically a coal stockpile.

Thus the controllability and amenity of coal-fired equipment have been markedly improved by the introduction of suitable coal handling equipment. This applies to the discharge of the ash as well as the coal.

Dependent on the method of combustion, handling systems have to deal with a wide range of ash size from large clinker pads to fine particles. Mechanical systems can give problems when handling ash because of its abrasive nature and the possibility of dust entering working parts. Therefore, dense and lean phase pneumatic systems and also hydraulic pipe systems have been developed because of their convenience and general cleanliness of operation.

The fly ash present in the flue gas is normally removed by means of high efficiency cyclones, bag filters or electrostatic precipitators, the principal requirements of gas cleaning are to meet the relevant emission standards at minimum cost. Therefore, for stoker fired equipment attention has been directed towards improving the efficiency of inertial devices because of their much lower costs compared to other equipment. This has included improvements to multi-cell cyclone arrangements. Also blow down systems have been incorporated where a small gas bleed (typically 10% of the total flue gas) is taken from the solids offtakes of

cyclonic devices and passed through a small fabric filter. By so doing, emissions can be reduced comparatively cheaply by some further 30%, the capital cost of the whole system being less than one half that of a full size bag filter plant.

Extensive trials have also been undertaken by CRE to evaluate the performance and relative costs of different bag filter cloth for coal-fired boilers. Again, these developments have led to increased reliability and lower costs for particulate removal.

6. TRANSFER OF TECHNOLOGY FOR COAL USE IN HOMES AND FACTORIES

It is not always appreciated in the West just what contribution can be made by technology transfer in the non-power sectors. For instance, in China domestic coal combustion efficiency is much lower than in good UK appliances. There is also a lot of scope for improvement in the industrial sector. In a recent report to the World Bank it was estimated that current consumption of around 350 million tonnes could be reduced by 100 mtpa if best Western technology and practice were fully deployed.. Significant efficiency and environmental improvements could be made in the non-power markets by technology transfer involving equipment which, relative to the power sector, is usually easier to fabricate and can be done in more modestly equipped factories requiring much lower initial investment. On the other hand it takes a lot of small boilers to give the same fuel saving benefit as one clean coal technology power station.

For technology transfer to work, both provider and recipient have to benefit. The provider will usually be a private, rather than a government organisation and must obtain appropriate financial returns (with funding agency aid where appropriate) and protect his intellectual property. The recipient needs to ensure obtaining the most appropriate technology and will need contracts that include appropriate training and after sales service.

CRE has been involved in international marketing of domestic/ commercial/industrial technologies in a modest way hitherto, and intend being far more active in future. A common route has been the development of equipment in collaboration with a UK manufacturer followed by selling licences aboard. The licensing vehicle has been Combustion Systems Ltd (CSL) a British Coal company which has concentrated on selling industrial fluidised bed licences - mostly for coal but including some oil firing. These systems are amenable to use with a range of coal types and qualities. Licences have been given overseas for a range of furnaces and boilers. Experience from 140 operating units in the industrial sector worldwide is fed back to CSL. In the domestic sector designs have been developed for clients in Mongolia, China, Russia, Poland and Czech Republic, whilst briquetting prospects are being evaluated for a number of countries including China and Indonesia.

If it is advice or practical investigations into coal use which is required then CRE is also able to undertake contracts through its Technical Services organisation. A recent example is a completed contract from the UK Overseas Development Administration for an energy efficiency study on a Chinese city. In East Europe and the CIS, CRE is already providing advice on energy efficiency and clean use of coal via a suite of contracts funded by the UK Government and the EEC.

On a broader front CRE has access to virtually all aspects of the coal chain including areas such as

- Marketing and fuel pricing strategies
- Mine design and operation
- Surface operations including coal preparation
- Transport and distribution
- Social restructuring following mine closures
- Energy efficiency and use of coal in all market sectors
- Environmental aspects of coal extraction and use

This cross cutting, multi disciplinary expertise is available on a worldwide basis, thus specific technology transfer initiatives can be considered within part of a much wider exercise where appropriate.

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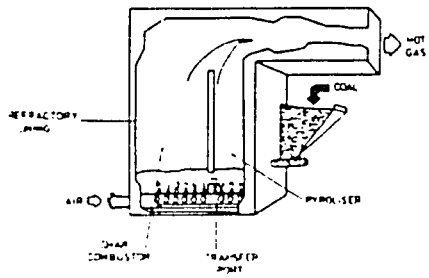

Figure 9 - Pyoliser-Combustor

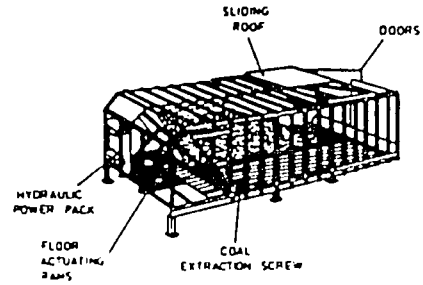

Figure 10 - Walking Floor Coal Receiver

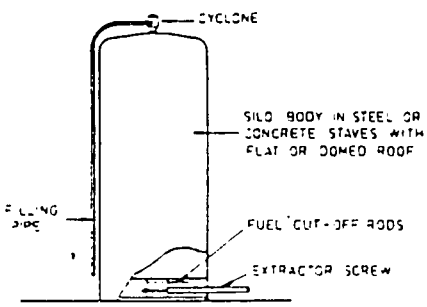

Figure 11 - Coal Silo

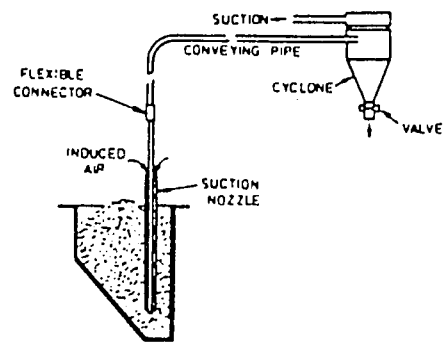

Figure 12 - Suction Nozzle

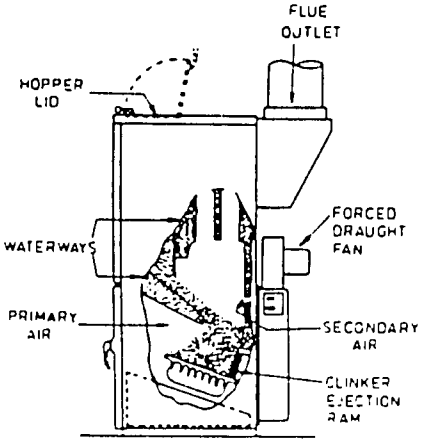

Figure 1 - Gravity Feed Boiler

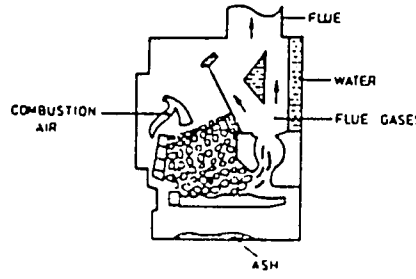

Figure 2 - Down Burning Design

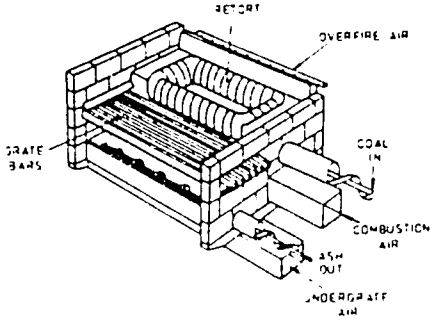

Figure 3 - Underfeed Stoker

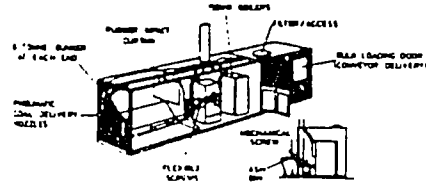

Figure 4 - Energy Capsule

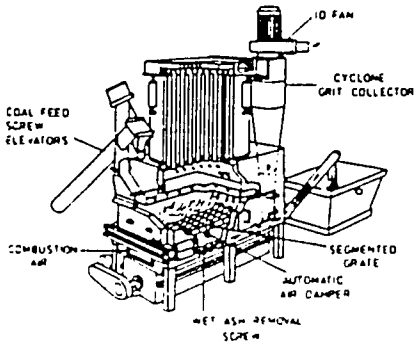

Figure 5 - Small Reciprocating Stoker

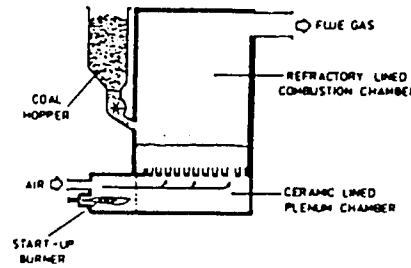

Figure 6 - Hot Gas Generator

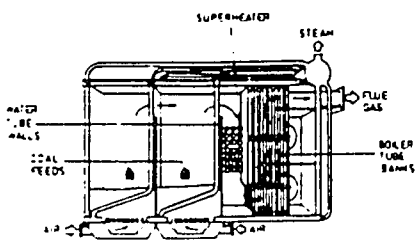

Figure 7 - Twin Bed FBC Boiler

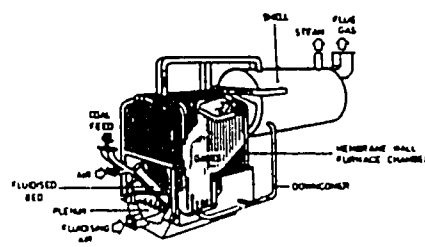

Figure 8 - Composite FBC Boiler

General Overview of Emerging Clean Coal Technology in the U.S. as Applicable to Asian Countries

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Introduction

The use of coal as a fuel for power generation is increasing throughout the world. This growth is particularly strong in countries where industrial output is expanding and electrification is increasing. At the same time environmental awareness is growing worldwide, heightening concern over the effects of coal burning on the environment.

The U.S. government and U.S. industry are collaborating to develop innovative technologies that utilize coal cleanly and efficiently under the U.S. Department of Energy's (DOE) Clean Coal Technology (CCT) Demonstration Program. This program is a $5 billion (U.S. dollars) national commitment, cost-shared by the U.S. Government and the private sector, to demonstrate a new generation of innovative coal processes in a series of full-scale facilities around the U.S.

The objective of the CCT Program is to demonstrate the more promising technologies in the commercial marketplace. To date, five rounds of projects have been selected for demonstrations, for a total of 46 projects. Approximately 20 of the projects involve the demonstration of advanced air quality control technologies. As a result of the work of programs like the U.S. DOE's CCT, two types of air quality control technologies have emerged:

- combustion technologies, such as Integrated Coal Gasification Combined Cycle (IGCC) and Fluidized-Bed Combustion (FBC), which efficiently remove SO_2 and NO_x in the combustion process and eliminate the need for postcombustion flue gas treatment equipment; and

- postcombustion technologies, such as Flue Gas Desulfurization (FGD) and Combined SO_2/NO_x Technologies, like the SNOX and the NOXSO processes, which simultaneously remove SO_2 and NO_x in an integrated flue gas cleaning system design and, in most cases, generate a salable by-product.

Other types of projects (e.g., precombustion technologies) improve the general quality of coal as a fuel for power generation or remove the pollutants from the coal before combustion.

Precombustion Technologies

To date, precombustion removal of sulfur from coal has had limited use in the U.S. because removal efficiencies are generally low and the cost are often high. Sulfur in coal can be found in two forms: organic and pyritic. The pyritic sulfur can be removed relatively easily through conventional coal cleaning processes, like coal washing. However, the pyritic sulfur comprises only 40 to 60% of the total sulfur in most U.S. coals. Current air pollution control regulations in the U.S. require much higher sulfur removal efficiencies.

In order to remove the organic sulfur in the coal, some type of solvent technology is typically employed. These processes are quite expensive when compared to the cost of postcombustion removal technologies like FGD. Solvent technologies may find some application when the coal is intended for use as a feedstock for advanced hydrocarbon conversion processes. In addition to their high costs, the fact that these processes require solvents makes them less desirable from an environmental standpoint. Preliminary research is being done in the U.S. on using microwave technology to clean organic sulfur from coals, which may hold some potential for the future.

If air pollution control regulations require high levels of SO_2 removal, like in the U.S., FGD is usually the more economical choice, particularly on a unit-by-unit basis. If high levels of sulfur removal are not required, precombustion techniques may be economically feasible.

Although it does not provide high levels of sulfur removal, coal washing may be appropriate for Asia for two possible applications:

- as a means of sulfur removal if SO_2 compliance levels are not high, and

- as a means of preparing high-ash coals for more economical transportation by removal of the mineral matter.

Currently, there are some precombustion technologies under development in the U.S. One of these is the Liquid From Coal (LFC) process available from SGI International and the Ziegler Coal Holding Company. The process economically converts low-rank

coals into a hydrocarbon liquid, similar to No. 6 fuel oil, and a greatly improved solid fuel with less sulfur and pollutants than the raw coal. Another process available from the Rosebud SynCoal Partnership is a technology that enhances subbituminous coal for boiler applications. The process is intended to remove excess moisture in the coal and increase the Btu content by approximately 40%, making transportation and operating costs more attractive.

Combustion Technologies

Fluidized Bed Combustion

One environmentally sound combustion technology emerging in the U.S. is FBC. The technology is commercially available in sizes up to 150 MW from several boiler manufacturers around the world. Development continues on technology refinements and scaling up of sizes.

The circulating FBC process utilizes a water-cooled combustion chamber and refractory-lined cyclone to recirculate bed material consisting largely of inert ash constituents. Combustion air is furnished at high pressure from forced draft fans. The combustion air suspends the circulating bed in the combustion chamber. Fuel and limestone are fed into the lower part of the combustor. Combustion takes place in a hot, turbulent environment that contains a relatively low concentration of combustibles. The reaction between limestone and sulfur in the fuel takes place in the combustor at a temperature of approximately 870°C. Heat is transferred to the water-cooled membrane wall combustor. A large fraction of the bed material is recirculated from the hot cyclone through a seal back to the combustor. From the outlet of the hot cyclone, the gas enters the convective heat transfer surfaces of the boiler. Bottom ash is removed from the process at the bottom of the combustor. Fly ash is removed by fabric filters. Sulfur is removed in the combustion process. The low combustion temperature helps control NO_x.

The Point Aconi circulating FBC installation is a project in startup being built for Nova Scotia Power Incorporated by Mitsui. Sargent & Lundy (S&L) is the engineer. The plant has a gross output of 200 MW and a net output of 165 MW. When the unit goes into operation this year, it will be the largest circulating FBC unit in the world. The unit is rated at 8700 kg/min, 122 bar, 537°C/537°C. The primary fuel is a locally mined bituminous coal with 5% sulfur content. No. 2 fuel oil is used for startup fuel and can also support up to 35% steam flow. The turbine cycle has four low-pressure heaters, a deaerator, and two high-pressure heaters.

Circulating FBC technology should be of particular interest for Asia because it provides good environmental performance without the complexity of an FGD system.

Slagging Combustors

A relatively new combustion technology being developed in the U.S. is the advanced slagging combustor. The slagging combustor burns coal, but results in low-NO_x and particulate emissions. Sargent & Lundy is working on a DOE-funded project with Riley Stoker Corporation in the U.S. to develop a low-emission boiler system (LEBS) using a slagging combustor. An advanced design slagging combustor, manufactured by Textron, will be tested late in 1993.

Sargent & Lundy is preparing the preliminary design of a 400-MW LEBS plant using slagging combustors. A proof-of-concept facility (30- to 50-MW range) will be constructed and tested, followed by the detailed design of the 400-MW plant.

Although a slagging combustor physically resembles a cyclone boiler, there are many differences. From an operational standpoint, the most significant difference is the low NO_x levels. These are achieved through substoichiometric (low-O_2) operation during that part of the combustion process where thermal NO_x is formed. Because of the different combustion process, one theory even suggests that fuel (bound) NO_x may be reduced. Another potential benefit of slagging combustors yet to be proven is the reduction of SO_2 through the injection of a sorbent such as limestone with the coal.

The slagging combustor uses an external vortex combustor to burn the coal at a high temperature. The key to the process is keeping the combustion temperature above the ash fusion temperature so that the production of fly ash is minimized and only slag is formed. Since little fly ash leaves the external combustor, the main boiler can physically resemble an oil-fired boiler. That is, the main boiler furnace does not have to be sized for firing coal. NO_x control is further enhanced by using an overfire-air system.

The slagging combustor by itself will probably have only limited application in the U.S. because it cannot achieve the very high SO_2 removal efficiencies that are required in most of the states. The slagging combustor will have to be used in conjunction with some flue gas desulfurization process. The slagging combustor has a lot of potential for Asia in that it might be eventually used to convert thermal plants fired with oil to firing coal.

Integrated Coal Gasification/Combined Cycle

Another environmentally sound combustion technique is Integrated Coal Gasification/Combined Cycle (IGCC). An IGCC project in the U.S. under the Clean Coal Technology Development Program that S&L is participating in is the Wabash River Repowering Project.

The Wabash River Project involves the use of coal gasification technology to repower a 100-MW steam turbine at an existing coal-fired power plant. The project is a joint venture between Destec Energy and PSI Energy. Upon completion, the Wabash River Repowering Project will be the largest IGCC power plant in operation in the U.S. and will also emit significantly lower flue gas emissions than most other high-sulfur coal-fired power plants.

The project will utilize Destec's coal gasification process, also known as the Sygnas process. The Destec gasification process is a two-stage, medium-Btu, oxygen-blown, entrained-flow process.

The Wabash River Generating Station consists of six pulverized-coal-fired units ranging in size from 100 to 245 MW. The turbine-generator on Unit 1, which has a nominal rating of 100 MW, will be the repowered turbine-generator. Unit 1 originally went into commercial service in 1953. The existing Unit 1 boiler will be abandoned. The coal gasification plant, the advanced combustion turbine, and the heat recovery boiler will all be located on property adjacent to the existing generating station.

The new combustion turbine will be a high-temperature design producing approximately 197 MW of electricity. Steam injection and fuel gas moisturization will be used for NO_x control. It should be noted that normally this machine's nominal output is approximately 155 MW. The power augmentation is gained due to the gas moisturization process undertaken as part of the gasification plant. Exhaust from the combustion turbine and steam integration for the gasifier will produce steam in the new heat recovery boiler. The boiler will be a single-pressure, superheat/reheat unfired natural circulation type with horizontal gas flow and will produce the necessary high-pressure steam for repowering the Unit 1 turbine-generator.

The fuel for the project will be a local bituminous coal. The coal will be delivered to the site by railroad and unloaded in existing coal handling facilities. A new coal preparation facility will process coal and water to produce the feed to the gasifier.

Coal gasification/combined-cycle has a significant heat rate advantage over conventional coal-based technologies. By utilizing the combined cycle in conjunction with coal gasification, units can take advantage of the combined cycle's high efficiency, which will likely increase in the future as combustion turbine technology improves. Conventional coal-based technologies using the Rankine cycle are reaching their efficiency limit, thereby limiting future improvements. Conventional pulverized-coal-fired plants and flue gas desulfurization systems typically have heat rates ranging from 2520 to 2654 kcal/kWh and 90% SO_2 removal. By comparison, coal gasification/combined-cycle plants can achieve heat rates ranging from 2140 to 2015 kcal/kWh with 98% SO_2 removal.

Unit 1 at Wabash River currently has a heat rate of about 2800 kcal/kWh, which is typical for a coal-fired power plant of this age and without flue gas desulfurization.

The heat rate of the repowered facility is expected to be about 2255 kcal/kWh, or more than 25% lower. This heat rate will be among the lowest of commercially operated coal-fired facilities in the U.S.

Coal gasification has significant advantage over other forms of direct coal combustion in terms of air emissions. The SO_2 and NO_x emissions from an IGCC unit, such as the repowered unit at Wabash River, will be dramatically reduced compared to the original unit's coal-fired configuration. Coal gasification/combined-cycle air emissions are only slightly greater than those from a combined-cycle unit firing natural gas. In terms of greenhouse gases (primarily CO_2), the coal gasification/combined-cycle unit emits about 15% less CO_2 compared to a comparably sized pulverized-coal-fired unit. This reduction is the result of its higher efficiency and lower heat rate, which ultimately result in lower coal consumption.

Coal gasification/combined-cycle technology produces an amount of solid waste comparable to a conventional pulverized-coal-fired unit. However, the solid waste produced in the gasification process is nonhazardous and relatively benign, consisting mainly of the mineral matter in the coal feed stock. The physical form and nontoxic nature of the solids leaving the gasification process are such that numerous potential product applications such as road paving aggregate and blasting grit are possible, thereby reducing the solid waste disposal needs.

Although, IGCC represents an exciting and a very environmentally sound coal technology, its applicability for Asia is probably limited at this point in time because of its costs.

Fuel Cells

Some research is being conducted in the U.S. to integrate fuel cell technology with the coal gasification process. High-pressure gas from the gasification process is reduced to low pressure through a turbine and then fed to the fuel cell. The fuel cell electrochemically converts the fuel's chemical energy into electricity.

Studies have been conducted where the fuel cell is substituted for the combustion turbine in an IGCC system. The resulting heat rate is substantially lower than a conventional IGCC system. However, because the fuel cell costs are higher than the combustion turbine, the cost of electricity for the fuel cell system were very close to the bus bar costs for the IGCC system. Thus, there is little economic incentive for developing the coal gasification-fuel cell system.

Fuel cell technology has applicability for Asia, particularly for electrification of distributed load centers. However, coal-based or coal-gas-based fuel cells are probably appropriate, primarily because coal gasification is not appropriate at this time for Asia.

Coal-Slurry Fuels

In the U.S. and a number of other countries, coal-slurry fuels are being investigated for potential use in boiler systems that now use oil. Initial research started with coal-oil mixtures but is now focused on coal-water mixtures, eliminating the need for oil. Coal-water fuels (CWF) can be burned under conditions that are typical of many oil-burning units without severe slagging or fouling behavior. Current research is centered on firing CWF in smaller sized boilers, with the expectation that the fuel mixture can eventually be used in larger units.

Coal slurry fuels have some potential for Asia as a replacement for oil fuel in existing boilers.

Postcombustion Technologies

FGD Systems

The basic postcombustion technology for utility applications in the U.S. is wet FGD. Wet FGD systems were first installed in the 1970s. Although dry FGD systems also have some applicability in the U.S., wet systems tend to predominate.

Although alternative FGD technologies being developed in the U.S. (like in-furnace injection or innovative combined SO_2/NO_x processes) will play a role in the electric utility industry's plans over the next decade, wet FGD will continue to be the technology of choice as SO_2 emission requirements in the U.S. become more stringent. This is because wet FGD systems have a considerable level of commercial development and capability to achieve ultra-high SO_2 collection efficiencies. Equipment suppliers, utility owners, and independent agencies such as the Electric Power Research Institute (EPRI) are directing extensive research and development efforts towards technical improvements because of the renewed demands for cost-effective wet FGD technology. Some of the significant design concepts or trends in the wet FGD field that will continue to mature or emerge for future compliance include

- the use of fewer and larger absorber modules—specifically, single absorber modules will be more frequently selected;
- SO_2 removal efficiencies in the range of 95 to 98%;
- the use of performance-enhancing additives for scale control and to boost collection efficiencies to ultra-high levels; and
- the increased use of high-performance alloys for the absorber modules.

The advanced FGD systems have some significant differences from earlier system designs. First, provisions are included to inject performance additives, such as organic acids. These additives supplement the base reagent by promoting or suppressing certain chemical reactions. The use of organic acid as a performance enhancer can boost SO_2 collection efficiencies from 95% to 98%. Second, hydroclones are used in the scrubber blowdown loop. The use of the hydroclone reduces the size of downstream dewatering equipment and can save a lot of space.

Numerous FGD technologies are available. Within the near future both wet and dry FGD systems, as well as seawater scrubbers for power plants located on the ocean, will begin to emerge in Asia.

Combined SO_2/NO_x Processes

Other postcombustion technologies that have potential advantages in plant efficiency, operation, and cost savings are processes that are capable of simultaneous removal of SO_2, NO_x, and particulates. For the most part, these technologies differ from the more conventional designs due to the following features:

- combination of high collection efficiencies for SO_2, NO_x, and particulates in an integrated process, and

- a salable or commercial by-product is typically generated rather than a solid waste.

One combined SO_2/NO_x removal process is the SNOX technology. Approximately 95% of the SO_2 and 90% of the NO_x in the flue gas are removed. The end product from the process is commercial-grade sulfuric acid.

Flue gas leaving the boiler is cooled in the air preheater by the discharge air from a wet sulfuric acid (WSA) tower. The flue gas then passes through a fabric filter or electrostatic precipitator where the particulate is removed. Next, a gas-to-gas heat exchanger is used to simultaneously heat the flue gas entering the selective catalytic reduction (SCR) reactor and cool the gas exiting the SO_2 oxidation reactor. The heated incoming flue gas is mixed with ammonia and enters the SCR reactor where the ammonia and nitrogen oxides are converted to nitrogen and water vapor. Following NO_x conversion, the flue gas is heated with an in-duct burner prior to entering the SO_2 reactor where SO_2 is oxidized to SO_3 by a catalyst material. The processed flue gas exits the SO_2 oxidation reactor and is cooled in the gas-to-gas heat exchanger. The flue gas then passes through the WSA tower prior to discharge to the atmosphere. In the WSA tower, the acid vapor is condensed, concentrated to high-purity sulfuric acid and then pumped to a storage tank.

A 35-MW demonstration unit was started up in the U.S. in 1992 and is presently undergoing extensive testing under the DOE CCT Program.

Currently, the costs for combined SO_2/NO_x processes are high compared to more conventional technologies. However, these high costs are because these technologies are currently based on first-generation designs. In the future, these costs can be expected to decrease with increased operating experience and cost optimization.

In the near term, the potential for these types of processes in Asia appears to be very limited.

Particulate Control

The control of particulate emissions from utility boilers in the U.S. is not necessarily an emerging technology. Electrostatic precipitators have been used in the U.S. since the 1950s. Two factors have provided renewed interest in the U.S. in particulate control:

- increasing emission control requirements at both the federal level and the state level, and
- the possibility of using the particulate control as part of an integrated approach to controlling other pollutants, like air toxics.

One particulate control technology finding new interest in the U.S. is pulse-jet fabric filters, based on some work done with pulse-jet types outside the U.S., particularly Australia. Most previous U.S. experience with fabric filters has been with the reverse air type.

A new variation of the pulse-jet technology is the Compact Hybrid Particulate Collector (COHPAC). Under development by EPRI in the U.S., COHPAC is a pulse-jet technology with a low-pressure/high-volume cleaning system and a high air-to-cloth ratio. The high air-to-cloth ratio allows COHPAC to be considerably smaller and less expensive than electrostatic precipitators and reverse air fabric filters.

Because of new more stringent emissions standards, existing precipitators designed in the late 1960s cannot meet the current opacity limits without adding new series precipitators or replacing the existing precipitators with new larger ones. The COHPAC technology is to place a baghouse after a precipitator to serve as a polishing device. The COHPAC baghouse is 50% to 80% smaller than conventional baghouses, with the corresponding space and capital savings.

A project, for which S&L is the engineer, is currently operating at a two-unit 575-MW lignite-fired plant in Texas. The actual operating results to date have been very favorable, especially with lignite fly ash. Lignite fly ash in the U.S. has been difficult to collect in precipitators and reverse air bag houses. The Texas project has four baghouses consisting of eight compartments for each 575-MW unit. The bags are

about 7 meters long and are made of Ryton, a polyphenylene sulfide fiber capable of continuous operation at 195°C with excursions up to 220°C.

COHPAC technology may have some benefit for power installations in Asia for the following reasons:

- COHPAC appears to work well on U.S. or Texas lignites, and presumably would work well on Asian lignites.
- COHPAC is ideally suited for fluidized bed boiler applications, where bag houses are usually the preferred flue gas cleanup technology.
- COHPAC's modularized construction makes it easy to transport to and erect at remote sites.

Transfer of Technology

Transfer of technology can cover two issues:

- transfer of knowledge, and
- transfer of hardware.

Transfer of knowledge is the process of moving skills and expertise from one entity to another, person-to-person, company-to-company, country-to-country. For issues like clean coal technologies, there are many ways available to transfer knowledge, such as:

- missions and reverse missions,
- conference and workshop attendance,
- training courses and seminars, and
- participation in EPRI.

Missions to visit countries, companies, and actual installations provide people with the opportunity to get a first view of the types of technologies and solutions available. Attendance at appropriate conferences and workshops, provide opportunities to meet and talk with people who have expertise. Training courses or seminars are excellent ways of providing knowledge on a more detailed level. Often these training courses or seminars are funded or can be funded by a foreign government.

EPRI is an organization funded by U.S. electric utilities. EPRI engages in practical research type work and transfers significant amounts of knowledge and expertise back to its member utilities. Environmental and clean coal technologies are two of its major research areas. EPRI is willing to discuss membership options with non-American utilities.

One program that S&L is developing with EPRI is the Clean Air Technology (CAT) workstation. The CAT workstation is an interactive computer program intended for use by U.S. utilities for finding solutions for complying with air pollution control regulations. The workstation is a user friendly program consisting of an extensive database of pollution control technologies. The database contains technology facts, costs, performance data, and experience data that allow one to examine and compare various pollution control technologies for a given power plant or application, and to run various "what if" scenarios comparing costs and performance impacts. Results are presented in the form of text, drawings, curves, tables, etc. The user-friendly aspects of the program allow the data to be accessed and manipulated very easily. The user can "call up" increasing levels of detail that describe the process, show where actual installations are in operation, identify suppliers, and so forth.

Transfer of hardware is a little more difficult and usually must be done through actual projects. The National Energy Policy Act of 1992 includes provisions for the development of a fossil energy technology program to export clean coal technologies. This program involves the U.S. DOE, U.S. Commerce Department, and U.S. Agency for International Development (AID), and includes the development of financial mechanisms to increase U.S. industry involvement in hardware transfer. Implementation of the technology transfer program would consist of a twofold approach:

- showcase a few advanced technologies in foreign countries, with financial assistance being provided by the U.S. DOE;

- export commercially available pollution control technologies from the U.S. with financing being provided by multilateral banks or commercial sources.

Finally, there is a program that has managed to incorporate technology transfer programs ranging from equipment demonstrations and engineering roundtable discussions to traditional training and orientation missions to the U.S. Asian Environmental Partnership (AEP). This program was originally started during President Bush's administration and has continued to grow. The U.S. AEP funds programs that address environmental problems, and has a specific emphasis on energy and environmental air quality. The following are some examples of the types of projects that the AEP has funded in the last 12 months:

- an environmental action team's analysis of air quality in the Mae Moh valley in Thailand,

- mapping of air quality resulting from the volcanic eruption of Mt. Pinatubo in the Philippines, and

- a number of training grants to Asian countries to study the design of safe power transmission lines.

Of the AEP's proposed $100 million budget for 1992-1996, approximately $10 million has been set aside for energy infrastructure and environmental programs. Specific information on U.S. AEP programs can be obtained from your regional U.S. AID representative.

Summary

There are many environmentally sound coal technologies being developed in the U.S. This paper addresses a few. Some of these technologies are very appropriate for use in Asia and it is expected that they will be implemented there in the future.

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Technology Options/Overview

Review of Vietnamese Coals

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Abstract

Vietnamese coals are represented by relatively large reserves of anthracite/semianthracite (about 3.223 billion tons), some bituminous coal (about 11 million tons) and different lignite grades (more than 30 billion tons). Anthracite grade coal is occurring mostly in coastal region (Quang Ninh Basin) and is of high quality (low sulfur and ash contents). Other coals occur mostly in inland position within northern part of the Vietnamese territory. The production of anthracite grade coals reached about 4 to 5 million tons, from which 30% are exported.

INTRODUCTION

Vietnam is a country situated in the Southeast Asia on about 326 000 sq. kms. Many deposits of raw minerals occur in Vietnam. Coal represents one of the most important raw material with relatively very huge reserves. Coal deposits are concentrated mostly in the northern part of the country in one large basin and in several smaller occurrences. Most of Vietnamese coals lies inclined. The inclination of 25 to 45° is characteristic for 65% of seams, 30% are over 45° and the rest is below 25°. Vietnamese coal industry is one of the oldest in Vietnam. At the present, coals are exploited in the Quang Ninh Province (Hon Gai, Cam Pha, Uong Bi, Mao Khe Mines) as well as in the Bac Thai (Lang Cam and Nui Hong Mines), Lang Son (Na Duong Mine), Nghe Tinh (Khe Bo Mine) and Quang Nam-Da Nang Provinces (Nong Son Mine). The deposits of anthracite to semianthracite coal grades and bituminous coals are of uppermost Triassic in age (Norian and Rhaetian), lignites are mostly Neogene.

SHORT REVIEW OF COAL DEPOSITS

1. The Quang Ninh Basin

The basin is situated in the coastal region east of Hanoi. It consists of three large deposits, i.e. Uong Bi, Hon Gai, and Cam Pha-Duong Hui sectors reflecting the geological structure of discontinuous strips of coal-bearing strata. Coal is developed in continental to lagoonal deposits forming 300 to 700 m thick horizon in red beds. Basin was folded at the Triassic/Jurassic boundary in the form of longitudinal open folds. Coal there lies horizontally to inclined (max. inclination of 40°). The coal seam represents relatively unified body without intercalations, only

Table 1 Technological Properties of Some Vietnamese Coals (after COALIMEX data)

Grades	Size mm	Moisture %max	Ash %max	Volatile Matter %max	Sulphur %max	Calorific Value kcal/kg
Hon Gai Anthracite Coal						
Lump Coal	35-100	6	8-12	6-8	0.6	7200
Lump Coal	50	4	6-8	5-7	0.6	8300-8100
Lump Coal	35-50	4	3-5	5-7	0.6	8300-8000
Lump Coal	15-35	5	4-6	5-7	0.6	8200-7900
Dust Coal	6-18	5	5-7	5-7	0.6	8100-7900
Dust Coal	0-15	8	6-8	6-8	0.6	8000-7800
Dust Coal	0-15	8	8-10	6-8	0.6	7800-7600
Dust Coal	0-15	8	10-15	6-8	0.6	7600-7200
Dust Coal	0-15	8	15-22	6-8	0.6	7200-6500
Dust Coal	0-15	8	22-32	6-8	0.6	6500-5600
Dust Coal	0-15	8	32-40	6-8	0.6	5500-4600
Uong Bi Anthracite Coal						
Lump Coal	25-100	5	9	.4-5	<1	7000-7200
Lump Coal	15-50	5	9	4-5	<1	7000-7300
Lump Coal	20-45	5	9	4-5	<1	7000-7200
Lump Coal	35-50	5	9	4-5	<1	7000-7200
Lump Coal	15-35	5	9	4-5	<1	7000-7300
Dust Coal	6-22	8	11	4-5	<1	6800-7000
Dust Coal 10C	0-15	8	15	4-5	<1	6000-6500
Dust Coal 10C1	0-15	8	22	4-6	<1	5500-6000
Dust Coal 10C2	0-15	8	30	4-6	<1	5000-5500

rarely there are thicker sedimentary interbeds. The thickness of coal seams varies commonly between 5 and 50 m, sometimes reaching up to 60 - 80 m. Selected technological properties of coal is given in Table 1. For the whole basin, in general, the coal is characterized by moisture 1-2%, ash content 3-17%, volatile matter 6-11% and calorific value 7800-8400 kcal.kg^{-1}. Over 60% of mining is in the form of coal dust and lump below 10 mm in size (Neumann 1959, Havlena 1965). The mining operates in open pits with short underground side galleries. In older publications, the basin was known as Tonkin Basin.

1.1. The Uong Bi Coal District

The deposit, situated in the east, contains two thick coal seams - Bo Dai and Uong Bi. The former has been mined in Dong Ri, Dong Vong, Canh Ga, Than Tung, Yen Tu, Khec Huoi and Ho Thien Mines. The latter one has been exploited in Co Kenh, Mao Khe, Trang Bach and Quang La sites. The reserves are estimated to about 1,284,283,000 tons, from which 112,721,000 tons have been already explored in detail. According to the ASTM D388 classification, the coal represents anthracite and a small proportion belongs to semianthracite.

1.2. The Hon Gai Coal District

The deposit is situated in the southern part of the main coal basin and extends from Bac Ninh to Ke Bao Island. It consists of Ha Tu, Nui Beo Ha Lam, Tan Lap, Bang Danh sites in the north and of Ha Tu site in the south. Three coal seems are developed in Ha To and Bang Danh with the thickness of 12-60 m, 7-27 m and 6 m. Reserves are estimated to about 712,310,000 tons, from which about 19,214,000 tons have been investigated in detail. According to the ASTM D388 classification, the coal belongs to anthracite and semianthracite.

1.3. The Cam Pha and Duong Huy District

The coal district is also situated in the southern part of the Quang Ninh Basin. Coal seams are mined in Coc Sau, Deo Nai, Cao Son, Mong Duong, Khe Cham, Khe Tam and Hga Hai sites. This district is the most important, having three seam groups. In the lower part, up to 150 m thick, there are three seams 30-50 m and up to 80 m thick. The middle seam group consists of several unimportant seams. The upper group contains 10 seams 0.5 to 3 m thick in a sedimentary sequence 60 m thick. Reserves are estimated to about 1,209,466,000 tons, from which about 241,433,000 tons have been investigated in detail. According to the ASTM D388 classification, the coal is anthracite and semianthracite.

2. Coal Deposits Situated inside the Vietnamese Territory

2.1. The Nui Hong Deposit

Here, the reserves are estimated to about 17 million tons in the semianthracite degree.

2.2. The Nong Son Deposit

The deposit lies in the Quang Nam-Da Nang Province and contains anthracite reserves.

2.3. The Lang Cam Deposit

The deposit contains about 9 million tons of volatile bituminous coal.

2.4. The Khe Bo Deposit

About 2 million tons are known in this deposit in the Nghean Province. The coal degree is medium volatile bituminous coal.

2.5. The Na Duong Deposit

The deposit, situated in the Lang Son Province, have reserves estimated to about 90 million tons of lignite B.

2.6. Dongiao Deposit
The deposit is of small extend and contains lignite A.

2.7. The Song Hong Deposit
The deposit was discovered during oil and gas exploration by drilling in the region of the Red River. Preliminary reserve estimations reached about 30 billion tons of lignite situated in shallow subsurface, about only 3 to 10 m below the soil. The coal can be preliminarily classified as lignite A.

WASHERY SYSTEM

In order to make coal of better quality after the mining, the coal is processed in washery plants constructed in each coal region. There is cleaned coals of many grades, receiving the material from numerous mines and producing washed clean coal of several production grades. The JIG has been used in washing plants in the first stage, and the product is rewashed by dense medium separator, sometimes also by dense medium cyclone according to demands of Clients. The total capacity of washeries is about 5 million tons of coal per annum.

COAL PRODUCTION AND EXPORT

The annual coal production was about 8 million tons in the past. Owing to lower demands in the internal market, when some water power station started to operate and the demand of industry decreased, the present coal production is distinctly lower. The production of 4.2 million tons was reported for 1991 and 4.5 million tons for 1992. The estimate for 1993 is about 5.2 million tons.

The quality of most of Vietnamese coals is high with high calorific values, low sulfur content and ash percentage. Therefore, they are suitable for burning in regions with high degree of atmospheric pollutions and they use need not very high construction costs for decrease in pollutants during the production of energy. They represent relatively clean energy source.

Owing to coal quality, about 30 % of Vietnamese coal production is exported, one third to Japan, one third to South Korea and one third to Europe (Belgium, Britain, etc.). The coal is exported via coal ports in Cam Pha and Hon Gai total loading capacity of about 1,500 t of lump coal and 4,000 t of dust coal per day.

THE FUTURE OF VIETNAMESE COAL

It is generally supposed, that the demand on coal will increase in the future mostly for the use in power stations and for the cement production. Therefore, the coal production can be estimated to about 6.1 to 6.5 million tons of clean coal in 1995 and to 7.5 to 10.4 million tons in year 2000. The proportion of export can increase, too.

To reach these demands, the capacity of already existing mines will be increased and mines will be restored. New mines will be opened, e.g. Yen Tu, Khe Tam, Nui Beo or Bac Bang Dangh, Ha Tu south and Khe Sim east. Simultaneously with opening of mines, washery plants will be improved too, e.g. in Hon Gai, Khe Tam, Cuaong I, Uong Bi, in order to make coal quality better and to reach the demand of foreing contractors, and also for the domestic use.

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IEA SECOND INTERNATIONAL CONFERENCE ON CLEAN AND EFFICIENT USE OF COAL AND LIGNITE ITS ROLE IN ENERGY, ENVIRONMENT AND LIFE

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Coalbed Methane as a Source of Fuel for Power Development Projects

COALBED METHANE - THE CLEANEST COAL UTILIZATION YET

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Abstract:

Coalbed methane, once believed to be only a major explosive danger in the mining of coal, is now a major source of methane gas supply in the United states. Today's technology for extraction has advanced to the point where coalbed methane is being developed solely as an economic gas resource today. The U.S. Government's tax credit program significantly enhanced the development of drilling and production technology for this resource.

Methane has long been used in the production of electric power in the United States. It is recognized as a clean burning and very efficient fuel. The development of the combined cycle, gas turbine electric generation equipment has significantly increased the efficiency to almost fifty percent through the use of gas turbines, steam recovery boilers and steam turbines.

Powerbridge, Inc. developed a strategy of acquiring ownership of natural gas reserves as a way to both provide the fuel resource necessary for financing and to improve the economics of power projects. In the process of implementing this strategy, Powerbridge found that coalbed methane resources had two characteristics that were very desirable for power projects.

First, coalbed methane wells produce at a much more constant rate through time than conventional wells. This is particularly desired as it more closely matches the consumption profile of the power plant. it also minimizes the excess production capacity in the early years and the additional capital required in later years to maintain the production capacity.

Secondly, coalbed methane wells are generally very shallow wells. Consequently, they are not as expensive to drill as deeper, conventional gas wells. Coalbed completion technology has developed to where knowledgeable operators can make economic completions.

Coalbed methane resources are being pursued beyond the United States. There are many projects underway including operations in England and Poland. It is reasonable to expect coalbed methane resources derived from coal fields around the world to provide significant methane supply in the future.

COALBED METHANE
A FUEL SOURCE FOR POWER PROJECTS

Coalbed methane, once believed to be only a major explosive danger in the mining of coal, is now a major source of methane gas supply in the United States. Today's technology for extraction has advanced to the point where coalbed methane is being developed solely as an economic gas resource today. Major sources in the U.S. are in the black Warrior basin in Alabama in the Eastern United States and in the San Juan Basin, in New Mexico in the Western United States. As of the end of 1992, coalbed methane resources provided six percent (6%) of the total gas reserves in the U.S. and this contribution has been growing

Methane has long been used in the production of electric power in the United States. It is recognized as a clean burning and very efficient fuel. The development of the combined cycle, gas turbine electric generation equipment has significantly increased the efficiency of almost fifty percent (50%) through the use of gas turbines, steam recovery boilers and steam turbines.

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COALBED METHANE
THE CLEANEST COAL UTILIZATION YET

Methane has always existed in coal seams and is a major explosive danger during the mining of coal. During most of the history of coal mining, this methane was considered a major operational and safety problem. A large investment is required to provide for vent holes and ventilation equipment to make the mining operation safe. The methane that is vented to the atmosphere is a source of environmental pollution. Only in rare instances was this methane gathered into a useful product.

In recent years, coalbed methane has achieved the status of a resource rather than a waste product which must be handled to mine the coal. This change of perspective is due to a number of things, but it is primarily associated with the increase in natural gas (methane) prices in the U.S. and the advance and adaptation of oil field completion and production technology to the production of coalbed methane.

In the U.S. the development of coalbed methane as a source of gas is one of the few success stories associated with government support of a technology. Even though the first San Juan basin coalbed methane well was developed over thirty-five years ago, there was little development of this resource until the early 1980's. Interest increased as natural gas prices escalated. However, development accelerated dramatically with the tax credit allowed for coalbed methane production from wells drilled before 1993.

Since 1988, the number of producing coalbed methane wells has been doubling every year. (See Exhibit I).

While the tax credit has been a major driving force in this dramatic growth, technological advancements have also played a major role. It is difficult to say whether the tax credit enhanced the rate of technology development, but it is certain that it stimulated the drilling of a large number of wells prior to the end of the qualifying period for the credit. The companies drilling these wells were also developing the technology in order to achieve successful operations as the credit is only obtained through production, not simply the drilling of the well. Consequently, the greater the production, the more the tax credit.

All areas of technology including types of completion, drilling fluids, perforating, stimulation designs, production equipment, and water disposal advanced during the recent years. The basic technology has been known for many years and used extensively in typical oil and gas reservoirs. However, each area required the development of new parameters, designs and concepts in order to optimize the production from the different coalbed formations. The most critical aspect of this new technology is simplicity to minimize cost.

Recently, the use of an air hammer drill was employed to drill wells of less than 2000 feet. While this drilling rig is limited to this depth range, very high penetration rates

(over 150' per hour) were achieved while maintaining an in-gauge, very straight hole. The drilling time was reduced from an average of about 7 days to 2-3 days representing a major reduction in drilling costs. In addition, the vertical, in-gauge hole helped increase the success rate of cement operations from about 50% to 100%.

Further, during the past 7 or 8 years, a great deal has been learned regarding how the coal formations behave during the hydraulic fracture treatment. This knowledge has permitted the use of much smaller treatments and less expensive propants. All of this knowledge has been used to determine the minimum treatment (this minimum cost) necessary to ensure a successful fracture.

Production technology has also advanced during this time. A coalbed methane reservoir produces its fluids much differently than the typical well. The methane in a coalbed reservoir is absorbed on the coal and water pressure prevents it from escaping. To produce the gas, a great deal of water must be produced first. A significant quantity of very fine grains of coal (coal dust) is also produced with the water. These coal fines are damaging to the pumps which were used to dewater the formations. Consequently, significant expense was involved with the number of workovers needed in early wells.

Pump technology, material technology and general production knowledge increased to significantly enhance the efficiency of the dewatering operation. In

particular, the development of the progressive cavity pump has allowed the movement of high volumes of fluids and coal fines without the wear that a typical rod pump experiences.

The production profiles (the rate of production with time) are much less than the profiles found with the typical conventional natural gas sandstone or limestone reservoirs. These conventional reservoirs tend to have very high initial rates relative to reserves with high annual decline rates (15% - 20%). The coal bed reservoirs, on the other hand, actualy have increasing production rates in the initial years, but they peak at a much lower level than the conventional well. They also decline at a much more moderate rate (5% - 10%). Consequently, it takes much longer for these coalbed methane wells to return a given amount of money than a typical gas well. This makes the total well cost much more critical in determining an economically successful well.

However, these low rate, long life production profiles associated with coalbed methane wells are particularly well suited to the needs of an electric power production facility. This is especially true for the independent power producer since the financing requirements for a power project generally requires a source of gas that will provide 150% of the plants requirements for the term of the debt. Consequently, the flatter the production profile, the less excess deliverability is developed to meet this reserve requirement. The low, flat profile of the coalbed methane well matches the consumption pattern of the power plant to a much greater degree than conventional gas well profiles.

Methane has long been used in the production of electric power in the U.S. It is recognized as clean and very efficient fuel. The development of the combined cycle, gas turbine electric generation equipment has significantly increased the efficiency to almost 50% through the use of gas turbines, steam recovery boilers and steam turbines.

Since the production profiles of coalbed methane wells provide a gas supply pattern which is much closer to the consumption pattern of an electric generation facility, this source of gas permits "mine-mouth" location of power plants. This also solves the difficult problem of transporting the natural gas. While there continues to be a debate as to whether it is more efficient to transmit electrons or molecules of gas, the critical mass needed to justify a new pipeline extension is difficult to generate in some coalbed methane areas. The critical mass needed to justify an electric transmission line is the power plant. Thus, locating a power plant at the coalbed methane source can resolve a difficult transportation problem.

Using coalbed methane in power plants not only eliminates the air pollution caused from methane ventilation during coal mining operations, it also helps solve another problem with coalbed methane production. Water disposal is often a problem as there is such a large quantity and it is sometimes required to be re-injected into another formation so as not to interfere with the fresh-water aquifers. Power plants often need to purchase large quantities of water for use in both the production of steam and in the cooling operations. The water produced from coalbeds is generally of sufficient

quantity to allow it to be used for the water needs of the power plant. Using this water lowers the cost of both gas production and electricity generation.

All of the synergies between coalbed methane production and electric generation are magnified in the international areas--particularly in the rapidly developing Asian theater. The need for additional reliable electric power is evident and many projections include a doubling of the electric generation capacity by the end of the century.

Further, the infrastructure needed to transport both natural gas and coal is often not available. By locating the power generation facility at the "mine-mouth", the need for this investment in infrastructure is minimized. Transmission lines must be built, but they are relatively easy and inexpensive compared to pipelines and rail systems to move the coal. Further, these lines would be required eventually to bring power to the mine area if the power plant were built elsewhere.

The production and use of coalbed methane from the generation of electric power converts an environmental hazardous waste product into a useful environmentally-friendly product. The use of tax credits in the U.S. has significantly increased the rate of technology advancement and has helped make coalbed methane into an economic resource. Its production characteristics are particularly suited to the requirements of electric power production. All of this is enhanced significantly in the rapidly growing Asian theater.

WORKSHOP A3

TECHNOLOGY OPTIONS: EMISSIONS CONTROL, COAL PREPARATION AND CLM FUELS

Carbon Dioxide Capture and Disposal as a Greenhouse Gas Abatement Option

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Introduction

The IEA Greenhouse Gas Programme is conducting a forty two month assessment of technologies which, capture, utilise and dispose of carbon dioxide generated from the use of fossil fuels in electrical power generation. The work is supported and directed by representatives from thirteen countries, the Commission of the European Community, the German industrial organisations RWE and DMT and British Coal who is also the Operating Agent. The work is carried out under an Implementing Agreement under the aegis of the International Energy Agency. Within member countries the Programme is supported by a network of organisations who contribute both funding and expertise. Membership is open to new members from both IEA member and non-member countries.

An agreed programme, initiated in May 1991 has systematically studied various components of the sequestration chain. This has been achieved by employing the best available contractors on each topic wherever they may be found. Work has been placed outside of member countries in the pursuit of excellence.

Assessment Basis

A set of parameters was agreed between the membership of the programme reflecting the international nature of the activity. In summary this includes:

Currency	:	US Dollars
Size	:	500 MW net output
Location	:	North West Europe coastal
Fuel	:	Coal - Australian (Drayton)
		Gas - North Sea (Brent)
Fuel Value	:	Coal $2.00 per GJ
		Gas $3.00 per GJ
Plant life	:	35 years
Financial factors	:	Time value of money - 10%
		Contingency - 10%
		Load factor - 85% after year 3 for coal, 90% for gas
		Insurance, commissionary costs, fees included
		Full equity
		No inflation
		Taxes excluded
		Effluent standards follow European directives

TOPIC	CONTRACTOR	STATUS
PF + FGD	British Coal (UK)	Complete
CCGT	SINTEF (Norway)	Complete
IGCC	ECN (Holland)	Complete
O_2/CO_2 Recycle (PF)	ERC (N Ireland)	Complete
Absorption Capture	H&G (UK)	Complete
Adsorption Capture	Monenco (Canada)	Complete
Advanced capture systems	MIT (USA)	Complete
Cryogenics capture	Intech (USA)	Complete
Membranes capture	TNO (Holland)	Complete
Disposal Review	In House	Complete
Fuels Utilisation	CSJ (Japan)	Complete
Chemicals Utilisation	Batelle (USA)	Complete
Ocean Disposal	Tecnomare (UK/Italy)	Complete
Aquifer Disposal	Stanley ICL (Canada)	Complete
Depleted Gas Wells	TNO (Holland)	Report Received
Direct Bio Fixation	CSJ (Japan)	In progress
Indirect Bio-Fixation	VTT (Finland)	Complete
Enhanced Oil Recovery	IPE Claushal(Germany)	In progress
Environment/Risk		Coming 1994
Transportation	Erdyn (France)	Contract
Solid disposal	Atkins/Air Products (UK)	In progress
IGCC (O_2/CO_2 Recycle)	ECN (Holland)	Complete
CCGT (O_2/CO_2 Recycle)	SINTEF (Norway)	Complete

Table 1. The status of IEA Greenhouse Gas R&D Programme studies as of October 1993.

Results

A number of studies have been carried out to investigate a series of power generation options. These options were then investigated in turn to evaluate short, medium and long term technologies when applied to, CO_2 capture and disposal options. A listing of the studies, their status and the contractors involved appear in Table 1.

Power Generation Studies

The power generation studies show an inverse relationship between efficiency and CO_2 emission rate as might be expected. Specific cost expressed in US dollars (1992 figures) per KW installed capacity does not bear a direct correlation with efficiency with costs expressed in ranges which reflect estimate accuracy. These results are illustrated in Table 2.

Study	Fuel	Efficiency (% LHV)	CO_2 (g/kWh)	CO_2 (vol % wet)	Specific Cost US$/kW	Power costs mills/Kwh
PF + FGD	Coal	39.9	830	13	900-1200	49
GTCC	Gas	52.0	410	3	600-800	35
IGCC	Coal	41.7	790	7	1600-1900	59
O_2/CO_2 recycle	Coal	32.8	1000	63	2200-2500	78

Table 2 The major cost and efficiency data for the four power generation base cases.

The design of the pulverised coal plant (PF) is based on subcritical steam conditions of 565°C/180 bar and a generic calcium carbonate slurry scrubber (FGD). The gas turbine plant (GTCC) employs two Siemens KWV V94.2 machines while Texaco gasification is the basis for the IGCC plant. CO_2 recycle refers to a process where combustion takes place in a mixture of oxygen and recycled carbon dioxide to yield conventional flame characteristics and essential pure CO_2 and water vapour. These studies have been reported in detail elsewhere (ref 1).

CO_2 Capture Studies

The second phase of the technical assessment option studies consisted of examining alternative technologies for capturing carbon dioxide. Described in Table 3 are what appear to be the best short term or close to market technologies.

Generation Technology	Fuel	Capture Technology	$ per ton CO_2 avoided	Incremental mills/Kwh
PF + FGD	Coal	MEA Absorption	46	28
GTCC	Gas	Membrane + MEA Absorption	31	10
IGCC	Coal	Shift conversion with physical absorbent	16	14
O_2/CO_2	Coal	Membrane separation	16	6

Table 3. The current "best fit" technologies for the capture of carbon dioxide when coupled with the four base case power generation studies.

Commercially CO_2 is currently captured for industrial use through absorption with monoethanolamine (MEA) from coal fired system flue gas. The membrane systems considered were polydimethylsiloxane and polyamide low temperature polymers where the gas absorption membrane acts in much the same way as a packed absorber in a conventional process.

Shift conversion in the IGCC process is a water gas reaction where water and carbon monoxide react to form carbon dioxide and hydrogen. Carbon dioxide is recovered at pressure using a physical absorbent in this case a polyethylene glycol ether.

CO_2 avoided is calculated by subtracting emissions from the total generated in the process of power production and operation of capture facilities for the technology in question from the emissions which would have resulted. The additional energy consumption, and so additional CO_2 formed in the operation of capture plant may represent over 30% of totals in some cases and is included in all of the calculations.

The captured CO_2 must be dried and compressed ready for disposal or utilisation. To accomplish this requires capital outlay in the order of $12,000-18,000 per tonne CO_2 shipped per day. The cost to transport CO_2 in a supercritical state to disposal or use is, naturally, completely dependent upon site conditions. If a 50 km pipeline system is assumed, then a further capital investment of $2,000 - $2,500 per tonne CO_2 shipped per day.

CO_2 Disposal Studies

Turning to the global potential and the costs for disposal, a vast range is provided by a number of authors. The costs for disposal developed by the IEA Greenhouse Gas R&D Programme (GHG) are compared in table 4 with those appearing in the literature.

Disposal Method	Potential Global Storage Capacity Gt CO_2	Cost $/t$CO_2$	
		(Literature)	(GHG)
Ocean Disposal	5000-70 million	-	1.4-6.8
Aquifers	318-10,000	21.8	2.2
Exhausted gas wells	300-1200	3.8	1.7
Exhausted oil wells	150-690		
Forestation (50 years)	180-360	1.0	3.3-8.5

Table 4. Estimates of global storage capacity and disposal cost for a variety of disposal technologies.

It is useful to note that a 500 MW power plant may emit 8,000-10,000 tonnes CO_2 per day, equivalent to 0.14 giga (G) tonnes over a 40 year life.

The indications are therefore that actual disposal is not expensive, but there are significant technical and environmental hurdles to overcome. A single utilisation opportunity which has been studied in detail uses 50,000 tonnes per year of CO_2 to manufacture 100,000 tonnes of dimethyl carbonate. Carbon dioxide avoided is 6,600 tonnes per year. Dimethyl carbonate would find application as a solvent or chemical intermediate for polycarbonate plastics under favourable economics, or possibly as an alternative to methyl tertiary butyl ether as a gasoline additive.

The cost figures reported for forestation reflect a tropical country scenario against an annual sequestration of 3 GT CO_2. The costs for industrialised countries are estimated at $17 to $46 per tonne CO_2 avoided.

Forestation, to compensate for CO_2 emissions from fossil fuel burning, is an alternative approach and is a much cheaper option. The storage time however may not be adequate and there are problems of land availability (a 500 MW coal fired power plant would require a forest area of 2000km$_2$).

Discussion

A contingency plan or insurance policy is being formed against the possible verification of models predicting global warming in the upper band of temperature rise projections. Some technologies being considered by the IEA Greenhouse Gas Programme are more longer term options; some are minimum regrets options; all are "backstop" technologies.

CO_2 Capture

Processes to capture CO_2 from power generation flue gases or process streams are largely a

matter of optimisation and demonstration. Generally, this is low risk technology and the transportation of CO_2 is a proven industrial practice. Disposal techniques however require extensive research and development. Many questions remain regarding ocean and aquifer disposal. Disposal and utilisation options generally tend to be niche opportunities depending on the geography, geology, energy costs and specific alternatives.

One study exercise has suggested new absorbent chemicals, high temperature ceramic membranes, integration of systems and equipment development has the potential to reduce energy cost in capture by 20% to 50%. In that capture is the major cost component in sequestration any improving cost picture is welcome.

CO_2 Utilisation

CO_2 has a wide range of uses. For those in the food and beverage industry it provides fast freezing and effervescence but does not provide "storage". Urea-based fertilizers however, allow CO_2 to be transported and is in fact a temporary storage. Uses, such as enhanced oil recovery (EOR) and bioenergy, which are still under investigation are of obvious interest. EOR could sink 0.4Gt/y possibly at negative cost if in real terms the price of crude oil is approximately $20 per barrel. Biomass as a fuel has an estimated value of $4.4/GJ in industrialised countries and $2.5/GJ in developing nations. In total utilisation may not dispose of more than 20% of the annual imbalance of global emissions but will add to world economic productivity.

CO_2 Disposal

Ideally CO_2 should be injected into very deep water (> 3000m) at a site where there is no upwelling; this would provide a retention time > 1000y with minimum environmental impact. It may be possible to achieve injection at this depth by means of vertical pipes suspended from ships or platforms but the technology does not exist at present and the cost is unknown. More conventional pipelines, laid on the seabed would, using present day technology be restricted to a maximum depth of 1000m; however with a refined injection technique (ref 2) and with careful site selection, a dense plume of CO_2 enriched seawater could be formed (ref 3) which could sink to much greater depths, again providing a long retention time. Injection at depths shallower than 1000m may not be acceptable because of the impact on the marine environment. Costs of disposal in the ocean are mainly pipeline costs and, if sufficiently large pipes are used (860mm), could be as low at $1/t CO_2/100km.

CO_2 could also be stored, as a solid in insulated repositories which, if sufficiently large and with high levels of insulation, could result in the CO_2 being released to atmosphere at a much lower rate over a time period of > 1000 years (ref 4). A study is under way to examine the practicalities and cost of this scientifically correct proposition. Early results suggest that in practice the method may prove difficult and costly.

CO_2 Removal from the Atmosphere

An alternative approach to capture and disposal of CO_2 is to remove it from the atmosphere by

photosynthesis. Compensatory forests represent the cheapest option available for CO_2 sequestration and our study has shown that sufficient land is available to remove >3Gt CO_2/year for 50 years. Costs are an order magnitude lower than capture plus disposal costs but there are concerns regarding the eventual fate of the plantations. A more sustainable approach is to use, where it is accessible, that land for the production of a biomass fuel which can be used to substitute for fossil fuel as noted earlier.

Overall Costs of CO_2 Capture and Disposal

A compilation of the results of the best combination of capture and disposal shows (Table 5), that given the inherent inaccuracy of estimates and uncertainty regarding databases a

	Additional cost mills/kWh	
	Gas	Coal
Capture	12.0	16.5
Dry & Compress	2.7	1.3
Transport & Disposal	0.9	1.9
Total	15.6	19.7

Table 5 *Additional costs associated with carbon dioxide capture and disposal.*

preliminary range of 1.5-2.0 cents/Kwh for gas and 2.0 to 2.5 cents/kWh for Coal is suggested over basic power generation cost.

Conclusions and Future Work

Although sequestration of carbon by capture and disposal may increase power cost from anything between 35% and 50% this approach is not unfeasible and therefore worthy of consideration as a mitigation option, using available technology.

Further effort is required to refine techniques and costs to establish the position of sequestration as an option among competing approaches, whether the competing options are technological or political.

A programme of comparative full fuel life cycle analysis is going to enhance the data of this paper in addition to including a comprehensive appraisal of externalities. Beyond the fuel cycle work the extension of the IEA Greenhouse Gas Programme is being discussed in terms of greenhouse gases other than CO_2 and more detailed studies of attractive options.

Opinions expressed are those of the authors and not necessarily those of the International Energy Agency, its secretariat, the Operating Agent or members of the Implementing Agreement.

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CLEAN & EFFICIENT USE OF COAL WITH CO_2 STABILIZATION

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INTRODUCTION

We live in a world where the ever-increasing use of fossil fuel has become a cause of great concern. At the present rate of emission, CO_2 build-up in the atmosphere is expected to double by the middle of the next century. This may cause significant climatological and hydrological changes, through what has come to be known as GLOBAL WARMING.

The options for preventing CO_2 accumulation are limited. Some of these are:

- switching over to nuclear energy;
- reliance on use of non-conventional energy;
- conservation in use of fossil fuel;
- capture of CO_2 from flue gas and its disposal into ocean depths;
- capture of CO_2 and reduction to syntheses gas for conversion to methanol/MTBE, with zero level CO_2 emission.

The present paper considers the last option. Carbon dioxide can be reduced to CO and H_2 by the following endothermic reactions:

$$CO_2 + C \longrightarrow 2CO + 173.65 \text{ KJ/mol} \quad \ldots (1)$$

$$H_2O + C \longrightarrow CO + H_2 + 130 \text{ KJ/mol} \quad \ldots (2)$$

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The energy required for the above is provided by the following exothermic reaction :

$$CaO + CO_2 \dashrightarrow CaCO_3 + 181.54 \text{ KJ/mol} \quad \ldots (2)$$

BACKGROUND

The capturing and sequestering of CO_2, has been studied by various authors. Marchetti (1977;1979) suggested collecting of CO_2 from the flue gases of ten large power stations in a 1,000 KM pipe line and disposing it off deep in the ocean (in the Strait of Gibraltar). Colombo et al (1989) studied the feasibility and economics of sequestering power plant CO_2 emissions from a 500 MW station in the deep ocean. They estimated the cost to be USD 275 million.

The use of dolomite, as CO_2 capturing and heat transfer agent, in the gasification of lignite for production of pipe line gas, was studied by Consolidated Coal Company (1965). The present authors in an earlier publication (1991) discussed alternative methods of CO_2 stabilization. They were:

- termination of carbon combustion at CO stage;
- reduction of CO_2 to CO and/or CO and H_2 for co generation of chemicals like formic acid or methanol ; and
- CO_2 utilization in bio-mass production.

The present paper describes the production of methanol combining CO_2 stabilization.

MODEL PARAMETERS

The flue gas that feeds the process is taken from a $CaCO_3$-CaO regenerator. The plant is assumed to gasify a high ash Indian coal to yield synthesis gas having the following composition:

CO	87.5% (by weight)
H_2	12.5%

Heating value 8,980 Kcal/kg [3]

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The composition of the coal used was as follows.

C	48.1
H	4.4
S	1.5
N	0.9
O	9.3
Ash	37.8
Heating Value	0.014 GJ/kg coal

PROCESS DESCRIPTION

A process flow diagram is presented in Figure 1. The individual processes involved are as follows:

1. Coal preheating.
2. CO_2 absorption.
3. CO_2 reduction in gasifier.
4. CaO regeneration from $CaCO_3$.
5. Purification of gas and recovery of CO_2.
6. Methanol synthesis.

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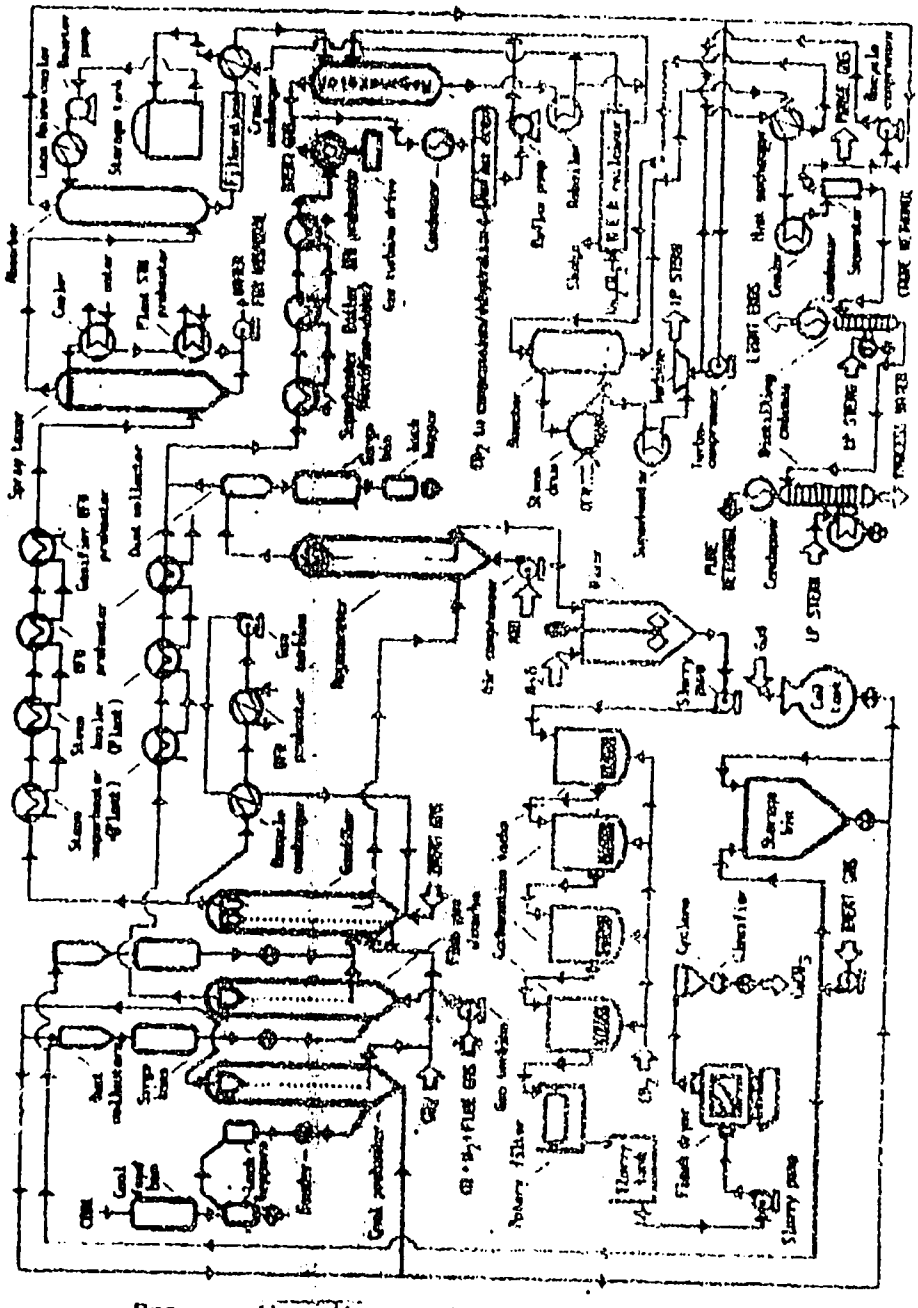
COAL PREHEATING

In the process, coal is utilized mainly for its hydrogen and carbon values and not as an energy source. Pulverized coal (23,800 tonnes per annum) is made available to the coal hopper by the coal preparation section.

From the hopper, coal is fed to the coal preheater. Nitrogen gas, from the CO_2 absorber, is used for heat transfer and as a coal fluidization media. Coal is preheated in this manner to around 300^{0}C (from room temperature).



Process flow diagram for methanol & ppt. $CaCO_3$ unit

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CO_2 ABSORPTION

The hot flue gas from the regenerator, is compressed and conveyed to the CO_2 absorber. Here the gases come into contact with calcined CaO (from the regenerator). The heat liberated is utilized in gasification of coal in a subsequent step. For this study, it has been assumed that 70% of CaO is carbonated to $CaCO_3$. The temperature inside the absorber is not allowed to exceed 850^{0}C. The unabsorbed gases (mainly nitrogen) are separated and used for preheating of coal, generating steam, etc. and the gases themselves are utilized as inert gas in the process.

CO_2 REDUCTION IN THE GASIFIER

The CaO/$CaCO_3$ material is withdrawn from the CO_2 absorber and conveyed to the gasifier, along with the preheated coal from the preheater, by high pressure, super-heated steam. CO_2, captured from the gas purifier, is also conveyed to the gasifier. Around 80% of the carbon in the coal feed is gasified at 850^{0}C, by reactions (1) to (3).

CaO REGENERATION

The remaining coal char and the CaO/$CaCO_3$ main stream are withdrawn together from the gasifier and conveyed, by compressed air, to the regenerator. Here, most (over 85%) of the remaining carbon is burnt off at 1,050^{0}C, supplying heat to decompose $CaCO_3$ to CaO.

The regenerator off-gases contain sufficient sensible heat to generate and super-heat all the steam required for the process and to provide power to the main air compressor, the recycle gas compressor and the inert gas compressor.

PURIFICATION OF GAS AND CO_2 RECOVERY

The gasifier off-gas is cooled to 40-60^{0}C and then passed to the absorption tower of the amine separation system, where CO_2 is absorbed from the synthesis gas (or flue gas) as per the following reaction :

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$$C_2H_4OHNH_2 + H_2O + CO_2 \longrightarrow C_2H_4OHNH_3^+ + HCO_3^-$$

This is a well established and widely used process for CO_2 removal. The Dow Chemical Company FT technology is based on a 80% MEA solution, with additives to control corrosion and inhibit the oxidative degradation of amines. The solvent also removes H_2S, SO_2, and NOx and, hence, no further purification of the synthesis gas is provided.

The CO_2, absorbed in the absorption tower, is recovered in the regeneration column by operating the column at elevated temperatures (100-120^{0}C) by stripping CO_2 from the amine solution. This gas is compressed and recycled to the gasifier. The amine is recovered from the regenerator and recycled to the absorber.

Since MEA also reacts with H_2S, SO_2, and NOx to form stable salts which cannot be regenerated in the stripping column, this has to be passed through a MEA reclaimer. Here, Na_2CO_3 is added to the amine, in order to precipitate out salts containing SO_2 and NOx (e.g. Na_2SO_3, Na_2SO_4 and $NaNO_3$). The regenerated amine is steam stripped and combined with the regenerator's reboiler vapor.

Since the CO_2 recovered from the synthesis gas is only 50% of the CO_2 input to the gasifier, the remaining 50% is recovered by cooling part of the off-gases from the regenerator and scrubbing it with MEA in the MEA absorber. The off-gases from the scrubber, in this case, mainly comprises of nitrogen, which is separated for re-circulation as inert gas.

METHANOL SYNTHESIS

For methanol synthesis, the off-gases from the MEA absorption tower are compressed in a turbo-compressor to the required synthesis pressure (generally 5 MPa), admixed with circulating gas, and pre-heated to the desired temperature by passing through a heat-exchanger. It is then passed through the methanol reactor.

Crude methanol is recovered by cooling the reaction mixture leaving the reactor. The un-condensed gas is recirculated. A small amount of purge gas is expelled from the loop to avoid accumulation of inert gas.

The main chemical reaction involved in methanol formation from CO and H_2 is as follows :

$$CO + H_2 \longrightarrow CH_3OH + 60.788\ kJ/mol$$

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CLEAN & [illegible]

The reaction heat generated is utilized in the generation of high-pressure and super-heated steam required for driving the turbo-compressor.

The crude methanol, from the separator, is distilled in the distillation columns to obtain pure methanol. The light-end column strips dimethyl ether, methyl formate and other low boiling impurities, while the second column removes water and other high boiling impurities. The re-boilers are heated with low pressure steam from the turbine exhaust. The light-ends are recovered from the condenser and pure methanol from the second condenser. About [illegible] tonnes per annum of methanol is thus produced.

METHYL TERTIARY BUTYL ETHER (MTBE)

About 36,370 TPA methanol is converted into [illegible] TPA MTBE by reaction with isobutylene.

PRECIPITATED CALCIUM CARBONATE

Part of the CaO recovered from the regenerator is converted to manufacture 45,000 TPA precipitated calcium carbonate.

ELECTRICITY

The process produces about 28 TPH surplus steam. This would generate about 9 MW of electrical power.

PROCESS ECONOMICS

The project cost, for operations under Indian conditions, is estimated at around USD 30 million. The annual sales turnover is expected to be about USD 38.10 million, yielding a pre-tax profit (on sales) of over 19%. The break-even capacity is estimated to be about 44%. There is no CO_2 emission.

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IMPROVED COAL UTILIZATION TECHNOLOGY: POTENTIAL TO REDUCE CARBON DIOXIDE EMISSIONS

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ABSTRACT

Virtually every assessment of the future energy requirements of both the industrial and developing countries indicates that the world will remain heavily dependent on coal as a secure and low cost supply of energy. Against this backdrop, there is growing concern over increasing reliance on coal because of the contribution of coal combustion to global carbon dioxide (CO_2) emissions and the potential impact this may have on future global climate patterns. Notwithstanding the scientific uncertainties surrounding the issue of global climate change, this paper reviews present and emerging coal utilization technologies to determine the potential for reducing future CO_2 emissions from coal.

The most practical and economical method known today for reducing CO_2 emissions from coal is to increase the energy efficiency of coal utilization technologies. This is particularly true for power generation, where each one percentage point increase in absolute power generating efficiency results in a 3 to 4 percent reduction in CO_2 emissions.

Existing commercially advanced technologies for producing power from coal can achieve significant reductions in CO_2 emissions as compared with the average thermal power plant currently in operation. This is especially true within many of the less developed countries where the average level of thermal power plant efficiency is well below the level currently being achieved in the OECD countries. In addition, there are a number of imminent and developing coal utilization technologies that offer the potential for even greater levels of energy efficiency. Moreover, these more advanced coal utilization technologies have the potential to produce power more economically than is possible with present coal-based technology. These technologies are reviewed in the paper.

INTRODUCTION

The subject of global climate change caused by man's activities remains a matter of scientific debate, but fuel and energy policies must take these uncertainties into account, balancing the requirements for economic activity and development of a rapidly expanding world population against the desirability of precautionary measures relating to possible climate change.

* The authors are Associates of the CIAB Global Climate Committee and the paper is based on the CIAB report "Improved Coal Utilisation Technology: Potential to Reduce Carbon Dioxide Emissions".

Analyses of future energy requirements indicate that the principal fuel sources on which the world currently relies will continue as principal sources for the foreseeable future, regardless of the policies adopted in relation to the issue of global climate change. It is, therefore, in the common interest that optimal use is made of all fuels, taking into consideration the whole range of relevant factors such as resource availability, economics and infrastructure considerations, and potential environmental impacts. It is also important that the emissions of all greenhouse gases be fully assessed with a comprehensive accounting from initial production to final end-use. In addressing these issues, it is necessary to appreciate the importance of coal in supplying global energy needs.

Coal currently provides approximately 30 percent of world energy, of which some 46 percent is devoted to power generation and 54 percent to industrial and domestic uses. Dependence on coal is greater in some non-OECD countries, notably China and India. Taking into account the relative abundance and distribution of identified reserves, it is essential that the continuing world dependence on coal is recognized so that this vital energy source is not jeopardised, with profound world economic consequences.

Whatever the conclusions from analysis of fuel options, it will clearly be wise to adopt those precautionary measures for reducing greenhouse gas emissions which have other advantages and which have no apparent disadvantages, whether or not global warming occurs. Among such measures, fuel and energy efficiency have the greatest immediate potential.

This paper outlines various developments in coal utilization technology which can make a significant contribution to achieving improved fuel and energy efficiency and subsequent reductions in CO_2 emissions. To assess the full scope for improvement, the potential benefits of widely applying the most efficient existing technology should also be added. These benefits are very substantial, particularly in developing countries. For example, the efficiency of electric power generation in OECD countries currently averages about 33 percent compared with levels nearer 25 percent in less-developed countries. These efficiencies are based on the gross or higher heating value of the coal.

Beyond the scope of this paper is the subject of efficiency improvements in the consumption of electrical power, such as the implementation of higher energy efficiency standards for electric motors and appliances, conservation, and other forms of waste reduction. These demand-side management measures also can translate into significant reductions in CO_2 emissions.

This paper considers the progress that has already been made in improving coal-fired power generation and the benefits and future potential of increased energy efficiency. Approaches to energy efficiency are then reviewed, beginning with existing and imminent technologies, followed by developing and future technologies. Finally advances in the utilization of coal for industrial and domestic uses are discussed.

ADVANCES IN COAL FIRED POWER GENERATION

Twentieth century developments in power generation have seen the advance from coal-fired non-condensing reciprocating steam engines with overall efficiencies of 8 percent to commercially advanced coal-fired steam turbines with overall efficiencies of 37 percent. Compared with the turn of the century, each unit of electrical power can now be generated from coal with less than one quarter the amount of primary energy consumed, resulting in a proportionate reduction in greenhouse emissions.

These advances in efficiency of power generation have been progressive, with 37 percent overall efficiency for coal-fired power generation being state-of-the-art for most developed

countries. However, many developing countries still produce power at well below these efficiencies with some at less than half this value. Hence, there remains considerable potential to increase their efficiency and reduce primary fuel use per unit of electricity produced, by applying existing technology with a corresponding reduction in greenhouse gas emissions.

ENERGY EFFICIENCY: BENEFITS AND POTENTIAL

Increasing energy efficiency extends the capability to meet worldwide economic requirements for energy from principal resources like fossil fuels. In addition, it reduces environmental impacts from recognized pollutants like particulates,, sulphur dioxide, nitrogen oxides, carbon monoxide, and hydrocarbons while mitigating growth in global CO_2 concentrations. Also, since it extends the life of energy facilities already in place, it reduces requirements for additional capital and energy resources for new facilities.

The potential and the benefits of increasing energy efficiency worldwide are considerable. For example, it has been estimated that the Canadian Industry Program for Energy Conservation (CIPEC) saved over $2.9 billion in annual manufacturing costs, has achieved a 24 percent energy saving target for the five years ending 1985, and is now setting even higher targets for the future. In Japan, energy consumption per unit GNP has reduced by more than 30 percent since 1973 and 20 percent since 1979. Within OECD countries, energy intensity improved by 20 percent between 1973 and 1985. Substantial further improvements in energy efficiency, particularly in the developing countries, should be possible by the year 2000.

APPROACHES TO IMPROVING ENERGY EFFICIENCY

Significant improvements in energy efficiency can be achieved on the supply side of power generation. Supply-side management is concerned with how energy is produced and delivered to customers. It deals with generation and transmission technologies and with increases in the efficiency of energy production. From the point of view of the coal industry, new coal utilization technologies of note are commercially advanced pulverised coal combustion, fluidised bed combustion, pressurised fluidised bed combined cycle and integrated gasification combined cycle, whilst longer term developments include fuel cells, and MHD systems. The emerging technologies have the potential to be cost competitive with existing power generation methods, but with considerable improvements in energy efficiency and environmental emissions.

TECHNOLOGIES FOR IMPROVING EFFICIENCY OF POWER GENERATION

Coal utilization technologies are discussed in the approximate order of decreasing maturity, and correspondingly increasing time scale to commercial deployment. The order of discussion also reflects an increasing potential to reduce CO_2 emissions.

Table 1 compares the power generation efficiencies of commercially advanced, imminent and developing coal utilization technologies against two base levels of average power plant efficiency. The higher figure is representative of the current average level of power plant efficiency in the more developed OECD countries. The lower figure is representative of the average level of power plant efficiency in many less developed countries. Also shown is the potential for reducing CO_2 emissions as existing thermal power plants are replaced by commercially advanced, imminent and developing coal utilization technologies.

As shown in Table 1, there is considerable potential for reducing CO_2 emissions as compared with the average of existing thermal power plants by :

(1) Deploying commercially advanced and emerging coal utilization technologies for new power generation in the less developed countries; and

(2) Replacing older power plants in the developed countries.

Such reductions would substantially offset any increase in CO_2 emissions due to worldwide growth in electrical power production.

TABLE 1

COMPARISON OF EFFICIENCY[1] AND THE CO_2 REDUCTION POTENTIAL FOR VARIOUS COAL-FIRED POWER GENERATION TECHNOLOGIES

BASE CASE	EFFICIENCY (%) Average Low	EFFICIENCY (%) Average High
Existing Thermal Power Plants	25	33

	EFFICIENCY (%)	POTENTIAL REDUCTION IN CO_2 EMISSION FROM BASE (%) From Low Base	From High Base
Commercially Advanced			
Pulverized Coal (PC)	37	31	9
Atmospheric Fluidised Bed Combustion (AFBC)	37	31	9
Imminent			
Pressurised Fluidised Bed Combustion (PFBC)	40	36	16
Integrated Gasification Combined Cycle (IGCC)	42	39	20
Hybrid IGCC/FBC	46	45	27
Developing			
IGCC/Fuel Cells	50	49	33
Magnetohydrodynamics (MHD)	55	55	40

1 Energy efficiencies are stated on a gross or higher heating value basis. Energy efficiencies for commercially advanced, imminent and developing technologies are mid-range estimates that may vary by 1-2 percent from the figures shown.

Commercially Advanced and Imminent Technologies

Pulverised Coal (PC)

Commercially advanced PC boilers equipped with flue gas desulphurisation (FGD) systems for SO_2 control are operating with efficiencies of 37 percent in developed countries. These power generation systems were built in the last 10 to 15 years and were designed to meet strict environmental standards and with improved efficiencies to meet the higher cost of fossil fuels experienced during the 1970's and early 1980's. Furthermore, many of these new power plants are operated at very high capacity factors and with high availability, which maximises fuel efficiency. The commercially advanced SO_2 FGD systems have also been designed to minimise power consumption.

Longer term, ultra-supercritical steam conditions in pulverised coal-fired power plants offer the potential for efficiencies approaching 45 percent. Improvements would involve higher combustion temperatures and pressures. This requires the introduction of new materials and production technologies. Progress already has been made in developing suitable materials having appropriate mechanical characteristics and showing resistance to hot corrosion and steam oxidation.

Fluidised Bed Combustion

Atmospheric fluidised bed combustion (AFBC) provides the possibility for reliable and economic burning of a wide range of coal types with potential efficiencies approaching 37 percent.

Fluidised bed combustion technologies also reduce emissions of sulphur and nitrogen oxides. Sulphur oxides can be captured by the use of limestone in the combusting bed. Nitrogen oxides are reduced by avoiding high temperature combustion. AFBC plants are now commercially available up to a scale of 150MWe. The technology is suitable for repowering lower-efficiency existing power plants and reducing carbon dioxide emissions by up to 30 percent.

The advantages of AFBC has been extended by the development of pressurised fluidised bed combustion (PFBC). PFBC is expected to achieve efficiencies of 40 to 45 percent when operated as combined cycle plant. Several PFBC units are operating, under construction, or planned for the United States, Europe, and Japan.

As with pulverised coal firing, efficiencies approaching 45 percent may be achievable in the future with the application of ultra-supercritical steam conditions to FBC technology. A 70MWe PFBC combined cycle demonstration plant incorporating an ultra-supercritical steam turbine will be operational in Japan by 1994 leading to a commercial plant in 1997 with a projected efficiency approaching 45 percent.

Integrated Gasification Combined Cycle Technology

Integrated gasification combined cycle (IGCC) technology has been identified by a growing number of utilities as the potentially dominant coal-based power generation technology for the late 1990's and beyond. In this technology coal is gasified to produce a gas stream which is cleaned and burned in a gas turbine to generate electricity. The waste heat from the gas turbine exhaust is then used to produce steam which drives a steam turbine connected to an electricity generator.

IGCC can convert a wide range of coals and can achieve efficiencies of 45 percent with a corresponding reduction in CO_2 emissions. In the oxygen-blown version shown in Figure 1, the gasifier product is cooled to remove 99 percent of the sulphur in a saleable by-product form. The oxygen-blown IGCC systems are being offered commercially on a worldwide basis by several companies. The air-blown IGCC version with hot gas cleanup (Figure 2) offers the potential for even higher energy efficiencies, but this technology is not developed beyond large pilot plant stage at this time. Several air-blown IGCC demonstration projects are under construction in the United States and Europe. A small plant is currently operating in Japan.

A hybrid or topping cycle (Figure 3) also is being developed in which the coal is partially gasified and then combusted to provide high turbine inlet temperatures. Coal which is not gasified is fed as a char to an FBC unit. The FBC unit provides flue gas for the gas turbine and steam for the steam turbine. As shown in Table 1, the hybrid cycle has the potential for achieving 46 percent efficiency with a corresponding reduction in CO_2 emissions. Air-

blown IGCC hybrid cycles are being piloted and demonstrated in the United States and the United Kingdom and could be ready for commercial deployment in the late 1990's.

FIGURE 1 IGCC WITH OXYGEN BLOWN GASIFIER

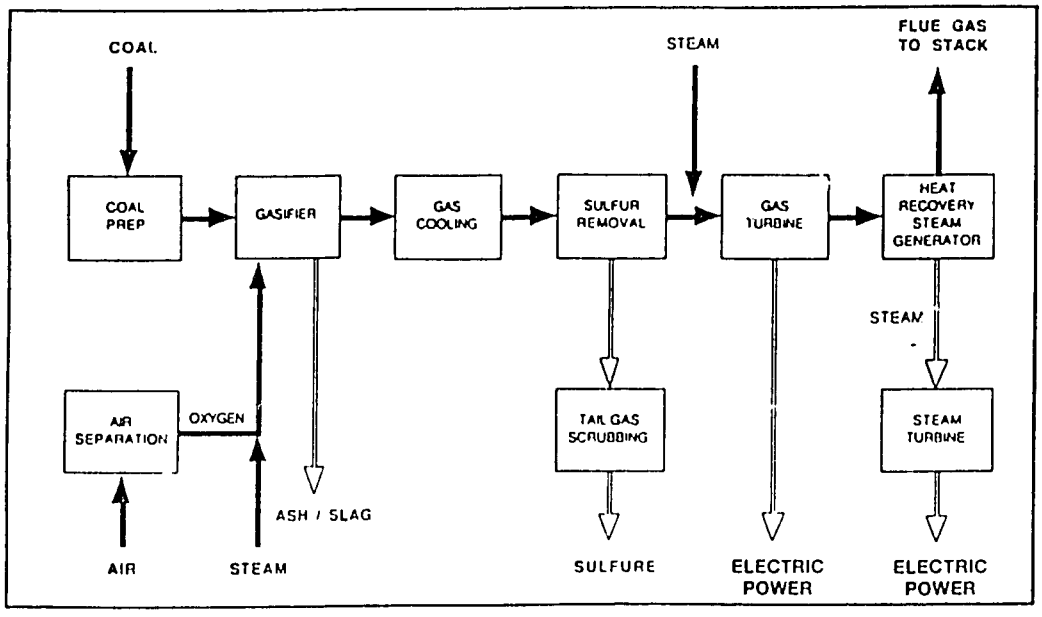


FIGURE 2 IGCC WITH AIR BLOWN GASIFIER

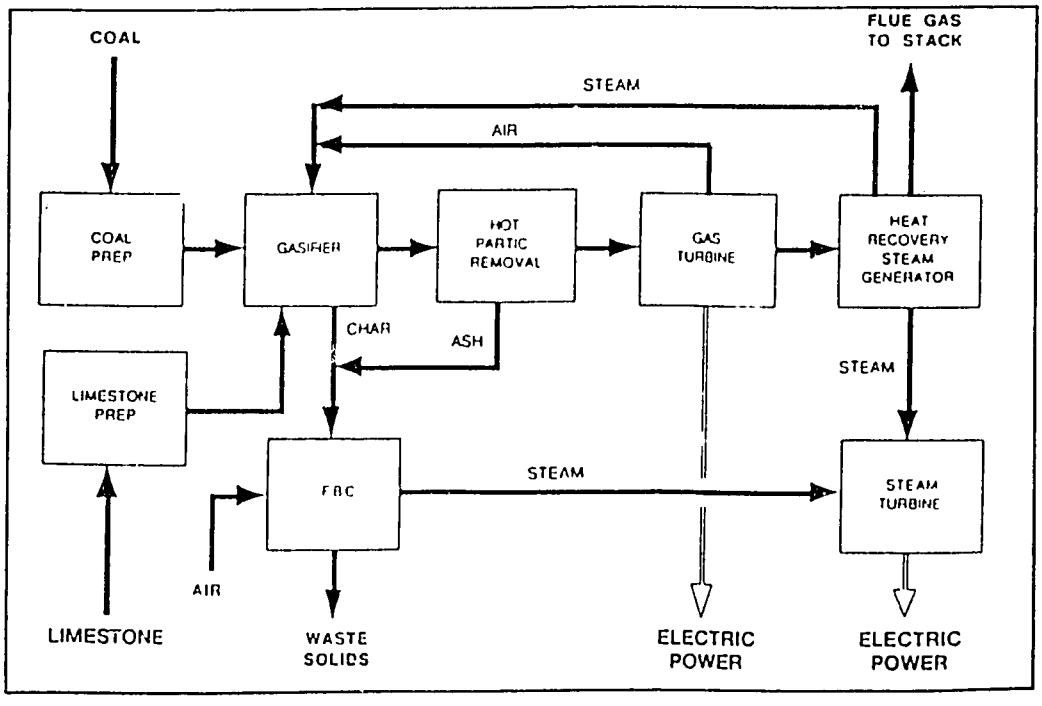
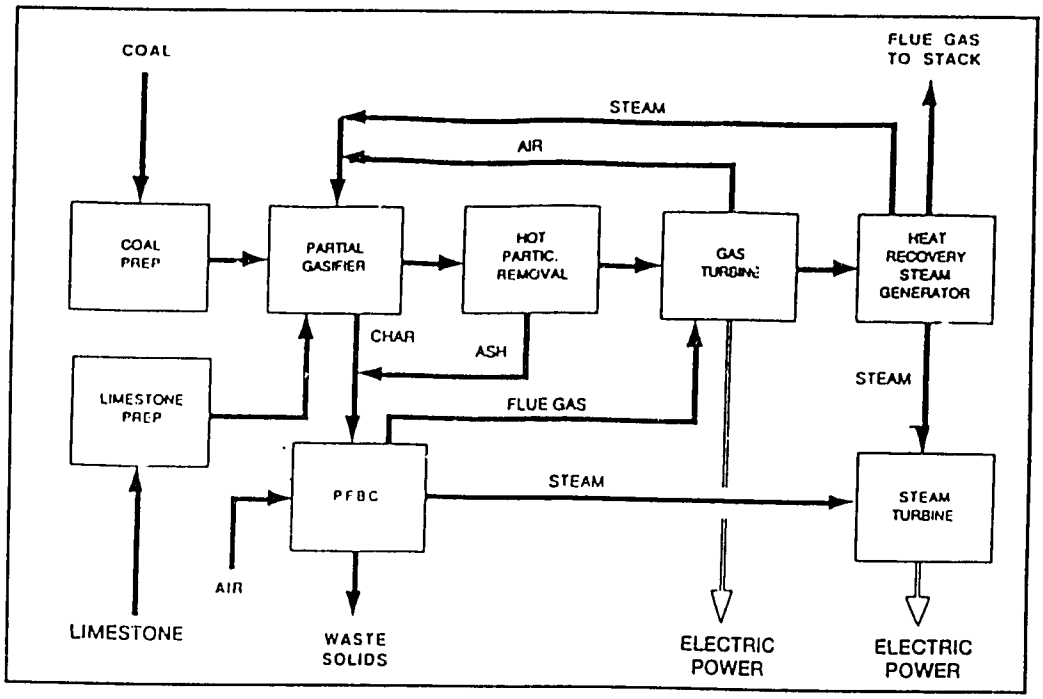


FIGURE 3 AIR BLOWN IGCC HYBRID CYCLE



Promising developments in Japan and other countries with high inlet temperature, high-efficiency gas turbines could make IGCC even more attractive in the future. Another concept called Externally Fired Combined Cycle (EFCC) employs a ceramic heat exchanger being developed specifically for gas turbines. EFCC is still in the small pilot plant stage, but could offer the potential for efficiencies approaching 43 percent for small units of about 50 MWe.

Developing Technologies

The following technologies are not as well developed as the preceding coal-based power generation technologies and generally involve more development hurdles. Realistically, commercial development probably could not occur until after the year 2000. However, these technologies illustrate the future potential for excellent energy efficiency and CO_2 emission reduction.

Fuel Cells

Fuel cells are devices in which hydrogen, which is obtained by reforming natural gas, methanol, coal gas or other fuel, reacts electrochemically with oxygen from the air to generate electric power. Fuel cells are classified according to the type of electrolyte used, into alkali, phosphoric acid, molten carbonate, solid oxide and other types.

Fuel cells have the potential for a very high power generation efficiency of 50 percent and corresponding low CO_2 emissions. These high efficiencies could be maintained under partial load operations. When exhaust heat from fuel cells is utilized in cogeneration systems, even

higher efficiencies could be realised. There is very little emission of NOx and SOx or discharge of cooling water. Low environmental emissions plus the absence of mechanical moving parts that can generate vibration or noise make fuel cells very favourable in terms of environmental impact and siting.

Much of the development activity with fuel cells is being done in the United States and Japan. Commercial applications could occur early in the next century.

Magnetohydrodynamics (MHD)

As part of the evolution of new power generating systems with high efficiency and superior environmental characteristics, the concept of direct coal-fired, inert gas MHD triple combined cycle systems is being developed.

The efficiency of the MHD system is expected to approach 55 percent. In a coal-fired MHD system, coal is burned to produce an extremely hot gas or plasma. A chemical "seed" (for example, a potassium compound) is added to give the gas an electrical charge. The charged gas is passed through a strong magnetic field producing electricity. Heat from the combustion gases is used to generate additional electricity by means of a conventional steam turbine.

Research on MHD systems is being conducted in several countries, including Japan and the United States. Practical implementation will not occur until several major development obstacles are overcome. Developing the advanced materials capable of withstanding harsh conditions is the greatest challenge for successful commercialisation of this technology.

COGENERATION

Cogeneration of heat and electric power is a very effective means to rationalise energy use, particularly when combined with a district heating system or a local plant requiring process heat. The combined production of heating and electric power (CHP) already is well established in several countries. Development started in the 1920's and received further impetus in the 1970's and 1980's with the increased interest in energy efficiency. CHP is especially favourable in situations where there is a high demand for heat concentrated in a small area (e.g. densely populated areas) and where demand characteristics for electricity and heat production are compatible.

In a conventional condensing power plant, the steam used to drive the turbine emerges at low pressure and a temperature of about 40°C before condensation and return to the boiler. About 45 percent of the primary energy input is rejected with the cooling water and a further 15 percent is lost in the flue gas and other parts of the process. The high energy efficiency of CHP is obtained by using the primary steam first in a turbine to produce electricity and then partially or completely to produce heat for a district heating network. The steam is condensed at pressure and temperature conditions which produce heating water at a temperature of 100-120°C. The overall efficiency of the fuel energy conversion to useful heat or power can be as high as 85 percent, with about 55 percent of the primary energy input being available for district heating.

ADVANCES IN INDUSTRIAL AND DOMESTIC USES OF COAL

In OECD countries, the largest proportion of coal is used for generating electric power. Elsewhere, a larger share goes to domestic and industrial uses (Table 2), where substantial improvements in efficiency can be made.

TABLE 2
1988 WORLD COAL USE[1]
(Billion tonnes)

	OECD		CPE's		LCD's		WORLD	
	Tons	% of Total	Tons	%of Total	Tons	%of Total	Tons	% of Total
Power Station	0.89	74	0.48	28	0.21	46	1.58	47
Steel/Coke	0.21	18	0.37	22	0.07	15	0.65	19
Industry/Domestic	0.10	8	0.85	50	0.18	39	1.13	34
TOTAL	1.20	100	1.70	100	0.46	100	3.36	100

1 Coal information 1990 International Energy Agency

In the case of iron making, the dominant technology is the blast furnace which accounts for approximately 60 percent of world iron production. Scrap recycling (electric arc furnaces) provides the remainder. The blast furnace accounts for 43 percent of the total energy requirements for steel production. The other requirements are for rolling, coking, sintering, etc. Significant developments in current blast furnace technology and related coal consumption can be expected from increased use of pulverised-coal injection and oxygen enrichment. The shift to pulverised-coal injection could reduce further coal consumption per unit of iron produced.

New developments in steel making include direct smelting and direct steel making. In direct smelting technology, a one-stage operation is possible, but a two-stage operation has better energy efficiency as the waste gases are used in the process. These technologies offer various advantages, including the direct charging of raw materials, flexibility, energy efficiency, and reduced emissions.

Similarly, there is considerable scope for achieving higher efficiencies in other domestic and industrial uses. For example, one approach which is particularly relevant in less-developed countries is the development of domestic boilers that will burn bituminous coal smokelessly. Particulate emissions could be reduced by about 90 percent and efficiencies could be more than doubled.

For industrial or small-scale power generation applications, many boiler designs using fluidised bed, chain grate, and other grate types have been demonstrated or are commercial. A high combustion efficiency can be achieved in such systems. Cogeneration of electricity with exhaust steam providing heat requirements, would be especially efficient for industrial applications. The introduction of these proven technologies into developing countries could produce the necessary energy with significantly less coal and lower resulting emissions, including CO_2.

CARBON DIOXIDE REMOVAL AND STORAGE

Several processes have been considered for the removal of carbon dioxide from combustion gas and its storage in ways that prevent it from reaching the atmosphere. The technologies for CO_2 removal are available, but would add substantial cost to power generation. Water, methyl ethanolamine, lime, caustic soda, and physical solvents have been suggested as agents for removing carbon dioxide. Liquefaction of CO_2 is a possibility, particularly if an oxygen-carbon dioxide combustion gas mixture or oxygen-gasification is used. Proposed storage methods for carbon dioxide include dissolution in deep oceans and saline acquefiers, storage as liquid carbon dioxide in depleted gas and oil reservoirs, in caverns, or as plant material.

The IEA is taking a lead in an international evaluation of all these possibilities and promoting a co-operative R&D and demonstration program to analyse options for CO_2 removal, utilisation and disposal from coal fired stations. The goal is to determine the technical feasibility and the costs involved in such approaches and to demonstrate that they are environmentally acceptable. Creating an environmental problem as a result of carbon dioxide disposal would not be acceptable. The program is being undertaken so that if remedial steps prove necessary, the scientific knowledge, economic costs and environmental consequences of CO_2 removal and storage will be better understood. Based on current technology, CO_2 removal and storage suffers from high cost and the uncertainty of containing stored material indefinitely.

CONCLUSIONS

It is apparent that there are substantial opportunities to improve the efficiency of coal utilisation, thereby extending the lifetime of reserves and helping to minimise emissions of carbon dioxide. Substantial progress in controlling CO_2 emissions can be made by applying state-of-the-art technology more widely, particularly in developing countries. In addition, some new developments are now reaching commercial application. Other technologies are still at the exploratory stage, but studies underway or completed, demonstrate that these emerging technologies offer significant future potential for further improvement.

It is critical that R&D in these areas be expanded so that the new technologies can be exploited as soon as possible and this potential for improvement be fully realised. Moreover, energy and environmental policy must be formulated to encourage the early commercial deployment of these technologies in both the developed and developing countries.

PRESENTATION BY HOWARD FEIBUS

AT THE

IEA SECOND INTERNATIONAL CONFERENCE
ON THE
CLEAN AND EFFICIENT USE OF COAL AND LIGNITE:
ITS ROLE IN ENERGY, ENVIRONMENT AND LIFE

NOVEMBER 30 - DECEMBER 3, 1993

Perspective on Coal Liquid Mixtures (CLM)

This document contains the proceedings of a workshop entitled Near Term Commercial CLM Applications. It was sponsored by the Executive Committee of the IEA/CLM Implementing Agreement, under the auspices of the International Energy Agency. The member countries of the Implementing Agreement that participated in the workshop are Italy, Japan and the United States. Representatives of countries with transitional economies were invited to participate and China did so. It was held in conjunction with the 18th International Conference on Coal Utilization and Fuel Systems.*

The workshop was held on April 26, 1993 and was the first of a planned series of workshops on CLM.** This series of workshops is part of a strategy to promote the commercialization of CLM. The contributions to the workshop articulate various aspects of the commercialization strategy and the underlying rationale for promoting this technology:

a) coal is in plentiful supply throughout the world and coal is and will continue to be a critical component of the world energy economy because it can supply clean, low-cost, secure energy;

b) CLM enables coal use to respond to environmental sensitivities to form an integrated system for the beneficiation, transportation and utilization of coal in a clean, low-cost way;

c) CLM technology has emerged and can be used to supply reliable, low cost energy today; and

d) technological advances will enable CLM to integrate beneficiation, transportation and utilization for conventional and advanced combustion systems, including:

- pulverized coal
- pressurized fluidized bed (PFB)
- integrated gasification combined cycle (IGCC).

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* The IEA-CLM Executive Committee wishes to thank the Coal & Slurry Technology Association for agreeing to this arrangement.

** Although the term CLM continues to be used for historic reasons, the trend worldwide is to focus on one specific form: coal water slurry (CWS)

Several graphics supplied by the JGC Corporation of Japan best illustrate the integration role of CLM. The first graphic (Figure 1) shows how it enables a chain to be formed to connect the production, beneficiation, transportation and utilization of coal through a closed, clean, cost effective system. The other graphics (figures 2a and 2b) show that at the point of utilization, CLM allows for the elimination of solids handling equipment, compaction of the space required for electricity production, and production of energy in a way that is as sensitive to environmental concerns as any other fossil fuel. The theme of these graphics is contained in one of the U.S. contributions which shows not only the integrated use of CLM but that it can be cost effective for utility and co-generation applications. The theme is also contained in both Italian contributions which demonstrate an integrated application in a Russian p.c. plant and describes a future use with IGCC.

These two graphics illustrate the long-term potential value of CLM, while showing the compatibility between clean electricity and coal. The keynote address for the workshop was delivered by S.F. Garribba of the International Energy Agency. His presentation articulates the case that growth in coal use is necessary in a growing world economy which needs a diversification of sources to satisfy demand in a way that enhances energy security. His presentation also forcefully and convincingly articulates the major issue to which the coal community must respond: how to reconcile energy and environmental policies in such a way that coal can be used in an environmentally compatible way and still be cost effective.

The second presentation was commissioned by the IEA/CLM Executive Committee and was prepared by K.V. Thambimuthu of the IEA Coal Research Service and outlines a strategy for CLM Commercialization. This presentation documents the technical progress that has been made since the 1970s and specifically describes current activities and achievements with respect to each element of the integrated chain needed for clean coal preparation, transportation and utilization.

Today, the elements of the chain can be integrated as demonstrated by commercial scale projects in China/Japan and Italy. Work is also underway to enhance the performance and cost-effectiveness of the technology for operation with P.C. plants, PFB plants and IGCC plants.

The individual country presentations show a consistency in the view of the long term role of CLM as the chain to integrate coal production with clean electricity generation. The various presentations show differing approaches to commercialization as follows:

<u>China</u>

China is a major producer of coal and is interested in CLM as a means of exporting coal in a form that is of interest to users (see the section on Japan). China also has a strong interest in CLM for domestic applications.

As a transitional economy, China freed the price of oil in 1992. At current domestic costs for materials and labor, CLM is cheaper than oil today and China represents a near-term market to displace oil. The presentation describes specific activities underway.

Italy

Snamprogetti has participated in Russia in a large pilot-commercial project, involving the CLM chain, which includes the CLM preparation plant, a 262 km, 20" pipeline with three pumping stations and the utility boiler at the pipeline terminal. Snamprogetti is also participating in a commercial scale demonstration in Sardinia in which beneficiated CLM is used to displace oil in a large industrial boiler. The plant started operation in July 1993. Finally, Snamprogetti has performed a feasibility study on the applicability of coal-water fuels in the People's Republic of China. This study was awarded to Snamprogetti by the International Centre for Scientific Culture (World Laboratory) of Geneva, and has been conducted in cooperation with Chinese organizations led by the former Ministry of Energy Resources and the Academy of Sciences of China.

The PRC CLM pipeline system study evaluates two alternative transport streams for transporting 7 MTA of coal transformed in CLM to large utilities and distribution centers located in the eastern provinces of China at distances of over 700 km.

With regard to Italy, the major consumer of oil, the national electric utility (ENEL), has previously conducted a large-scale, long-term demonstration of CLM in an oil-designed boiler, but does not foresee commercial application in the near term during which oil is not expected to be more costly than CLM.

Italy is planning to use natural gas-fired combined cycle for new electric generating capacity. Apparently, to keep future options open, Italy is interested in coal gasification which can be integrated in the future with the combined cycle plants. Further, Italy has recently become interested in gasifiers fed by CLM, presumably, in part, to realize the integrated use of CLM with transportation and IGCC.

Japan

The most ambitious commercialization activity for CLM technology is taking place in Japan. Commercial scale projects are being implemented to transport CLM from China to Japan for industrial use by JGC and within Japan for use in a 500 MW utility boiler by Japan COM Company. Japan is pursuing an approach that is expected to be economically viable in the long run while supplying adequate amounts of energy in a secure, environmentally sound way.

JGC has had a one-year operating experience with bilateral CWM trade. Japan COM company is starting commercial operation of its 500,000 ton/year CWM plant.

United States

While the U.S. has participated in large scale activities in the past, the approach to CLM commercialization has shifted.

The initial incentive to commercialize CLM was to displace oil in utility and industrial boilers. During the past decade, use of oil in utility boilers has declined. In addition, oil prices are expected to be sufficiently low for the next decade that CLM will not be competitive. In addition, recent regulatory decisions (the WEPCO decision), have further reduced any economic incentive to convert from oil to CLM in utility or industrial boilers.

The DOE Coal Research, Development and Demonstration Program has recently shifted its strategy to focus on the development of advanced power systems (including advanced p.c. systems), having higher efficiency, lower emissions and lower costs than current power systems.

The development program includes advanced fine coal cleaning and beneficiated CLM to integrate coal production with low cost, clean coal electricity production. Current testing activities, initially begun to minimize derating in oil-designed boilers, is providing critical data for the design of new p.c. boilers to efficiently burn CLM. One of the U.S. contributions to the workshop is a conceptual case study illustrating the current status of beneficiated CLM technology: it can provide competitive energy (for large scale electricity and cogeneration applications) while dramatically reducing powerplant space requirements, and eliminating solids handling and associated environmental control equipment. This CLM interest is to promote the clean use of energy both domestically and for export.

As a major coal producer, the U.S. currently produces increasingly large quantities of coal fines that must be disposed of. In addition, there are many slurry ponds containing large quantities of coal fines. A number of advanced fine coal cleaning processes are now emerging that can economically reduce the ash levels (typically from 50% to 10% or less). This technology has provided a new potentially clean, low cost resource that can now be commercially exploited.

One of the U.S. contributions consists of a case study to examine the economics of using a low sulfur coal waste (prepared, delivered and burned as CLM) to substitute for a higher sulfur coal to comply with the recently passed Clean Air Act Amendments of 1990. The study shows that the plant can convert to CLM while reducing the cost of producing electricity, and targets a significant market niche that CLM may be able to capture in the next decade.

Conclusion

The contributions to the Workshop that are contained in these Proceedings describe elements of an emerging industry that the reader will find stimulating.

●CWM製造プラン
CWM manufacturing plant
(Rizhao City, Shandong Province, China)
水煤浆制造工厂
●兖州炭坑(中国山東省兖州)
Yanzhou coal mine
(Yanzhou, Shandong
兖州的矿井(中国山东

FIGURE 1

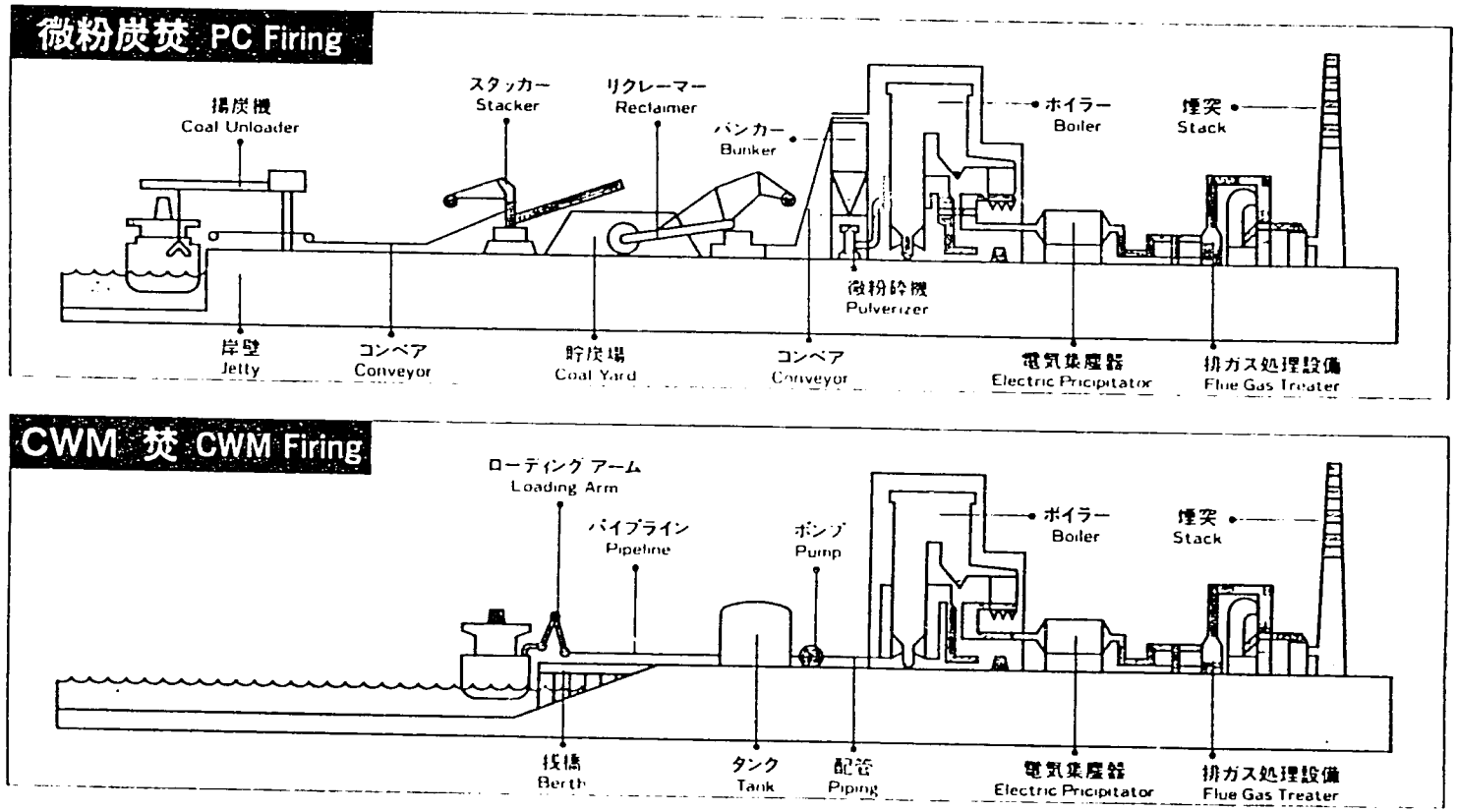

微粉炭焚 PC Firing
揚炭機
Coal Unloader
スタッカー
Stacker
リクレーマー
Reclaimer
バンカー
Bunker
ボイラー
Boiler
煙突
Stack
微粉砕機
Pulverizer
岸壁
Jetty
コンベア
Conveyor
貯炭場
Coal Yard
コンベア
Conveyor
電気集塵器
Electric Pricipitator
排ガス処理設備
Flue Gas Treater
CWM 焚 CWM Firing
ローディング アーム
Loading Arm
パイプライン
Pipeline
ポンプ
Pump
ボイラー
Boiler
煙突
Stack
桟橋
Berth
タンク
Tank
配管
Piping
電気集塵器
Electric Pricipitator
排ガス処理設備
Flue Gas Treater

FIGURE 2a

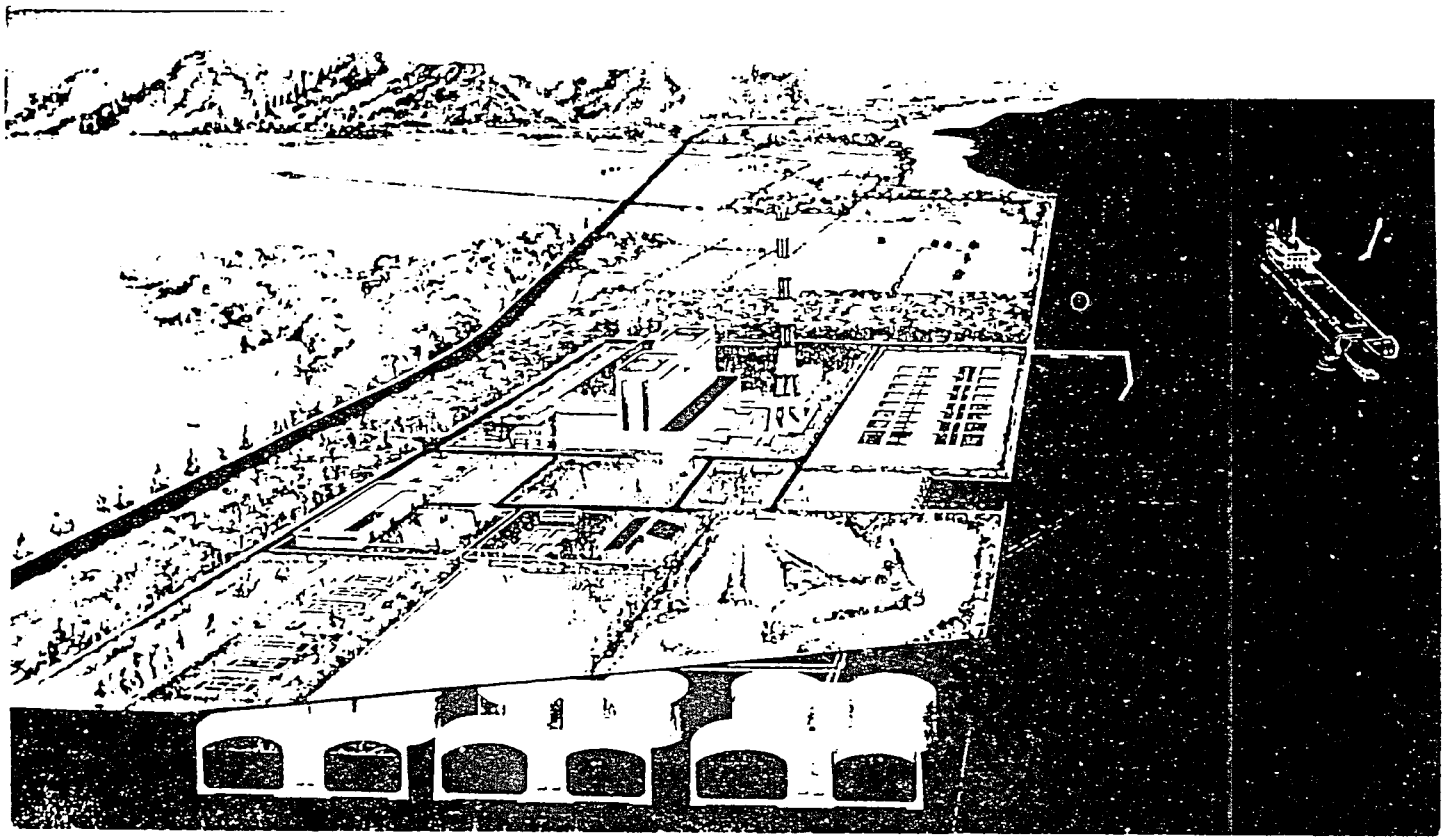


FIGURE 2b

CLEAN COMPETITIVE COAL WATER FUEL

Donald D. Dunlop — Fuels Management, Inc.

C.E. Capes — National Research Council of Canada

IEA Second International Conference
On Clean And Efficient Use of Coal And Lignite

Hong Kong Marriott
30 November - 3 December 1993

CLEAN COMPETITIVE COAL WATER FUEL

Coal Water Fuels (CWF) have been under development for more than 20 years. The first generation CWF was developed by Consolidation Coal (Consol). Consol built a 100 mile pipeline to demonstrate the efficacy of moving coal by pipeline in competition with railroads. The Black Mesa Pipeline in the southwestern area of the US has moved more than four million tons of coal per year for more than 20 years.

These early slurries were relatively coarse in particle size and contained about 50% solids. The slurry was not stable and required careful control to avoid settling in the line or erosion of the line.

More recent work has focused on the production of stable, more highly loaded slurries (eg 70-75%). FMI participated in efforts toward a successful commercial demonstration at the Nakoso Power Station of Tokyo Electric Power in 1986. At that time CWF could be produced for about $20-22 per barrel of oil equivalent (BOE). Early in the year of 1986, oil prices rose to $35 per barrel, then fell dramatically late in the year rendering CWF uneconomic.

Analysis of the cost components showed that the cost of the parent coal accounted for about 50-60% of the cost of CWF. Thus lower cost CWF had to come from lower cost parent coal. The obvious candidates were waste from conventional coal wash plants and sub bituminous coals. Because of the high moisture and oxygen contents of sub bituminous coals they tend to sell for less than bituminous coals.

This paper will describe the recovery of coal from wash plant wastes using low oil agglomeration. The paper will also describe a novel drying technique for sub bituminous coals and the co processing of sub-bituminous coal and heavy oil to produce an upgraded oil and a de watered, partially de oxidized coal.

Preliminary economic analysis shows that each approach has attractive economic yields. Clearly economics are site specific and thus each prospective site would have to be evaluated on the economics of that site.

CWF FROM WASH PLANT WASTE

Conventional wash plants using froth flotation cells vary widely in efficiency. FMI has identified a number of them where the application of low oil agglomeration (LOA) would significantly improve their operation. LOA can be applied economically to recover coal from waste ponds as well.

The National Research Council (NRC) developed the LOA technology. It has been demonstrated at the commercial level in a 700 T/D plant at Phillipsburg, Pennsylvania in 1991. The LOA process consists of adding a small amount of oil (1-2%) to a suspension of coal and ash. Coal, being oil wet, adsorbs the oil and forms weakly bonded agglomerates. The agglomerates are removed in a froth flotation cell. The ash is removed from the bottom of the cell. The coal removed from the cell is then processed into CWF. Since the coal is generally less than 100 mesh, only a small amount of grinding is necessary to produce a stable slurry. Carbon recoveries in the order of 90% are not unusual. A sketch of the technology is given in the Appendix.

An example of an economically attractive application of LOA to recover waste and produce CWS is a facility in Kentucky. A plant to produce 330,000 TPY of CWS was designed. The capital cost is estimated at $8 million. The annual cash flow projection is $4.5 million. FMI believes there are a number of applications for the process World Wide.

DRYING AND MOISTURE READSORPTION IN LOWER RANK COALS.

Coals lower in rank than bituminous have high inherent moistures which are contained in the porous structure of the coal particles. Such inherent moisture is retained in the "air dried" state and can only be removed by thermal drying. Unless the dry coal is required for further immediate processing, however, it is unproductive to dry much below the air-dried moisture content, otherwise the coal will quickly readsorb moisture on exposure to the atmosphere. In addition, excessive drying of lower rank coals can lead to fines generation in shipping and may create serious fire and explosion hazards. The production of CWF from these dried fines eliminates such potential hazards.

A number of approaches have been examined to prevent moisture readsorption and to block off the internal pore networks from the atmosphere. Traditional approaches have included briquetting to mechanically densify and compact the coal particles into a larger entity. Other more recent approaches have used direct contact drying (for example, in oil or hot water) at temperatures sufficiently elevated to cause changes in the porous structure of the coal.

NRC/FMI examined a further approach to the drying of lower rank coals, based on thermal drying in a non-oxidizing or reducing atmosphere. We have also examined both agglomerated and unagglomerated coal feedstocks using the oil agglomeration process. Oil agglomeration has an inherent dewatering capability due to the displacement of surface and interstitial water by the

hydrophobic adsorbed oil. While oil agglomeration is not able to reduce the inherent moisture bound within the structure of particles of lower rank coal, the adsorbed oil in thermally dried agglomerates will help to prevent the readsorption of moisture by the dried product. We have also found that comparable results can be obtained using a reducing agent in the drying operation. Data showing these results are given in the Appendix.

Laboratory scale tests were carried out on Adaro coal from Indonesia and on Cordero coal from the Powder River Basin in the U.S.A. In each case, the coal had a size consist of 100% minus 6mm and about 50% minus .6 mm. Oil agglomeration was done in a Waring blender using No.6 fuel oil as the agglomerating agent with product recovery and dewatering in the laboratory flotation cell and centrifuge, respectively. Thermal drying was done in a laboratory furnace capable of a range of temperatures and atmospheres. Moisture readsorption on the product was examined both in an atmosphere saturated with moisture and by immersion in water.

These tests showed that the drying temperature and the drying atmosphere are very significant parameters in determining the moisture readsorption properties of the product coal. Above 250^{0}C drying temperature and in mildly reducing atmospheres, reabsorbed moisture can be limited to the range of 4 to 5%. Even small amounts of adsorbed agglomerating oil (2% and less) in the dried product were shown to be beneficial in limiting the amount of moisture readsorption. In addition, preliminary results from XPS analysis indicate a reduction in the oxygen content on the surface of the coal following these treatments.

This work has shown that novel drying techniques, from combinations of drying temperature, drying atmosphere and adsorbed oil from the agglomeration of the feed coal, can produce high quality products from low quality coal. As with the coprocessing option, the question is the cost of the operation which can only be answered by further laboratory and pilot tests. Laboratory data and a process sketch of the technology are presented in the Appendix.

FMI has done an economic assessment of this process. Based on the use of Powder River Basin Coal, the capital investment is estimated at $42 million for a one million ton per year plant. A cash flow of the $15 million per year is projected.

Co PROCESSING

The concept of the co processing of oil and coal has been tested and discussed for many years. The bulk of the effort has been on high temperature, high pressure catalytic hydrogenation processes. The quality of the products from these efforts was

very high. However, the high capital and operating costs rendered the economics unfavorable.

The approach of FMI has been to start with a proven process(fluid coking) and to simply add coal to the coking reactor.[D]. While this is a relatively high temperature, process (850° F Plus) it operated at about two atmospheres of pressure and no catalyst is required.

The impact of fluid (or delayed) coking on heavy oils is well understood. The pyrolysis of coal is also well understood.[Y] The products in general are gas, liquid and coke. For example, the pyrolysis of a sub bituminous coal at 500°C yielded

	Wt.%
Coke	57.6
Oil	8.5
Gas	6.2
Water	27.8

Obviously yields will vary depending primarily on coal type, and temperature.

Considerable work has also been done on the pyrolysis of coal[X] in the presence of liquids such as phenanthrene and naphthol. The work done at 250°C to 350°C range was described as an extraction operation as opposed to a pyrolytic phenomenon. The chemistry of the solvent was the most important variable. These studies do establish a certain synergism as to the pyrolysis of coal in the presence of a liquid medium.

The coking of heavy oils has been a commercial petroleum process for more than 50 years. Its basic objective is to destroy 950°F plus materials and produce 950°F minus materials along with petroleum coke. An example of fluid coking of a typical 15° API residuum at 950°F may result in the following yields:[Y]

	Wt. %
Gas	7
Naphtha	20
Gas Oil	45
Coke	28
	100

Earlier work on Co Processing[T] has shown yet further benefits. This is the removal of oxygen from low rank coals. Most sub bituminous coals contain oxygen ranging from 15 to 30%. Varghese[T] shows an example of the impact of Co Processing on the oxygen content of the product as follows.

(D) Dunlop, U.S. Pat.5,145,489 8/8/92
(T) Varghese USPat#4427532 1/24/84
(X) Chemistry of Coal Utilization, p. 346, John Wiley & Sons 1963
(Y) Hydrocarbon processing, Nov. 1190 p.110

	Belle Air Coal	Coal/Coke Product
Carbon	63.8	83.2
Hydrogen	5.4	4.2
Oxygen	24.6	4.2
HV BTU/#	11219	14689

Clearly the reduction of oxygen in the coal significantly enhances its value as shown by the increase in heating value of the product.

It is also obvious that the Co Processing of the coal will reduce the volatile matter of the coked coal. FMI financed a study of the combustion of a fluid coke water slurry at Babcock and Wilcox[S] Research Laboratories. To the surprise of most experts:

(1) The coke burned without the need for supplemental fuel.
(2) The unburned carbon on ash was reduced to conventional values with the addition of only 6% supplemental fuel.

A review of the forgoing suggests that Co Processing can produce high quality products from a low quality coal and a low gravity oil. The question is the cost of the operation. To answer the question in a rigorous manner would require laboratory and pilot plant data which are not currently available. FMI believes that a joint Canadian-US project would show a return of 30% on equity. A Flow Plan of the process is given in the Appendix.

FMI believes that there are at least three areas of the World where sub bituminous coal and either RFO or heavy oils are in close proximity. These are (1) Indonesia, (2) the Powder River Basin in the USA and in (3) Alaska. FMI has ongoing discussions with the principals in each area.

CONCLUSION

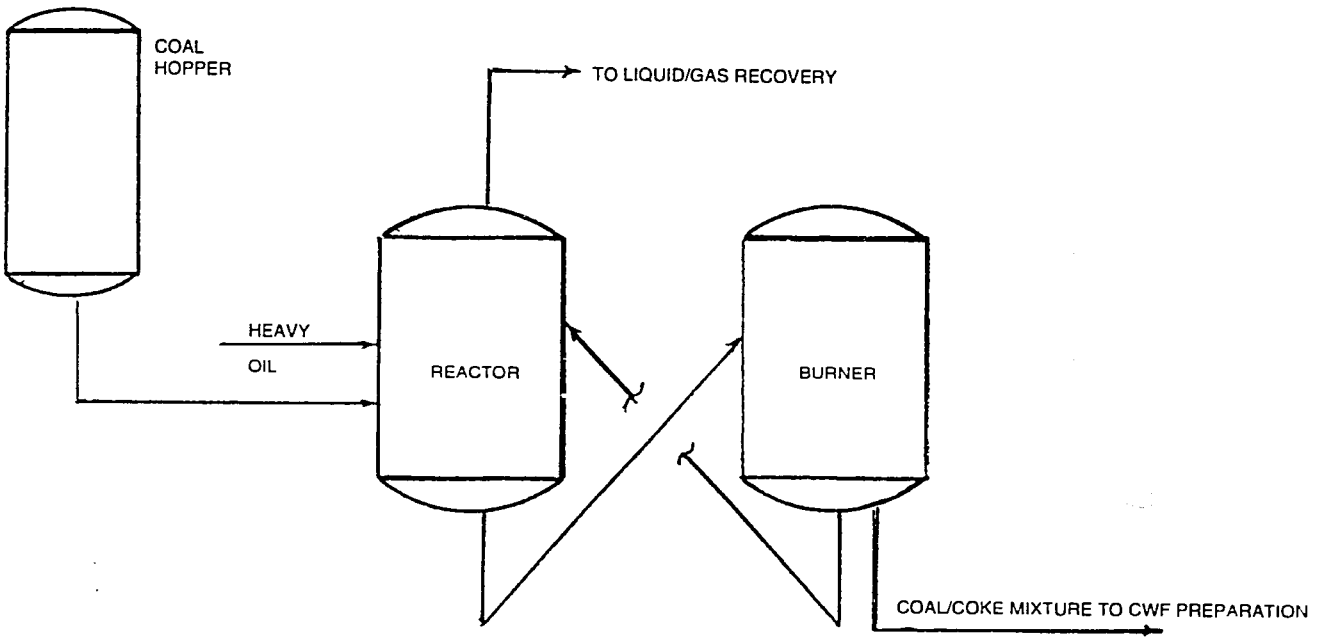
NRC/FMI conclude that a recent Chinese-Japanese work on commeralizing CWF has established CWF as an article of commerce. From our work we conclude the folowing:

* CWF from bituminous coal waste is commercially viable using LOA to clean the waste.
* CWF from sub bituminous coal is viable using the NRC/FMI drying technology.
* The marriage of petroleum processing technology makes CWS economic in three major coal producing areas world wide using the patented FMI process.

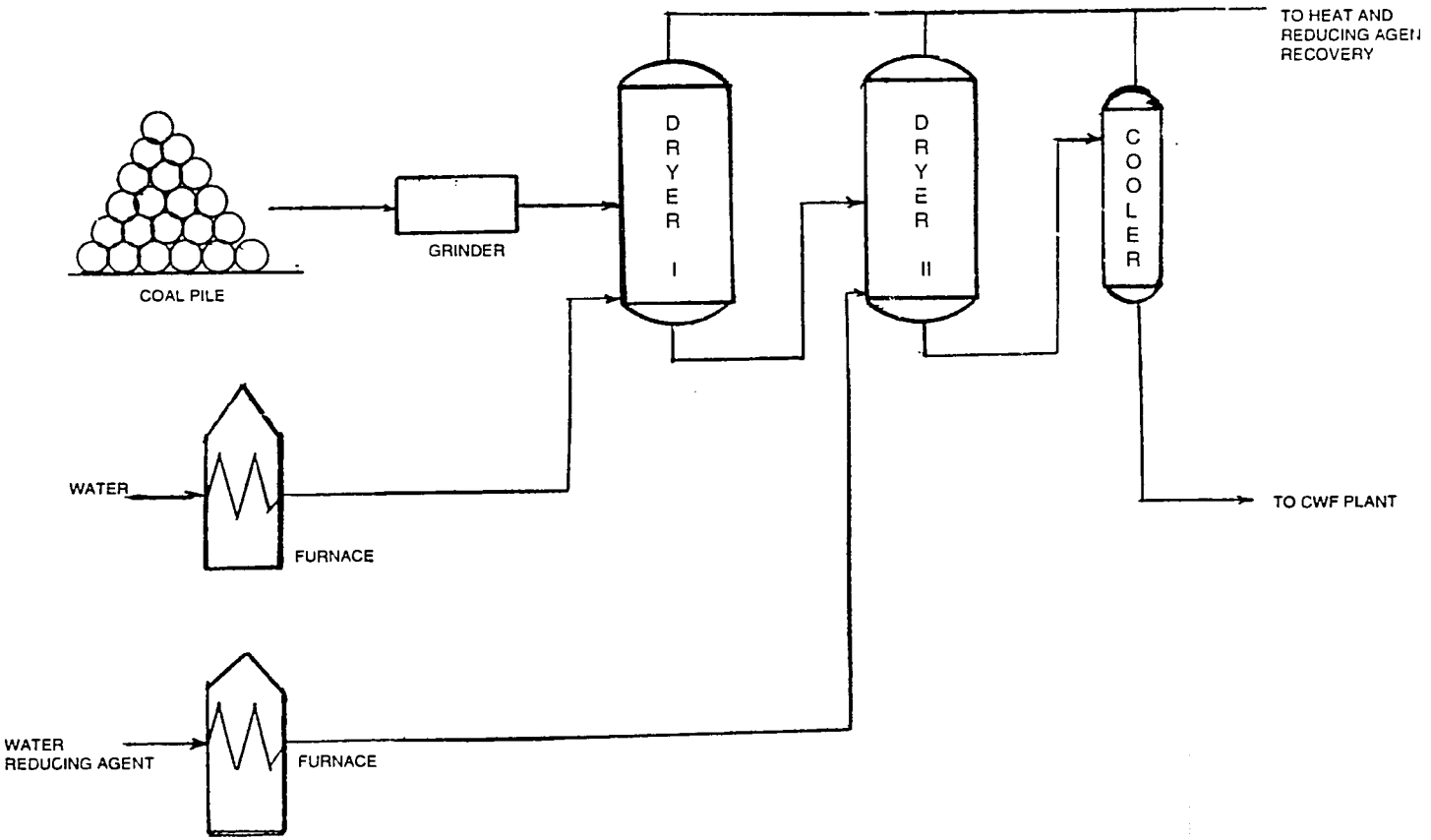
(S) Private Communication

The authors wish to express their appreciation to Richard Coleman and Floyd Toll for conducting the experiments reported herein.

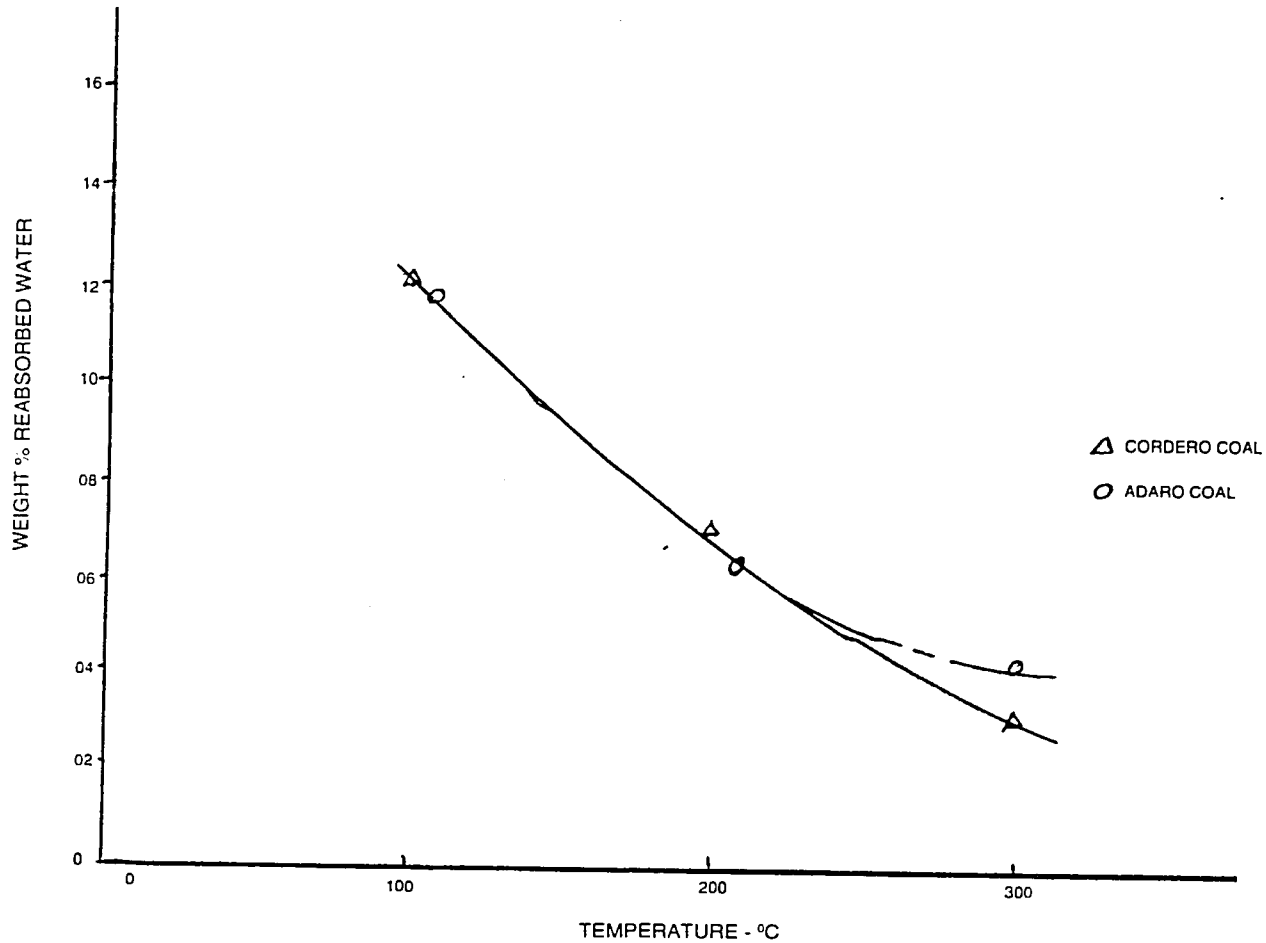
CWF FROM CO PROCESSING



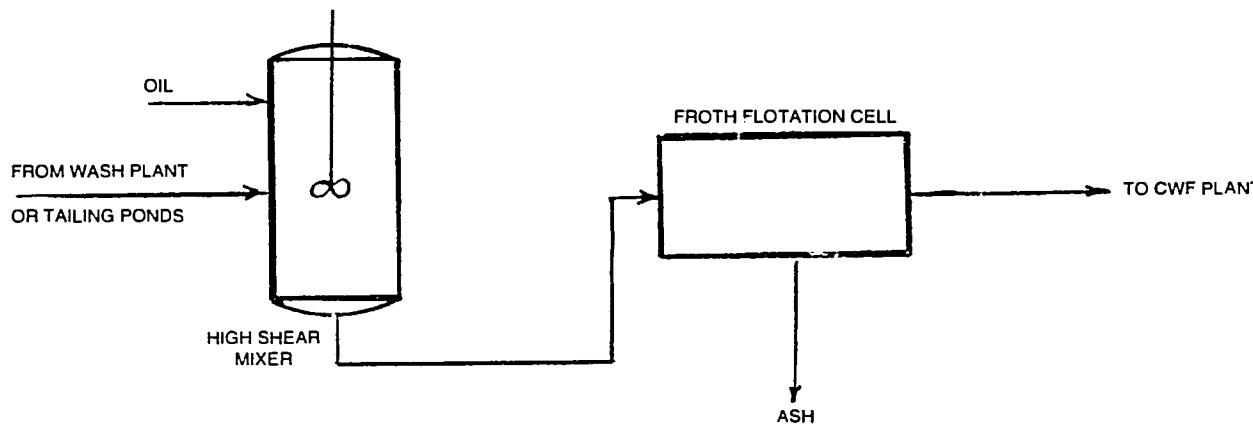
LOW RANK COAL DRYER



NRC/FMI SUB BITUMINOUS COAL DRYING



CWF FROM WASH PLANT WASTE



IEA Second International Conference on the Clean and Efficient Use of Coal and Lignite: Its Role in Energy, Environment and Life

Workshop A(3) - Technology Options/Emissions Control, Coal Preparation and CLM Fuels

" Clean and Efficient Coal Handling Systems" Development of Coal Cartridge System(CCS)

by
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1. Introduction

Coal is the world's most abundant fossil fuel and there are sufficient reserves for more than 200 years, even if output should increase. These deposits are relatively evenly distributed around the world and it is unlikely for coal to raise such security problems of supply as oil used to have in 1970's and might have again in the future. Then coal is the most reliable fossil fuel and it is expected to play an important role for energy supply in the next century.

Coal accounts for 28 percent of world total primary energy consumption and stays the second largest energy source position in 1992. The major coal using sectors are electricity generation, steel making, cement manufacturing, paper and pulp production and other industrial sectors. Approximately 60 percent of the world's coal production is used to generate electricity and 25 percent of the coal production is made into coke for use in steel making. The electricity generation is the dominant sector and is furthermore projected to become the fastest growth coal consuming sector in most economies.

Japanese industries including electricity generation sector have been fully enjoying advantages of low price abundant imported oil from middle-east before series of oil crises. The share of oil in primary energy consumption reached almost 78 percent in 1973, while coal share remained only 16 percent and total coal consumption was 80 million tons at that time. Thermal coal consumption was especially low, only 11 million tons. Late 70's and early 80's, efforts have been concentrated on energy conservation and substituting fuel oil with other energy sources such as coal, natural gas and nuclear power to reduce such high and unsettled oil dependency and obtain the security of energy supply.

Japan's total coal consumption in 1992 is around 108 million tons and account for 18 percent of the primary energy consumption. This number is a little higher than it was in the past but rather lower than world's average coal share, which is 28 percent. The coking coal consumption is accounting for 64 million tons or 59 percent of total coal consumption but future demand of coking coal is estimated to be flat or declining because of extended introduction of pulverized coal injection process(PCI) into blast furnace and presumable reduction of steel production. On the other hand, the current thermal coal consumption is 42 million tons or 39 percent of total coal consumption and is expected to double in the 2000. According to a long term forecast of energy supply and demand formulated by Japanese Government(MITI) in October 1990, the total demand of coal will increase and amount to 142 million tons by the year 2000.

Burning coal in cement kilns, utility boilers and large scale industrial boilers have become more economically attractive because of the price difference between oil and delivered coal just after oil crises. Then most of all cement kilns have converted fuel from oil to coal. Some existing coal designed oil firing utility boilers moved back to coal firing again and some coal fired utility boilers have been newly installed and commissioned since then. Another considerable number of coal fired utility boilers are now under construction or being planned to be built and commissioned near future. A large number of relatively larger coal fired boilers also have been newly built by energy

users in industrial sector to replace oil fired boilers and enjoy a real price advantage over oil or natural gas. However there have been few cases to build new small scale coal fired boilers since smaller coal fired boilers are not so economically attractive as larger coal fired boilers. The problems posed by coal use in small scale boilers, such as high capital requirement, more space requirement, more burdensome operating conditions and environmental regulations concerning NOx, SOx , particulates and noise emission control, dust suppression and ash disposal restriction, are all significant cost consuming obstacles against enhancement of coal use in industrial sector. Most of the smaller industrial boilers are not base load and new coal fired boilers should meet swings in demand, which occur so often and so quickly. This is another challenging issue for the coal fired boilers. While there are so many small size oil fired industrial boilers, which are more than 30 years old and have the potential to be replaced by new coal fired boilers, and the economies for increased industrial coal use are promising in general, the adoption process to the smaller boilers is fraught with not only economical uncertainties such as fuel price trends but also unresolved technical problems to improve coal economics.

Coal Cartridge System (CCS) is considered seriously as one of the potential breakthroughs to minimize the disadvantages of coal use in small scale boilers and improve coal use economics.

2. Concept of Coal Cartridge System (CCS)

(1) Conceptual Design of CCS

CCS is a series of systems to process coal in a central plant, to deliver the pulverized product coal to several small or medium size of coal use customers in a neighboring area by tank trucks, to collect fly ash from the customers by tank trucks again and to process fly ash for disposal.

In the central plant, CCSCenter, feed coals are provided from an adjacent bulk terminal, where they are unloaded and stored, and are blended to control product quality to meet requirements of customer's boilers. Finely blended coals are dried, pulverized and classified in a gas-swept mill system. Hot gas oxygen content of the gas-swept mill system is controlled to prevent pulverized coal from explosion. Particle size and quality controlled product coals(CCS coal) are stored in product coal bins or CCS coal bins under inert gas atmosphere. Then the CCS coal is pneumatically loaded to tank trucks to be delivered to customers and it is unloaded there pneumatically again. During loading, transportation and unloading, product coal is always handled under inert gas atmosphere or oxygen content controlled gas such as truck engine exhaust gas. Delivered CCS coal is also stored under inert gas atmosphere in the customer's pulverized coal bins. Since ready dried and pulverized coal is fed to boilers from the bins, it is expected to perform quicker response for boiler load changes and higher combustion efficiency in this system compared to the usual mill feed system. Fly ash stored in fly ash bins, separated from flue gas after coal burning is recovered by tank trucks and collected in a centralized fly ash processing and disposal site, which is called Ash Center. Fly ash can be used for the source of construction and building materials.

Expected capacity of one unit of CCS is from 300,000 to 800,000 tons per year, depending on

size and number of customer's boilers in single unit area where tank trucks can deliver product coal economically and practically, which is estimated within 50-km radius around CCS Center. Product coal supply depots and fly ash collection depots should be necessary in some case.

(2) Advantages of CCS

CCS is developed to solve the problems of coal use in small scale boilers in industrial sector and CCS customers have the following advantages:

+ *Space saving for smaller coal use customers*

Most of the smaller industrial boilers are located in industrialized complex area, where is very crowded, costly and even difficult to have enough space to build coal storage yards, pulverizing facilities and ash dumping lands. CCS is a effective way to encourage potential coal users in such a crowded area because fuel coal is already blended , dried and pulverized in the CCS center near bulk terminal and fly ash after burning coal is also collected in the centralized Ash Center. Then each coal use customers are not required to hold the coal yard, the pulverizing facilities or the ash dumping land. Only required facilities beside the boilers are pulverized coal bins and fly ash bins for 2 or 3 day storage.

+ *Trouble-free handling*

CCS coal is handled pneumatically under the inert gas atmosphere all the way through inlet of customer's boiler burners after CCS storage bins in the CCS Center. Fly ash is also handled pneumatically. CCS is a complete closed system and coal is handled very cleanly and safely. Then CCS coal is free from the troubles such as sticking, plugging, clogging, spontaneous combustion and explosion, which happen during usual coal handling and are labor consuming and dangerous. CCS coal can be used as easily as fuel oil.

+ *Environmentally benign*

As mentioned above, coal yard including unloading facilities, pulverizing mills and ash disposal facilities are not installed in customer's site and CCS coal is handled completely in the closed system. Environmental issues such as dust and noise usually arising from coal handling and milling, are not necessary to be considered in the customer site. Disposal of fly ash is also out of scope of the customer's works. It is not necessary for the customers to consider that issue either.

+ *Clean, stable and highly efficient combustion*

Since smaller boilers have intrinsic sensitiveness to coal qualities, unexpected changes of coal qualities such as calorific values, moisture contents, S contents, N contents, combustion characteristics, ash contents and compositions resulting dust collecting, slagging and fouling characteristics are always critical for boiler operation and environmental emission control. CCS coal

is already prepared and finely quality controlled even moisture contents to meet the operating condition and environmental emission standard of the customer's boilers by selecting source coals and blending a multiple of coals and sometimes managing particle size distribution. Then it always gives stable and fine control of boiler operation and environmental emission. Another advantage of the CCS is to meet the requirements of swing operation which is very common for smaller industrial boilers. Most smaller industrial boilers are swing load and they change boiler load from day to night, from weekdays to weekend, from season to season according to requirement of energy demand of the plants or factories. Unexpected load changes of main process of the plants are sometimes likely and the boilers might suffer big and quick load swings to respond to the main process changes. So, swing boilers always have to be prepared to respond such a quick changes and turn-down operation. Coal fired boilers are not necessarily good process to respond such a quick change because feed coal pulverizing mills are insensitive to load changes and always have time lag to respond. However, CCS coal boilers are equipped with pulverized coal feed bins instead of pulverizing mills and they are prepared to respond any changes of boiler load which are required from the main plant operating conditions.

+ *Economically attractive*

Coal replacement for smaller boilers become marginal because of higher investment costs of coal fired boilers than those of oil fired boilers: Total investment for coal storage yard, blending facilities transportation conveyors of feed coal, pulverizing mill, boiler itself and environmental emission control units such as ESP, scrubber and so on are enormous for a small size industrial boiler compared to the real coal price advantage over oil, running cost advantage.

CCS would gain the advantages of location and scale-up, because CCS Center can be built nearby bulk terminal and facilities of the Center are large enough to enjoy scale merit. Total erection cost per ton of burning coal can be reduced. Then, applying the CCS, the combined costs of fuel, transportation, plant investment and operation such as blending, pulverizing and burning for smaller boilers can be minimized and favor coal.

3. Test programs of CCS development

Conceptual design studies of CCS have been initiated for substituting fuel oil of industrial sector with coal since 1980, just after a series of oil crises. Despite of widening oil-coal price gap, coal still remained unsuitable fuel for use in smaller industrial boilers because of disadvantages of coal use, such as higher capital cost, more space requirement, more burdensome operating conditions and stringent environmental regulation. CCS is believed to be one of the breakthroughs to improve those coal's disadvantages.

Results of conceptual design studies of CCS have brought a recommendation of a pilot plant test program to conduct technical demonstration of CCS with pilot plants as an integrated total system. And technical issues to be solved in the test program were summarized as follows:

Technical issues to be solved

Each separate technologies applied to CCS are not new and already available. Reliability of the integrated total system, however, should be developed and demonstrated. And also individual technologies should be fully developed and matured to meet the objectives of CCS.

+ *Preparation of CCS coal*

Combining existing blending, drying and pulverizing technologies systematically and effectively, safe and stable operations should be demonstrated to produce expected cost and quality of product CCS coals.

+ *Storage of CCS coal*

Pulverized coal has the potential to initiate spontaneous combustions and sometimes even explosions under oxygen containing atmosphere. Operating standards or procedures for protecting CCS coal stored in product coal bins from such spontaneous combustions and explosions should be prepared.

+ *Transportation of CCS coal*

Operating standard for loading and unloading of CCS coal to and from tank trucks should be prepared to secure clean, safe and trouble-free handling.

+ *CCS coal combustion*

Demonstration of clean, highly efficient and load flexible combustion should be required in small scale commercial boilers.

+ *Ash collection and disposal*

Demonstration of ash transportation by tank truck and development of practical ash disposal methods.

(1) Pilot Plant Test Program (1983---1987)

A project of the Pilot Plant Test Program started in 1983 and was provided with the MITI's subsidy for coal utilization technology development. After one year study, pilot plant construction sites were decided to be Tokuyama city for a CCS coal preparation plant and Iwakuni city for a CCS combustion boiler. Both cities are in Yamaguchi prefecture and are 50 km apart.

In 1984, CCS Promotion Association was established to carry out this Test Program. More than 30 private companies have joined this Association.

+ *CCS coal preparation pilot plant at Tokuyama*

-- construction completion date : December15, 1984

-- location : Harumi public berth adjacent to coal yard in Tokuyama port

-- plant area : 2,275 m^2
-- production capacity : 15,000 tons per year
-- plant configuration : raw coal storage/blending bins(3), product CCS coal silo(170 m^3), pulverizing mill(5tons/h) with hot gas circulation(gas-swept), a bag filter and N_2 supply facility

+ *Tank trucks (4) :* 10 tons each

+ *CCS combustion boiler at Iwakuni*
-- construction completion date : September 20, 1985
-- location : Union Sekiyu Industries' Iwakuni plant
-- plant area : 658 m^2
-- boiler capacity : 15 t/h saturate steam generating
-- boiler configuration : CCS coal storage silo(70 m^3), 2 drums-water tube-natural circulation type boiler(12kg/cm^2) with 4 low-NOx burners and staged combustion, multi-cyclones and a bag filter, a fly ash bin, N_2 supply facility and back-up fuel oil system

Total production of CCS coal at Tokuyama Pilot Plant during continuous operation from 1985 thorough 1987 accounts for 16,300tons and 13,200tons of those were transported to Iwakuni Boiler to test and demonstrate continuous operation of CCS coal combustion. The remaining 3,100 tons of CCS coal was transported to Hoshizaki plant of Daido Special Steel 650 km away from the Pilot Plant by tank truck for the combustion trial in electric furnaces. Fly ash produced at Iwakuni Boiler was also brought back by tank truck and land reclamation test was conducted in other place of Tokuyama Port.

All the objectives of CCS Pilot Plant Test program were successfully performed. The technical issues concerning CCS coal preparation, storage, transportation and ash collection, transportation and disposal were all solved and demonstrated perfectly.

(2) Demonstration Test program of Commercial Plant (1990---1994)

Experimental results of the Pilot Plant Test Program have seemed promising, but the technologies should be demonstrated on sufficient larger scale. Commercial scale demonstration of CCS is necessary to establish process and equipment standard, as well as to demonstrate the basic economics of CCS.

After intensive studies to evaluate the possibility of all Japan's industrialized market areas for CCS in 1989, Aichi(Nagoya)area was selected as one of the most promising areas for CCS

commercialization and the potential areas to build a commercial scale CCS coal preparation plant for demonstration of CCS technologies and economics.

The project of the Demonstration Test Program of CCS was initiated in 1990 and was promoted by Center for Coal Utilization, Japan(CCUJ) supported by MITI's subsidy. Construction of the CCS coal Preparation Plant in Aichi Refinery of Idemitsu Kosan started in 1990 and completed in 1991. The first customer of CCS coal was Nagoya factory of Nichiha, a building material manufacture. Their 100 t/h steam generating coal fired boiler was newly installed for CCS in 1991. Another customer, Miai factory of Nisshinbo(textile) built a new 70t/h steam generating coal fired boiler for CCS in 1992.

Outlooks of the CCS coal Preparation Plant and the customers' CCS boilers are as follows:

+ *CCS coal Preparation Plant*

-- plant area : 9,600 m^2

-- production capacity : 200,000 tons per year

-- plant configuration : raw coal storage bins(2x 400m^3), coal blending facility, product CCS coal silos(4x 680m^3), pulverizing mills(2x 25 t/h) with hot gas circulation(gas-swept), a bag filter, truck scales(4) and N_2 supplier

-- typical CCS coal properties : HHV : 6,850 kcal/kg, moisture : 3 %, ash : 13 %, sulfur : 0.5% nitrogen : 1.8 %, AFT : 1360 C, -200 mesh : 80 %, Fuel Ratio : 1.45

+ *customer's boiler(Nichiha)*

-- manufacturer : Kawasaki Heavy Industries

-- boiler capacity : 100 t/h steam generating(100 kg/ cm^2, 528 C)

-- draft : balanced

-- environmental emission control : FGD(SOx), SCR(NOx), bag filter(particulates)

+ *Customer's boiler(Nisshinbo)*

-- manufacturer : Mitsubishi Heavy Industries

-- boiler capacity : 70 t/h steam generating(39 kg/cm^2, 375 C)

-- draft : balanced

-- environmental emission control : ESP(particulates)

The Test program has not been finished yet and it continues until the end of March in 1995. Though the evaluations of the commercial scale demonstration of CCS are still underway, it seems that CCS is actually a promising technology to adopt coal in smaller industrial boilers

judging from successful operations of the CCS coal preparation plant and successful and highly efficient operations of the customer boilers. However, it seems unlikely to observe CCS's economical attractiveness because coal can not offer industry an opportunity for substantial cost reduction under such poor circumstances for coal as current lower oil price and higher exchange rate of yen, resulting CCS's potential customers stay back and demand of the CCS coal is as low as a half of output of the preparation plant. This economic study should be continued.

4. Summaries

Development and demonstration of Coal Cartridge System is seriously considered to encourage industry to use coal, minimizing the disadvantages of coal use in small scale boilers and improving economics of coal use. Based on conceptual design study of CCS, successful operation of pilot plants was conducted in Yamaguchi prefecture and established technical basis of CCS from 1983 to 1987. After studies of potential CCS demand, commercial scale demonstration CCS preparation plant and CCS boilers were installed in Aichi area. Technical reliability of integrated total system of CCS was successfully demonstrated there. However, economics of CCS is not so attractive as expected under such poor circumstances for coal as current lower oil price and higher exchange rate of yen. Whether or not future energy price trend widens oil-coal price gap, is a key factor in the decision process for small industrial boiler economies. Then oil price trends are critical for the potential customers of CCS to determine. As the oil price under these market conditions should be assumed to remain relatively low and steady for a while, CCS can not offer now the potential customers an opportunity of energy cost reduction by use of coal. For the longer term, however, energy price trends will be different, increasing spread between the price of oil and those of delivered coal, and we believe that industry will appreciate again available energy supply sources and prices, as well as consideration of security of supply and take the CCS.

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Its Role in Energy, Environment and Life

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Topici: Technology Options/ Emissions Control, Coal Preparation and CLM Fuels

Title: New Development of Processing for Coal Beneficiation

Professor Pei Hong Ling

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Abstract

China is the largest Coal production country in the world. By 1990, China produced 1090 million tons of ROM coal and up to 1400 million tons by the year 2000. In 1990, the total number of Coal Preparation Plants in P.R.C. is 335 sets, treating 254 million tons of ROM coal. By the year 2000, it will be 328 coal preparation plants treating 425 million tons of ROM coal.

Homogenization of ROM coal is very important especially for different seams with different washability and different quality. For coal blending, we need bunkers and automatic tripping device. Simatic -150A and MC-5800 micro computers are used. The Ultrasonic level transmitter or Nuclear level Sensors should be used.

Centrifugal force cleaning is more efficient than gravitational force cleaning. Because, the gravitational constant is 'G' which equals 980 cm/sec². We can not changge it when we are on the earth. But the Centrifugal force $m.v^2/r$ can be changed. At the apex of the cyclone, the accerleration increases to over 200 times thangravity.

In order to close the water circuit, we use oil agglomeration, flocculants and dewatering equipment such as high frequency dewatering screens and centrifuges.

The whole plant is under computer control.

NEW DEVELOPMENT OF PROCESSING FOR COAL BENEFICIATIION

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INTRODUCTION

CHINA IS ONE OF THE LARGEST COAL PRODUCTION COUNTRY IN THE WORLD . IN 1987, CHINA PRODUCED 920 MILLION TONS OF RUN OF MINE (ROM) COAL, WHICH WAS MORE THAN 26 MILLION TONS OF NET INCREASE OVER 1986. BY 1990, THE NATIONAL PRODUTION WILL HAVE REACHED OVER 1000 MILLION TONS AND UP TO 1400 MILLION TONS BY THE YEAR 2000.

IN CHINA, COAL OCCUPIED 76.3% OF TOTAL ENERGY CONSUMPTION IN 1987. COAL IS THE MOST IMPORTANT ENERGY RESOUCES IN CHINA UNTIL THE END OF THIS CENTURY.

ACCORDING TO STATISTICS OBTAINED BY THE END OF 1987, PROVEN RESERVES OF COAL IN THE COUNTRY HAVE REACHED 800.000 MILLION TONS. WE DO HAVE ALL KINDS OF COAL INCLUDING COKING COAL, STEAM COAL, ANTHRACITE, BROWN COAL, AND PEAT.

ACCORDING TO THE REQUIREMENT OF THE MARKET, CHINA MUST DEVELOPE HER COAL PREPARATION PLANTS, DURING THE PERIOD FROM 1986 TO 1990, MORE THAN FIFTY (50) COAL PREPARATION PLANTS WILL BE BUILT UP, WITH A TOTAL CAPACITY OF ABOUT 100 MILLION TONS.

THE FOLLOWING NEW DEVELOPMENT OF PROCESSING FOR COAL BENEFICIATION SHOULD BE CONSIDEERED.

HOMOGENIZATION OF ROM COAL

IN ORDER TO GET THE HIGHER YIELDS, HOMOGENIZATION OF ROM COAL IS VERY IMPORTANT. BECAUSE IN A COAL FIELD, DIFFERENT COAL SEAMS HAVE DIFFERENT WASHABILITY AND DIFFERENT QUALITY.

HOMOGENIZATION CAN BE OBTAINED BY USING MASS FEED RATE COAL BUNKERS LOADED BY USING AN AUTOMATIC ROM CONVEYER TRIPPING DEVICE. A TYPICAL HOMOGENIZATION AND BLENDING SYSTEM SHOULD HAVE AT LEAST FOUR COAL BUNKERS, EACH WITH A MASS DISCHARGE FEEDER. EACH BUNKER IS LOADED TO A FIXED LEVEL BY USE OF AN AUTOMATIC ROM CONVEYER TRIPPING MECHANISM THAT COUSES EACH BIN TO BE FILLED SEQUENTIALLY UNTIL ITS APPROPRIATE LEVEL IS REACHED. EITHER ULTRASONIC LEVEL TRANSMITTER OR NUCLEAR LEVEL SENSORS SHOULD BE USED TO SENSE THE APPROPRIATE LEVEL.

THE LEVEL TRANSMITTER OF THE ULTRASONIC RANGING TYPE TRANSMIT ULTRASONIC ENERGY PULSES VERTICALLY DOWNWARD. THE TIME OF ARRIVAL OF THE REFLECTED ENERGY DETERMINES THE LEVEL IN THE BIN.

THE NUCLEAR LEVEL SENSOR IS MADE UP OF A NUCLEAR RADIO ISOTOPIC SOURSE, MOUNTED ON ONE SIDE OF THE BUNKER, AND AN ARRAY OF GAMMA - RAY DETECTORS, MOUNTED ON THE OTHER SIDE OF THE BUNKER . NUCLEAR DEVICES ARE RELATIVELLY EXPENSIVE BUT PROVIDE ACCURATE AND RELIABLE MEASUREMENTS OF COAL LEVELS.

THE NORMAL WAY OF ACHIEVING GOOD HOMOGENIZTION IS STACKING BY THE CHEVRON METHOD AND FRONT RECLAIMING. WHEN OPERATING WITH A CIRCULAR HOMOGENIZTION PLANT, STACKING MAY BE DONE EITHER BY TTHE KELLY METHOD OR BY THE CHEVRON METHOD.

IN CHINA, FANGEZHUANG COAL PREPARATION PLANT USE SIMATIC-150A AND MC-6300 MICRO COMPUTORS.

BEST AVAILABLE DOCUMENT

CENTRIFUGAL FORCE CLEANING

CENTRIFUGAL FORCE IS MORE IMPORTANT THAN GRAVITATIONAL FORCE FOR THE PREPARATION OF CHINESE COAL. BECAUSE THE WASHABILITY OF CHINESE COAL IS VERY DIFFICULT ESPECIALLY THE COKING COAL. THE GRAVITATIONAL CONSTANT IS "G", WHICH EQUALS 980 CM/Sec^2 WE CANNOT DO ANY THING ABOUT IT EXCELT WE WANT TO LEAVE THE EARTH. BUT WE CAN INCREASE THE ACCERATION OF THE CENTRIFUGAL FORCE TO SEPARATE THE COAL AND REFUSE. SUCH FORCE CAN BE AS MUCH AS SEVERAL HUNDREDS TIMES GREATER THAN GRAVITATIONAL FORCE. MICHAEL SOKASKI AND M. R. GEER WROTE: "IT IS APPARENT THAT THE FORCES CAUSLNG THE PARTICLES TO SEPARATE IN A STATIC BATH ARE PROPORTIONAL TO "G", WHEREAS IN A CYCLONE THEY ARE PROPORTIONAL TO V^2/R WHICH IS MUCH LARGER. AT THE APEX OF THE CYCLONE THE ACCERLERATION INCREASES TO OVER 200 TIMES GREATER THAN GRAVITY". THEREFORE, WE CHOICE THE CYCLONE AS OUR MAIN EQUIPMENT TO TREAT ROM COAL AND FINE COAL. THE BRITISH LARCODEMS (ϕ 1.2M) CAN HANDLE RAW COAL SIZED 100MM-0.5MM. THE RAW COAL CAN CONTAIN UP TO 50% REJECT. THE FEED RATE CAN BE UP TO 250T/H. THE VOLUMETRIC CAPACITY OF THE LARCODEMS IS 800 M^3/H AT THE DESIGNED INLET PRESSURE EQUIVELENT TO 10.8 M. OF MEDIUM.

CHINA HAS BUILT UP 600 MM. DIAMETER HEAVY MEDIUM CYCLONES IN PINGDINGSHAN COAL PREPARATION PLANT AND MAJIAGOU COAL PREPARATION PLANT. THE CAPACITY IS 50-74 TONES PER HOUR PER CYCLONE. THE FEED SIZE IS 50-0.5 MM. MAGNETITE IS USED AS HEAVY MEDIUM. WE ALSO USE THE FLOTATION TAILINGS AND FINE REFUSE AS HEAVY MEDIA. THE TYPE OF THE CYCLONE IS DBZ-1.

IN CAI-TUN COAL PREPARATION PLANT. THREE-PRODUCT CYCLONES DIAMETER 500 AND 300 HAVE BEEN BUILT UP. THE FEED SIZE IS 35-0.5 MM. THE CAPACITY OF THE THREE PRODUCT CYCLONE IS 40 TONES PER HOUR.

THE WATER ONLY CYCLONES. TYPE WOE-35, WOE-50, ARE USED IN CHINESE COAL PREPATION PLANTS ALSO.

THE AMERICAN KREBS ENGINEERS. ROBERTS & SCHAEFER. AND MCNALLY CO.ETC. HAVE BUILT UP HUNDREDS OF COAL PREPARATION PLANTS USING DIFFERENT MODELS HEAVY MEDIUM CYCLONES AND WATER CYCLONES, TO APPLICATE DIFFERENT SIZES AND CAPACITIES. MAXIMUM TOP SIZE. 50MM. DOWN TO 100-150 MESH (0.15 - 0. 10MM) THEREFORE. THE CAPACITY OF FLOTH FLOTATION WILL BE REDUCED OR THE FLOTATION PROCESS MIGHT BE CANCELLED.

OIL AGGLOMERATION AND CENTRIFUGING

OIL AGGLOMERATION RELIES ON DIFFERENCES IN THE SURFACE PROPERTIES OF COAL AND DIRT TO EFFECT SEPARATION. OIL AGGLOMERATION CAN PRODUCE A DENSE. COARSE GRANULAR PRODUCT OF ACCEPTABLE STRENGTH AND LOW WATER CONTENT WITHOUT THE NEED FOR VACUUM FILTERING OR THERMAL DRYING. CMI MODEL EBW CENTRIGUGE WILL BE USED FOR DEWATERING. THE TOTAL MOISTURE OF THE CLEAN COAL IS PROSPECTED BELOW 7% INCLUDING 1.5% OIL BY WEIGHT OF COAL SOLIDS.

CLOSED WATER CIRCUIT

WE WANT TO RECIRCULATE THE WATER IN THE PLANT. THE REQUIREMENT OF THE SOLID CONTENT OF THE RECIRCULATING WATER SHOULD BE 10-100 gm/L AND THE EFFLUENT MUST BE BELOW 0.1 gm/L. THEREFORE. WE NEED TO ADD FLOCCULANTS TO ACCERATE THE SETTLING RATE OF SOLID. LONG - CHAIN FLOCCULANTS OF HIGH MOLECULAR WEIGHT. SUCH AS SUPER - FLOC 127, SEPARAN MG200. NALEOLYTE 603 ETC. IN CHINA, POLYACRYLAMIDE IS THE MOST POPULAR FLLOCULANT AND DUAL ATOMIZER SHOULD BE USED.

BEST AVAILABLE DOCUMENT

COMPUTOR CONTROL

THE USE OF COMPUTERS IN THE COAL PREPARATION PLANTS IS RELATIVELY NEW. HOWEVER, COMPUTER SYSTEMS HAVE BEEN INSTALLED IN PREPARATION PLANTS OF USA, UK, CANADA, AUSTRALIA, CHINA AND MANY OTHER COUNTRIES.

THE MAIN BENEFITS OF THE COMPUTOR CONTROL INCLUDED:

1) MORE EFFICIENT USE OF MANPOWER;
2) IMPROVED PLANT PERFORMANCE AND EFFICIENCY;
3) BETTER USE OF THE PLANT THEREBY PROVIDING HIGHER PRODUCTIVITY;
4) IMPROVED QUALITY CONTROL RESULTING IN INCREASED YIELDS;
5) IMPROVED INFORMATION FOR MANAGEMENT ON OVERALL PLANT PERFORMANCE USES OF COMPUTERS IN PROCESS PLANT OPTIMIZATION.

AT FIRST, WE SHOULD HAVE GOOD INSTRUMENTATION USED IN THE COAL PREPARATION PLANT INCLUDED NUCLEAR DENSITY GAGES, BUNKER LEVEL INDICATORS, WEIGH BELT FEEDERS, BELT SPEED SENSORS, LIQUID LEVEL DETECTORS, AND LIQUID FLOW RATE METERS. NONCONTACT MEASUREMENTS SUCH AS ULTRASONIC, ECHOSONIC, NUCLEONIC, AND DOPPLER VELOCITY TRANSDUCERS HAVE BEEN DEMONSTRATED TO BE RELIABLE IN COAL PREPARATION PLANT APPLICATIONS.

IN CHINESE COAL PREPARATION PLANTS, MORE THAN 200 SETS OF PC-1500 POCKET COMPUTORS HAVE BEEN USED AND ALSO BCM-3 MICRO COMPUTORS. APPLE-2 MICRO COMPUTORS. THE FANGZHUANG COAL PREPARATION PLANT WHICH WAS IMPORTED FROM WEST GERMANY, SIMATIC-155-A AND MC-6000 MICRO COMPUTORS HAVE BEEN USED. THE XINGLONGZHUANG COAL PREPARATION PLANT WHICH WAS IMPORTED FROM U.S.A., AMERICAN GENERAL ELECTRIC' S LOGITROL-500 AND LOGITROL-550 COMPUTORS HAVE BEEN USED ALSO. THE CHINESE COAL RESEARCH INSTITUTE IN TANGSHANG HAS INVENTED THE AUTOMATIC IN-LINE ASH MONITOR FOR MINUS 13MM SIZED COAL. THE MOISTURE CONTENET IS BETWEEN 12-14%. THE ASH CONTENT IS BETWEEN 4-13%. THE THICKNESS OF THE COAL BED IS BELOW 150MM. THE ACCURACY OF THE IN-LINE ASH MONITOR HAS BEEN FOUNDED TO BE WITHIN 0.3 - 0.5%. THE RADIO ISOTOPE IS AMERICIUM (AM-241). THE AUTOMATIC IN-LINE MOISTURE MONITOR, TYPE MC HAS BEEN USED FOR COAL SIZE 13-0 MM. TOTAL MOISTURE RANG IS BETWEEN 6 - 14.5%. THE ACCURACY IS ± 0.5%.

CONTROL OF THE HEAVY MEDIA CYCLONE PROCESSES IS SUFFICIENTLY WELL UNDERSTOOD. IT COULD BE AUTOMATED WITH LITTLE DIFFICULTY. THE RESEARCH OF CONTROL OF THE WATER ONLY CYCLONE PROCESSES IS GOING ON BY THE CANADIAN CYCLONE ENGINEERING SALES LTD.

A COMPLETE MONITORING SYSTEM OF THE WATER RECOVERY SECTION AND STRATEGIC POINTS THROUGHOUT THE PLANT COULD BE CARRIED OUT. THE SYSTEM WILL INCLUDE THE FOLLOWING INSTRUMENTES:

1) ELECTRICALLY AND PNEUMATICALLY ACTUATED VALVES;
2) FLOWMETERS, (DOPPLER ULTRASONIC VELOCITY);
3) DENSITY METERS (NUCLEAR);
4) PH METERS AND TEMPERATUER METERS;
5) TURBIDITY METERS;
6) VARIABLE SPEED ELECTRIC DRIVES WITH TACHOMETER FEED BACK;
7) STRAIN GAUGES;
8) LEVEL INDICATING EQUIPMENT;
9) LAMP EQUIPMENT AND VARIOUS FREQUENCY SOUND ALARMS;
10) PRESSURE INDICATING EUIPMENT.

BEST AVAILABLE DOCUMENT

COMPLETE COMPUTER CONTROL SYSTEM CONSISTING OF THE FOLLOWING:

1) PROCESSOR, MINIMUM 16 K WORDS CORE MEMORY, BOOTSTRAP LOADER, REAL TIME CLOCK;

2) DISK AND CONTROLLER;

3) PRINTER;

4) INDUSTRIAL INTERFACE CONTROL BOX;

5) SOFTWARE PACKAGE;

6) ACTIVE I/O TERMINAL, VIDEO TYDE.

FOR SUCCESSFUL CONTROL PROCESS INSTRUMENTATION MUST BE REPEATABLE. FIBER OPTICAL COMMUNICATION CABLES ARE BECOMING POPULAR IN THE PROCESS CONTROL INDUSTRY. IT IS EXPECTED THAT THESE LINES WILL BE USED IN AUTOMATED COAL PREPARATION PLANTS. ANOTHER REQUIREMENT IN ANY COMPUTER CONTROL SYSTEM IS TO PROVIDE RELIABLE SIGNALS AT THE MAIN COMPUTOR.

CONCLUSION

CHINA WANTS THE SERVICES OF A COAL PREPARATION PLANT THAT HAS A HIGH DEGREE OF EFFICIENCY AND A LOW COST PER TON OF OPERATION. THE COAL PREPARATION PLANT MUST BE BUILT AT THE CHEAPEST COST. THEREFORE, ADVANCED TECHNOLOGY FOR IMPROVING COAL QUALITY IS ESSENTIAL TO INCREASING CHINA' S DOMESTIC AND EXPORTABLE COAL PRODUCTION TO THE DESIRED LEVELS. I WOULD LIKE TO POINT OUT THE FOLLOWING FIVE POINTS ON THE NEW DEVELOPMENT OF PROCESSING FOR COAL BENEFICIATION:

1) HOMOGENIZATION OF ROW COAL IS NEEDED;

2) CENTRIFUGAL FORCE CLEANING IS IMPORTANT FOR CHINESE COAL, EITHER BY HEAVY MEDIA CYCLONES OR BY WATER ONLY CYLONES.

3) OIL AGGLOMERATION AND CENTRIFUGAL DRYING WILL BE INSTEAD OF THERMAL DRYING;

4) CLOSED WATER CIRCUIT WITH FLOCCULATION WILL BE USED;

5) COMPUTOR CONTROL IS REQUIRED NOT ONLY FOR REDUCING OPERATING MEN BUT ALSO FOR PROMOTING THE QUALITY OF THE CLEAN COAL AND THE EFFICIENCY OF THE PLANT.

THANK YOU.

(VIDEO RECORDS AND SLIDES ARE PREPARED FOR THIS PAPER.)

BEST AVAILABLE DOCUMENT

"ADVANCED FLOTATION: Packed Column Froth Separation for Fine Coal Cleaning"

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ABSTRACT

Among several emerging new technologies for coal cleaning, the packed flotation column stands out as the only high efficiency device meeting nearly all performance targets set by the US Department of Energy for Btu recovery and ash/pyritic sulfur rejection. The packed column, originally developed for beneficiation of minerals and paper de-inking operations, is now being explored by many for coal cleaning applications including fine coal recovery from waste ponds. The packed column performs like multi-stage open columns because its unique packing design is capable of supporting a very deep froth bed without causing froth channeling or overturn. Besides providing intimate particle-bubble contact, the packed column overcomes the intrinsic problem of vertical mixing of an open column. The scrubbing action of the packing to cleanse the entrained ash-forming particles from the coal froth is the key factor for sharp separation. A premium coal of 1% to 3% ash can readily be produced at 80 to 90% combustible matter recovery on many US coals. Effective flotation extends down to particles of only a few microns in size. The practical limitation is not the separation device but the degree of liberation needed and the cost of grinding. Since the new technology has also been tested successfully for recovery of coarse coal (top size of 0.5 mm), significant opportunities are created with this technology toward secure energy supplies through economical use of coal in an environmentally acceptable manner. This paper presents the status of advanced flotation machines and processes that show promise for imminent industrial adaptation.

INTRODUCTION

1. Background

Coal is a major energy resource of the world. The responsible use of coal is vital to maintaining or improving the standard of living for the majority of world population, including those living in the United States. Rapidly changing global market has encouraged technical developments in coal cleaning to control emissions and to minimize operating costs. Coal cleaning reduces the amount of sulfur and mineral matter. The cleaning process also provides a more acceptable fuel for compactly designed combustion and boiler systems. The benefits of coal cleaning on system performance are numerous. Not only does it decrease ash-handling requirements, but when coal is ground to fine particle sizes to liberate mineral matter, boiler tube erosion is minimized because fly ash particle sizes are smaller and abrasive ash species (such as quartz) are reduced. Also, heat transfer performance when firing these cleaned coals is better because less ash accumulates on the tubes.

2. Emerging Fine Coal Cleaning Technologies

Among several emerging new methods, physical separation remains the center of interest because of its near term potential. The principal methods take advantage of the differences in physical properties between coal and mineral matter to achieve the separation. Even though the physical process only removes ash and pyritic sulfur, it can convert many high-sulfur coals into compliance coals more economically than competing technologies. However, to achieve a high level of pyritic sulfur rejection, coal needs to be comminuted to fine sizes say, minus 200 mesh, resulting in a large quantity of coal below 400 mesh size. Conventional fine coal cleaning consisting of sub-aeration flotation poses problems when dealing with such fine particles. Accordingly, the expanded use of

coal resources requires the developments of advanced coal cleaning technologies that can provide economic performance while reducing environmental impacts.

The leading processes now under development are: (1) Selective agglomeration, (2) Heavy-liquid cyclone separation, and (3) Advanced flotation. Selective agglomeration technology, which has received considerable attention from researchers over the last 10 years, suffers from economic problems due to the high dosages (6-10%) of agglomerant required. The heavy-liquid cyclone appeared to be an attractive technology initially, but the losses of organic liquids via absorption in the product and tailings have become a major environmental concern. It is doubtful if the heavy-liquid cyclone can work effectively for particle sizes below 325 mesh, even with very low-viscosity, high-gravity liquids. In comparison, advanced flotation offers considerable advantages in terms of rejection of mineral matter and collection of fine coal particles using small air bubbles.

In the following, the status of advanced flotation technologies is reviewed in an effort to assess the impact to improved fine coal cleaning. Special emphasis will be on the development of an almost ideal counter-current mass transfer device - packed column.

3. Evolution of New Flotation Concepts

Flotation is a complex process involving a variety of subprocesses with respect to time and space in the flotation machine. It may include mass transfer through particle-bubble attachment from slurry to froth, and from froth into concentrate. Conversely, detachment also may occur. The physical and chemical nature of the material to be treated and its interactions with reagents and air bubbles are all critical for a successful performance.

Advanced flotation extends the principles of conventional froth flotation to particles of micron size. The current development of a number of innovative flotation systems can be compared technically and economically, but the evaluation of new flotation technologies should carefully consider overall system benefits, such as product handling, dewatering cost and ease of operation and control. Again, one system may come to dominate while others disappear. Future flotation circuits will make use of methods suited for the particular flotation requirement [1].

ADVANCES IN FLOTATION MACHINE DESIGN

1. Conventional Flotation Equipment

The flotation machines can be categorized as mechanical, pneumatical, froth separators, columns and other variations [2]. Until recently, flotation was almost completely dominated by the agitation type mechanical device, usually consisting of banks of stirred tanks. The major development in the evolution of the conventional flotation machine has been the steady increase in the size of individual units for economy of scale. However, compromise is very often made between the separation efficiency and the capacity of the machine.

The agitation-type of flotation machine is being asked to do several conflicting tasks. It has to provide turbulence to maintain particles in the suspension and promote contact between particles and the small air bubbles introduced into the pulp by the stirring action; and also to provide a quiescent region for efficient separation of the loaded bubbles from the remaining pulp through froth drainage. Entrainment, particularly of fine hydrophilic particles, was recognized as the main mechanism interfering with selectivity early in the development of the model for flotation [3], yet the importance of froth cleaning is usually overlooked or treated entirely empirically. A basic understanding of the problems with conventional flotation cell design along with the competitive nature of the mining industry on a global basis has recently resulted in the rapid development and acceptance of new flotation concepts, including some novel flotation cells which seem to find favor in various applications.

2. Novel flotation Cell Designs

Several of the newer methods employ different techniques for increasing air and slurry contact and achieving improved flotation performance. Froth washing can give improved concentrate grades. Some stress a shorter residence time so that more compact flotation plants can be designed and constructed. The removal of impeller/motor mechanism can give reduced power requirements. However, significant economic benefits must be realized from the circuit before any of these new concepts can be accepted by the industry. The inroads made by column cells have to date been in the right trend. Advances in the understanding of separation mechanisms with respect to slurry and airflow rate, uniform bubble size distribution, and froth washing, have enhanced the column applications for coal cleaning. Highlights of the new flotation design concepts include: Flash flotation, AFT flotation, Open and Packed Column flotation and many others currently under development [4]. It is quite likely only a few of these will survive after industrial scrutiny.

Recent advances in conventional column flotation have shown clear benefits in actual froth separation. During scale-up in commercial-size columns, however, vertical mixing and bubbles coalescence have proven to be significant problem areas, thus needing very tall columns or a drop in performance. These problems are addressed by the unique design of the packed column.

DEVELOPMENT OF PACKED COLUMN CELL

1. Overview

The development of the packed column (or static tube) flotation system has proven to overcome most of the shortcomings of conventional flotation methods including open columns. The packed column was originally developed for treatment of fine-grained iron ore more than 10 years ago and later expanded to many applications including de-inking for paper pulp recycling. It is intriguing to see the successful demonstration of the packed flotation technology in such a wide scope of applications.

Producing an iron ore concentrate of >66% Fe from a feed of 30-35% Fe in a single step has indeed set a new standard. In several pilot and industrial scale test campaigns for sulfide ore concentration, the packed column has significantly outperformed the open columns. For example, at the similar concentrate grade of 32-33% Cu, the packed column improved the recovery from 42% to 77% even operated at much higher (almost 3 times) throughput capacity per unit cell volume. The extension of the technology to coal applications has also become an instant success. The cleanest coal produced by the new process corresponds to about 90% ash removal and almost total removal of pyritic sulfur, the theoretical limit for physical separation. Moreover, the packed column process has been effective to treat particles down to subsieve size ranges. The distinct design feature of the packed column is its in-line packing that has led to significant improvements in process economics as well as metallurgical performance in grade and recovery [5-8].

2. Packing Structure and Operations

The packed column flotation machine, which is presented schematically in Figure 1, incorporates a packed-bed column design to provide small flow passages for intimate particle/bubble contact (For illustration, the size of the column is arbitrary). A most effective packing structure found is a stack of corrugated plates as shown in the exploded view. The packing plates are arranged in blocks positioned in layers at right angles to each other. These stacked corrugated plates obviate the need for an air sparger, since they break any bubbles into small sizes. Capillary effects between the plates support an almost unlimited froth height.

This device, which resembles a conventional flotation column from the exterior, has a pulp inlet at an intermediate location, a water inlet near the top and an inlet for introducing compressed air into

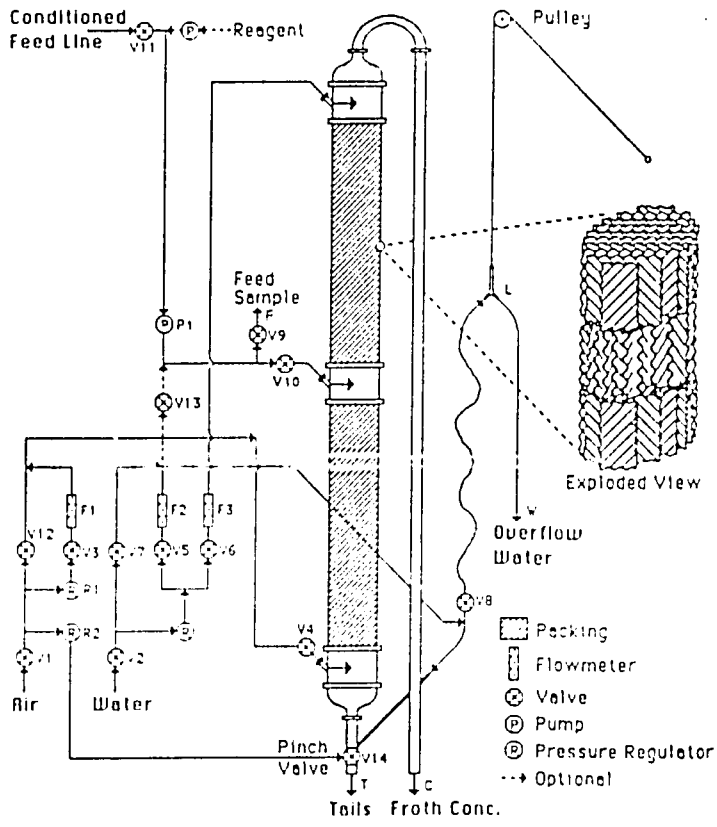

Figure 1. Packed Flotation Column Setup.

the bottom of the column. Wash water percolates down through a maze of small flow passages conforming to the shape of the packing structure. Low pressure air is added directly to the bottom (no sparger). Bubble size is uniform as air takes a tortuous path upon rising through the packing. Coal concentrate is pneumatically conveyed to the next processing step (no launders), while the tailing stream exits at the bottom. It has been shown that the effective volume of the machine is the major factor for scale-up considerations, provided the unit cell geometry of packing elements does not change significantly. As air passes upward through the winding flow passages, it continuously disperses into fine bubbles that carry the floatable particles into a froth compartment in the upper portion of the column, where the clean product is discharged through an outlet. Wash water descending through these same flow passages induces entrained mineral particles to separate from the clean product. With adjustment of the machine operating parameters, various degrees of separation can be obtained.

The operating conditions of the packed column can be manipulated in accordance with the requirement of each system. The key factors affecting its separation performance are reagent addition, feed rate, air rate, wash water, and most imporantly the pulp level and/or froth-bed height. Depending on the particle size and pulp density of the feed material, the feed rate can be varied from 0.5 to 2.0 TPH/m^3 and the pulp density ranged from 5 to 40% solids. It should be noted that the feed rate can be scaled up directly by cell volume, or by cross-sectional area if the column height is unchanged.

3. Typical Coal Cleaning Results

The packed column flotation, has consistently demonstrated its ability to reject 85-90% of the pyritic sulfur from many of the U.S. coals at over 85% combustible matter recovery. The quality of coal can be easily monitored with the froth-bed height adjustment through a pressure-controlled tailing discharge outlet. The typical coal flotation test results obtained using the packed column flotation process are presented in Table 1. The results of packed column flotation are extremely promising when compared with conventional methods.

Table 1. Comparison of results for selected bituminous coals.

		Packed Column Flotation			Conventional Flotation		
Coal	Head %Ash	Stages No.	Quality %Ash	%Rec. Btu	Stages No.	Quality %Ash	%Rec. Btu
Western Canadian (-65 mesh)	15.1	1	9.9	98.3	1	11.3	98.6
			8.4	96.3	2	10.4	96.0
			7.9	93.5	3	7.8	78.0
			5.6	80.6			
Upper Freeport A (-100 mesh)	18.1	1	7.0	98.6	1	6.4	85.4
Upper Freeport B (-325 mesh)	13.6	1	2.5	84.9			
Illinois #6 A (-100 mesh)	42.7	1	4.6	93.5			
			3.8	91.3			
			3.6	89.6			
Illinois #6 B (-400 mesh)	14.1	1	3.3	94.1			
Pittsburgh A (-400 mesh)	17.5	1	2.9	92.4			
Pittsburgh B (-325 mesh)	12.0	1	3.0	99.2			
			2.6	96.1			
			1.9	78.2			
		2	2.6	98.1			

The effectiveness of the packed column flotation process is demonstrated by its excellent selectivity, maintaining both high Btu and mass recovery of coal with low dosages of reagents. Table 2 lists the results of a round-robin testing program, organized by ICF Kaiser Engineers sponsored by the U.S. Department of Energy. These results were based on tests using a standard sample of Pittsburgh No. 8 coal ground to 325 mesh. The data show that the packed column process is superior to all of the other leading processes in terms of Btu and pyritic sulfur rejection.

The results of a recent study show that the coarsely packed column has significantly improved the throughput capacity, up to three times per unit cell volume of the finely packed column without compromising the fine coal cleaning efficiency [10]. Table 3 presents the test results on Upper Freeport coal with 19 mm packing, including the test conditions. The test performance under this program was evaluated using a Selectivity Index (SI): SI = (Tailings ash/Product ash) x Yield. A higher SI value equals to a better separation and, hence, better performance of the column. The results indicate that a clean coal product containing 5 to 6% ash was obtained, and in one series of tests, Btu recoveries were about 90 to 94%.

Table 2. Round-robin test results for leading fine coal cleaning process

Process[a)]	% Btu Recovery	% Pyritic S Rejection	Efficiency	$/t of SO_2 Removed
	Grind: -325 mesh			
All Mineral	95.9	58.0	54.0	673
B.D. Research	99.4	69.2	68.6	N/A
CAER	97.7	79.7	77.4	308
Deister	94.6	68.9	63.5	383
ISGS	95.6	74.3	70.0	372
VPI	80.3	88.6	68.9	263
MTU Process	**96.6**	**86.1**	**82.6**	**321**

a) CAER = Center for Applied Energy Research;
ISGS = Illinois State Geological Survey;
VPI = Virginia Polytechnic Institute;
MTU = Michigan Technological University (Packed Column).

Table 3. Coarsely Packed Column Test Results on Upper Freeport Coal with 19 mm Packing

Test No.	Feed Flow g/m	Feed Solid %	Fuel Oil kg/t	Pine #2 Oil kg/t	Air Flow l/min	Wash Water l/min	*Pulp Level cm	Froth Height cm	Product %Ash	Product %TS	Product Btu/lb	Performance Yield	Performance BtuRec	Performance TSR	Performance SI
1	140	4.0	0.93	0.93	22.7	0.61	5	223	10.2	1.13	13835	78.5	91.3	30.7	479
2	140	4.0	0.93	0.93	22.7	0.61	0	229	9.4	1.14	13974	77.7	91.3	30.8	522
3	140	4.0	0.93	0.93	17.0	0.61	0	229	8.7	1.10	14095	73.9	87.6	36.5	488
4	140	4.0	0.93	0.93	28.3	0.61	0	229	9.1	1.12	14026	78.6	92.7	31.2	575
5	140	4.0	0.93	0.93	28.3	0.91	0	229	7.8	1.12	14250	76.5	91.6	33.1	644
6	140	4.0	0.93	0.93	28.3	1.21	0	229	6.6	1.08	14458	73.6	89.5	37.9	698
7	140	4.0	0.64	0.64	19.8	0.91	50	180	7.6	1.05	14258	52.2	62.6	57.2	251
8	140	4.0	1.25	1.25	22.7	0.91	-25	253	9.0	1.13	14043	81.5	96.2	28.1	689
9	140	4.0	1.25	1.25	22.7	0.60	-25	253	5.1	1.08	14717	73.8	91.3	37.7	975
10	140	4.0	1.25	1.25	22.7	0.40	-25	253	5.6	1.09	14631	75.9	93.4	35.4	965
11	140	4.0	1.25	1.25	28.3	0.40	-25	253	5.5	1.10	14648	76.8	94.6	34.0	1033
12	200	4.0	0.93	0.93	17.0	0.60	-25	253	6.5	1.11	14475	66.2	80.6	42.6	515
13	200	4.0	0.93	0.93	17.0	0.80	0	229	6.9	1.07	14406	64.7	78.4	45.9	450
14	200	4.0	0.93	0.93	17.0	0.40	0	229	8.4	1.10	14147	70.2	83.5	39.7	435
15	200	4.0	0.93	0.93	22.7	0.40	0	229	9.0	1.15	14043	77.0	90.9	30.8	539
16	200	4.0	1.25	1.25	22.7	0.40	0	229	10.6	1.18	13766	83.9	97.1	22.7	613
17	200	4.0	1.25	1.25	22.7	0.40	-50	277	7.6	1.15	14285	79.4	95.4	28.7	780
18	200	4.0	1.25	1.25	22.7	0.60	-50	277	7.1	1.17	14371	78.9	95.3	27.9	832
19	200	4.0	1.25	1.25	22.7	0.80	-50	277	6.5	1.15	14475	77.2	93.9	30.6	853

Column Size: 10.2 cm ID x 610 cm tall
Head Analysis: 21.4% Ash, 1.28% TS, 11,895 Btu/lb
Feed Size: -35 mesh; Feed Rate: 140 g/min and 200 g/min (~4 g/min/l of cell volume)
BtuRec: Percent Btu Recovery
CMR: Percent Coal Matter Recovery
AshRej: Percent Ash Rejection
TSR: Percent Total Sulfur Rejection
SI: Selectivity Index

*Pulp level referenced to feed inlet position (170 cm from the top)

The results of several series of tests conducted on the Lower Freeport coal are shown in Figure 2. The data indicate the performance of the packed column is equivalent to that of about five stages of conventional batch flotation. This coal is difficult to clean because it is the reject from a fine coal cleaning circuit. The feed coal contains more than 40% ash but still could be cleaned to under 10% product ash in most cases at over 80% Btu recovery.

Additional tests on the same coal was run using different sizes of packing at a fixed feed rate, but with varying dosages of reagents. These data shown in Figure 3 are compared directly to the same column with no packing. More open packings give similar performance. The very obvious advantage of the packing in comparison with that of open or no-packing columns is shown in the data presented.

Unlike any other conventional flotation methods, the packed column flotation is actually a froth separation process since it involves mass transfer that takes place almost exclusively in a froth phase imbedded in the packing elements. Figure 4 shows the effect of froth depth on the selectivity of packed column flotation. The data clearly substantiate the advantages of deep froth bed. Also, scale-up of the packed column is straightforward. This is especially true when the similarity of the unit cell geometry and wall effect within the packing structure in different cross-sectional areas of the separator is maintained. Applications for many other minerals have also been successful. The technical advantages are primarily relied on froth separation effectively preventing fines entrainment.

5. Economic potential of the Packed Column

As with any form of processing, the ultimate criterion of success is economic viability. The major advantage of the packed column over conventional and other columns is its ability to produce higher quality concentrates at equal or better coal yield. A comparison of estimated capital for a 40 TPH clean coal plant and the annualized cost per ton of cleaned coal is shown in Table 4.

It should be noted that the packed column delivers the best quality coal at the least cost. Based on this data, the payback time for a fully installed plant in all three types of plant can be estimated in less than one year.

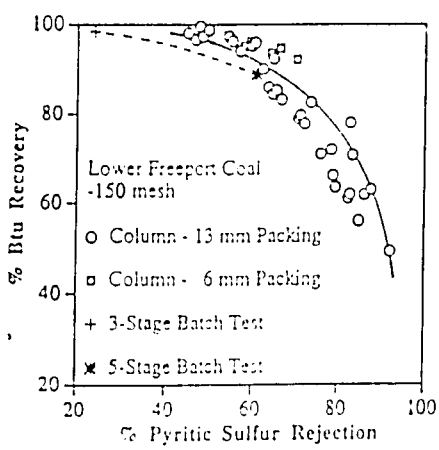

Figure 2 Comparison of Packed Column with Standand Batch Tests.

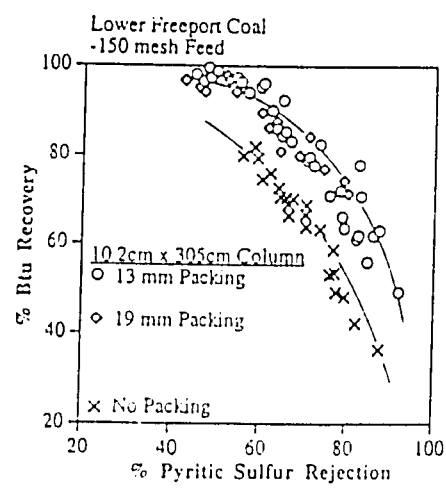

Figure 3. Comparison of Column Performance with and without Packing.

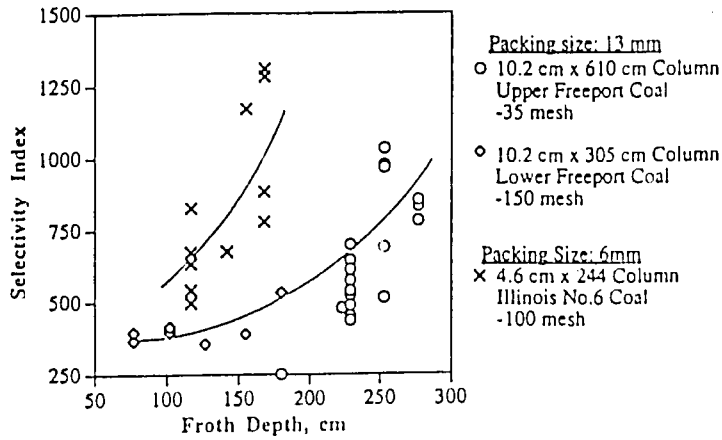

Figure 4. Effect of Froth Depth on Packed Column Flotation Performance.

Table 4. Cost Comparison of Various Flotation Unit Operations to Produce Superclean Coal

Economic Parameters	
Plant capacity	40 TPH
Plant life	20 yrs
Debt	100 %
Interest rate	11 %
Raw coal	12 %ash
	4 %S

Cost Items	Conventional	Column	Packed Column
Stages	3	1	1
Total Capital	680,000	550,000	600,000
HP	250	200	120
Annual Cost, $/yr			
Operation &Maintenance			
Power	77,500	62,000	37,200
Reagents	40,000	14,000	9,700
Supplies	5,000	3,000	1,000
Manpower	250,000	200,000	150,000
Total O&M	372,500	279,000	197,900
Capital Amortization	85,391	69,066	75,345
Total Annual Cost, $/yr	457,891	348,066	273,245
Clean Coal			
%ash	3.60	3.32	2 60
%S	2.00	2.02	1 65
%Btu Rec	95 64	89.02	96 56
%Yield	85 40	78.75	83 70
ton/yr	113,445	104,677	111,187
Cost, $/ton of clean coal			
Flotation	$4.04	$3.33	$2.46
Other Unit Operations	12.24	10.57	9.8
Total Plant Cost	$16.28	$13.90	$12.26

SUMMARY AND CONCLUSIONS

1. Advanced flotation technologies have a significant role in the future of coal utilization.

2. Among several emerging new technologies, packed column flotation has met almost all requirements set by the U.S. Department of Energy for high separating efficiency at acceptable process economics.

3. Packed column can work with both coarse and fine-sized particles and is flexible to produce clean coal of different ash contents over a wide range, thus allowing a plant to control the clean coal quality and meet specifications at an optimal coal recovery level.

4. The packed column is commercially viable and offers the following advantages over an open column: (1) constantly breaking bubbles into fine sizes, thus eliminating the need for a bubble generator, (2) allowing repeated bubble-particle interaction, (3) preventing vertical mixing in the column, and (4) providing extensive froth support.

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SIGNIFIANCE OF RECENT SCI ADVANCES TO FUTURE OF COAL LIQUID MIXTURES

BY

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1. INTRODUCTION

There has been signifiant interest in recent years in development of domestic fuels which could displace those presently imported by certain countries industry . Because of the large quantity of fuel consumed by the electric power generation industry , much of this interest has been focused on fuels to replace oil and gas combusted in existing utility boilers . Many of these efforts have focused on the use of coal as the replacement fuel since it is the world 'most abundant fossile fuel (1).

It has been suggested (2) that concentrated coal-water slurries can be utilized as an economical means for the transportation of coal over long distances or as substitute fuel for oil or coal-oil mixtures for electric power generation .

The growing importance of coal-oil mixtures and coal-water mixtures as alternate fuels to replace oil in industrial boilers and furnaces has been demonstrated in recent years . The symposia on coal slurry combustion and technology have brought together a large number of workers interested in the various methods of preparation and handling of coal-oil mixtures (COM) and coal-water mixtures (CWM) , their rheology and stability , their combustion characteristics and other aspects of this technology (3) .

Since coal is a complicated mixture of carbonaceous and inorganic matters , the physico-chemical properties of each coal must be understood in order to optimize the rheology and the stability of the slurries .

The purpose of this paper was to optimize the preparation conditions of concentrated (>70%) aqueous suspensions of coal that would be stable and fluid enough to replace a conventional fuel in existing systems of transportation , storage and combustion . To do this , it was imperative that two parameters be controlled : the stability and the fluidity of the suspensions . The high percentage (up to 30%) of mineral impurities in the coal may have a considerable effect on the charge and surface potential of the coal particles , and consquently on the stability of the suspensions . The choice of stabilizers and thinners then depends directly on the nature and quantity of these impurities (4) .

2. OPTIMIZATION OF THE SURFACE CHARGE DENSITY AND SURFACE POTENTIAL OF COAL-WATER SUSPENSIONS

To estimate the physico-chemical interactions between dispersed particles and the stability of the suspension , it is necessary to appreciate their surface charge and surface potential (5) .

This electrical double layer displays a fundamental role in the field of colloidal phenomena like , for instance , stability , electrokinetics , micelle formation , elecroadsorption , flottation and polyelectrolyte properties . To estimate the influence of physico-chemical interactions between particles and dispersive medium on stability of suspensions , it is necessary to know surface charge and potential of solids . Of course , these parameters only are not sufficient to represent the both nature and whole of the interactions . Nevertheless , surface charge and potential constitute very important parameters in studying attraction phenomena between solid surfaces . Dispersion stability is characterized by zeta potential measurements of dispersed solid particles (6) .

Unfortunately , there is no exact analytic solution to the Poisson-Boltzmann (P-B) equation for a charged particle . Many numerical solutions have been proposed by Muller and Hoskin by using electronic calculation techniques (7,8) . More recently , Loeb et al. (9) proposed tables giving the surface potential as a function of distance for a variety of electrolytes at different concentrations .

All these theories even they are useful , lack clarity . Indeed , they don not propose simple mathematical functions for the surface potential and charge . In this section , we have gone back to the primitive model of classical P-B equation in the case of spherical particles in assuming the same classical approximations . The ion

is simply treated as a point charge .

The influence of certain physico-chemical parameters such as the ion valence in the case of dissymmetrical electrolytes has never been seriously studied . We proposed in a previous study (10) a more realistic solution of non-linear P-B equation using the spherical coordinates , gave the equations of the electrostatic potential $\Psi(r)$ in the case of 1-1 , 1-2 and 2-1 electrolytes and established the exact expression of the surface charge density σ_0 of a charged shere for different electrolytes 1-2 , 2-1 , 1-3 , 3-1 , 2-3 and 3-2 . This theoretical study allowed us to classify the different electrolytes with decreasing order of charge density :

$$\sigma_0 (2\text{-}3) > \sigma_0 (1\text{-}3) > \sigma_0 (3\text{-}2) > \sigma_0 (1\text{-}2) > \sigma_0 (3\text{-}1) > \sigma_0 (2\text{-}1) > \sigma_0 (1\text{-}1)$$

to obtain more stable suspensions of negatively charged solid particles ir water when preparing it , one must chose electrolytes (1-3) or (2-3) which highly increase the electrostatic repulsion between particles .

These theoretical results were confirmed by experiment in studying the surface charge and potential of the suspensions of coal in water in the presence of different dissymmetrical electrolytes like $Na_2 SO_4$, $Na_5 P_3 O_{10}$, $Ca Cl_2$, $Na_3 PO_4$ and Na Cl . This study showed that electrolytes (1-3) or (2 3) such as $Na_2 SO_4$ or $Na_5 P_3 O_{10}$ which highly increase the surface charge density and the surface potential of the coal particles in water .

Finally , we have showed that the surface potential and charge of coal-water suspension are interdependent .

3.INTERACTION ENERGY BETWEEN PARTICLES OF COAL IN WATER

The most important physical property of colloidal dispersions is the tendency of particles to agglomerate. The encounters betweeen particles in a dispersed medium are frequent as a result of the brownian motion and the stability of the dispersion results from the interaction between particles during these encounters. The principal cause of aggregation is the attractive force of Van der Waals (VDW) between particles while the stability against aggregation is a consequence of the repulsive forces between the double electrical layers of particles of identical charges and also the affinity particle-solvent (11).

The D.L.V.O. (Deryaguin, Landau, Verwey and Overbeek) theory (12 ,13)

only takes into account the interaction between particles having a double electrical layer. This theory is applied in principle to dispersions in aqueous medium and used for an estimation of the relative values of the attractive and repulsive forces .

The interaction energy of VDW is given by:

$$V_A = -\frac{A}{6}\left[\frac{2a^2}{H^2+4aH} + \frac{2a^2}{H+2a^2} + \mathrm{Log}\left[\frac{H^2+4aH}{H+2a^2}\right]\right] \qquad [1]$$

Where A is the Hamaker constant of the sytem, a the radius of the particles and H the separation distance between the particles.

The repulsive electrostaic energy V_E between two particles is equal to:

$$V_E = \pi\,\varepsilon\,a\,\Psi^2\left[\mathrm{Log}\left[\frac{1+\mathrm{Exp}(\kappa H)}{1-\mathrm{Exp}(\kappa H)}\right] + \mathrm{Log}\left[1-\mathrm{Exp}(-2\kappa H)\right]\right] \qquad [2]$$

where Ψ is the electrical potential of the surface,

ε : the permittivity of the medium

κ : the Debye-Hückel constant by the following formula:

k: the constant of Boltzmann and T: the absolute temperature

The total potential energy of interaction V_T between two particles in D.L.V.O. theory is given by:

$$V_T = V_A + V_E \qquad [3]$$

Therefore, V_T depends upon five parameters: a, A, φ, κ and H.

We tried to apply this theory in order to understand the stability of high concentrated coal-water suspensions.

The conclusions of this complete analysis indicate that a stable suspension may be obtained with an ionic strength equal or below 5.10^{-3} mol.dm^{-3}, a surface potential φ higher than |50| mV and a particle radius settled between 1 to 5 µm. A small A value also contributes to a good stabilization.

Experimentally we can act upon the surface potential Ψ (zeta potential) by modifying the pH of the medium, the agitation time of the suspension and the ionic strength κ.

With φ and κ optimised, only the size of the particles a and the constant of

Hamaker can be changed. For economic considerations, we have to grind coal within a range of 0-300 µm . The radius a is therefore fixed by gaussienne distribution within the interval [0;0300] µm . Finally, to modify the constant of Hamaker, we introduce some polymeric dispersants or some polyelectrolytes in the medium. In this case, new repulsive energies appear and overcome the attractive energy of Van der Waals, which will stabilize the suspension by a steric effect .

We would also remind that the surface potential may be increased by using some ionic dispersants like polynaphtalene sulfonates and lignosulfonates which also allow to lower the Hamaker constant.

The study of the evolution of the surface potential for coal suspensions versus the pH with or without an electrolyte has been undertaken by zetametry with the help of a Laser Pen Kem zetameter (model 500), which enables to determine the zeta potential of colloidal particles from measurement of their speed of displacement in an electrical field .

On the other hand, when we often observe a high negative charge of the coal in acid medium. While in this area of pH, the adsorption of protons should rather favour the creation of a positive surface charge . For instance, the zeta potential reach -20 mV at pH values around 3. At this pH, Cl^- ions should be neutralised by H^+ . Otherwise coal particles are still wet with water at this pH, while they normally should be hydrophobic in acid medium since the ionisation of superficial groups (-OH, -COOH, etc...) being very weak .

In fact , the wetting by water is due to the mineral impurities in th ecoal, such as alumino-silicates which set the high nagative surface charge of the coal . This hypothesis has been confirmed by studiyng the influence of the demineralization upon the surface charge and points out, without any doubt, the influence of mineral impurities upon the surface potential of coal . This has led to the interesting result that thinners and stabilizing agents of concentrated clay suspensions, as lignosulfonates, tripolyphosphates, polynaphtalene sulfonates, etc... must also be good thinners and stabilizing agents for ground coal-water.

These findings lead us to study the evolution of zeta potential versus the pH in the presence of TPPNa (sodium tripolyphosphate). It can be observed that the zeta potential increases to reach -75 mV for a TPPNa concentration of 10^{-3} M, hence an excellent stability for the suspension . This result then confirms the theoretical model discussed in section 2 .

This very important result should allow to prepare coal-water suspensions definitely stable in presence of TPPNa and lignosulfonates.

4. STUDY OF A STATIC STABILITY TEST : APPLICATION TO HGHLY CONCENTRATED COAL-WATER SUSPENSIONS

The stability of coal-water concentrated suspensions is of vital importance for bulk transportation , as opposed to pipeline transportation and for storage . It is imperative that a slurry can be produced which will remain in suspension for extended periods of time .

Stability is directly dependent upon the yield stress of the fluid which depends in turn on the reactions between the colloidal fraction of the particle size distribution and the chemistry of the system . A stable slurry , therefore , demands a compromise using a size distribution for maximum packing efficiency but containing a colloidal fraction sufficient to react to the chemistry for acceptable stability (14) .

The stability of the suspension depends on the following factors : the densities of the coal and liquid , viscosity of liquid , the surface properties of coal - its relative hydrophilic nature , its zeta potential and its morphology . At very low concentrations , free settling occurs according to the stokes equation . The concentration of coal increases , the stability becomes a complex phenomenon . There are lots of particle - particle interactions taking place which will hinder settling . The particles may also adhere to each other to form clusters (flocs or coagula) . Depending on the state in the suspension , the suspension can be broadly classified into three types : Aggregatively stable suspension , flocculated suspension and coagulated suspension in which the sediment formed might be compact and difficult to break (15) .

Another popular method of measuring stability in glass containers is a rod penetration test . A glass container filled with slurry is allowed to stand for a period of time , after which a glass rod of specific weight and diameter is dropped into the slurry and allowed to penetrate through it . The time it takes for the rod to travel from the surface of the slurry to the bottom of the container is measured : the shorter the time of travel the more stable the system (16) .

We intend in this section to compare between two techniques used to obtain information both on the stability and the fluidity of highly concentrated coal in water slurries : the techniques are penetrometry and viscosimetry .

Penetrometry technique consists in the dropping, with no initial speed, of a glass rod with known dimensions (length L and diameter d) into the suspension , installed in a graduated test-tube.The rod is submitted to its weight P (gravity) and the viscous forces f of the suspension. The fundamental principle of dynamics gives the equation :

$$m \frac{\overrightarrow{dv}}{dt} = \vec{f} + \vec{P} + \overrightarrow{F_A} \qquad [4]$$

Now , equation 4 can be written:

$$m \frac{dv}{dt} + \frac{C_r s \rho}{2} v^2 = mg - V_x \rho g \qquad [5]$$

where x is the displacement of the rod , and g the gravitational acceleration . $V_x = s\,x = m(t)/\rho_S$ (the volume of the rod sunken into the suspension). ρ_S and ρ are the volumic masses of the glass and the suspension respectively , m (t) is the buoyancy of the sunken part of the rod at time t , v the instantaneous speed of the rod , s the rod section area and C_r the viscous resistance coefficient .

Solution of equation 5 is generally very complicated , however , if we use the experimental data , we obtain :

$$v = \frac{dx}{dt} = \frac{418.342}{C_r} \sqrt{1 + C_r - \frac{C_r}{89.2} x} \qquad [6]$$

x is expressed in cm and v in cm/s .

By integration , we obtain x(t) and v(t) as a function of time t :

$$x(t) = \frac{89.2}{C_r} \left[4.690 \sqrt{1 + C_r}\, t - 5.499\, t^2 \right] \qquad [7]$$

$$v(t) = \left[\frac{418.342}{C_r} \sqrt{1 + C_r} - \frac{981}{C_r} t \right] \qquad [8]$$

The viscous forces are highly dependent on C_r and decrease as a function of the time t . The limiting speed v_l of the rod decreases as a function of the resistance coefficient C_r . This last parameter can be related to the viscosity η (called

theoretical viscosity) of the suspension by a semi-empiric relationship :

$$\eta = \frac{1}{24}\frac{C_r}{1000}\rho\, v_l d \qquad [9]$$

Information on the stability of these suspensions was obtained by using the previously described penetrometry technique . A suspension is considered to be "stable" and its stability equal to S days, if the rod entirely penetrates in less than 6 minutes after a settling of S days .

Certain rheological properties of the suspensions for instance the limiting speed v_l , the resistance coefficient C_r and the viscosity η were obtained (Table 1) by applying the theory previously developed .

Table 1.

Values of limiting speed , resistance coefficient , theoretical and experimental viscosities as a function of settling time

Settling time(day)	limiting speed v_l (cm/s)	C_r	theoretical viscosity η(cp)	experimental viscosity η(cp)
20	0.200	4.4×10^6	1800	1950
40	0.083	2.5×10^7	4300	4500
60	0.067	3.9×10^7	5400	5500
80	0.025	2.8×10^8	14000	not measurable
90	0.013	9.8×10^8	27000	not measurable

There is a good correlation between calculations and experimental data . It can be observed that in order to obtain a fluid suspension , the resistance coefficient C_r must be lower than 10^7 and the limiting speed v_l higher than 0.1 m/s . The uncertainty between calculated and measured viscosities is less than 10% .

This study reveals the importance of the resistance coefficient C_r that can

be used as a criterion for the evaluation of CWM stability and fluidity .

The "fluidity" of the suspensions is only obtained after addition of stabilizers and dispersing agents . It was measured by determining the viscosity of the suspensions (containing 75% solids) with a Rotovisco RV3 viscosimeter made by Haake . The testing of the slurries was accomplished by steadily increasing the shear rate to which the sample was subjected from zero to approximately 300 s^{-1}, steadily decreasing γ back to zero , and then repeating the cycle . Experimental viscosity of the CWM was determined at 100 s^{-1} from the initial and equilibrium flow curves .Results obtained show that there is a good correlation between viscosity of our concentrated suspensions measured by penetrometry technique and that obtained by a viscosimeter (Rotovisco MV II) .

5. CONCLUSION : PREPARATION OF CONCENTRATED , STABLE AND FLUID SUSPENSIONS

According to the above findir.gs , we were able to affirm that the thinners and stabilizers of concentrated clay (aluminosilicates) . such as the lignosulfonates and polyphosphates used as thinners in drilling muds , should also be good thinners and stabilizers in suspensions of ground coal in water since the surface charge depends on the silicate content . Following this hypothesis , we admit that the stability is due to the electrical repulsion of the charged particles . If the charge on the particles is high (zeta potential > 60 mV) , the particles repel each other and the suspension is stable . If the zeta potential is less than ±20 mV , the Brownian movement of the particles promotes their hitting and attaching to each other , and there will be lumping and flocculation (DLVO theory) .

Intensive research has been undertaken over the past decade in the analysis and production of coal suspensions in oil and in water . This research is generally described in the form of patents . But the effect of the surface charge and of various additives on the charge is never approached systematically .

This investigation allowed us to analyze systematically the variation of the zeta potential as well as charge , as a function of pH , in the presence of the different dispersants and additives at different concentrations .

Concentrated coal suspensions (about 75% of solid by weight) were prepared in water by using different additives , for instance sodium tripolyphosphate (NaTPP) and surfactants like the Surfaron (S1520N100 : sodium polynaphtalene

methane sulfonate) and lignosulfonates (by coupling of the dispersion and stabilizing effects) with the optimum concentrations of these two products .

The results of the penetrometry technique also reveal that the concentration ratio C_{NaTPP} / $C_{lignosulfonate}$ must be higher than 2 in order to get fluid and stable concentrated suspensions (75 % in coal) . The stability of the suspensions was then greater than two months , but with a viscosity of 1900 cp .

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LOW GRADE COAL UPGRADING: APPLICATION OF LIQUIDS FROM COAL (*LFC*) TECHNOLOGY TO LOW GRADE COALS IN THE PACIFIC RIM

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INTRODUCTION

In an earlier paper [1] the economic incentives for upgrading low-rank subbituminous coals from the Powder River Basin in the Western United States, using the mild gasification **Liquids From Coal** (*LFC*) Process, were discussed. Four incentives are identified:

1) two value added co-products a clean, high heating value solid, referred to as **process-derived fuel** (*PDF*) and a fungible petroleum substitute, referred to as **coal-derived liquid** (*CDL*);

2) a reduction in the relative cost of transporting these value-added co-products to market, as the result of removing most of the moisture and a substantial portion of the volatile matter;

3) added incentive provided by amendments to the Clean Air Act that encourage coal-fired electric generation fuel switching to low-sulfur Western U.S. coals; and

4) favorable tax treatment, in the form of tax credits, for the co-products from these *LFC* Clean Coal Refineries.

These economic incentives have led to the demonstration of the mild gasification *LFC* technology at a plant located in Gillette, Wyoming, capable of processing up to 1000 short tons per day of Buckskin Mine subbituminous coal. This Demonstration Plant (see Figure 1) is owned and operated by ENCOAL Corporation[1], a subsidiary of Zeigler Coal Holding Company. The construction and first two years of operation of the ENCOAL Demonstration Plant ($72 million) has been and continues to be co-funded by the U.S. Department of Energy's Clean Coal Technology Program. Construction began in the fall of 1990 and was completed in the summer of 1992. The plant continues to meet its objectives of demonstrating the technology at near-commercial capacity and of providing *PDF* and *CDL* for market evaluation and acceptance [2,3].

During the period of ENCOAL Demonstration Plant construction and initial operation, SGI International as the technology licensing contractor for the TEK-KOL Partnership has been testing low-rank coals from the United States and around the world, in an effort to identify other significant economic opportunities for upgrading subbituminous and lignite coals. One of the most compelling opportunities is that represented by East Asia and the Pacific Rim, in part because of some parallels with the Powder River Basin situation, but also because of regional characteristics that provide added inducement.

1 The ENCOAL plant has a license for the use of the *LFC* technology from the TEK-KOL Partnership, jointly owned by SGI International and SMC Mining Company. The latter is another unit of Zeigler Coal Holding Company that also owns and operates the Buckskin Mine. SMC Mining Company was formerly owned by the Shell Mining Company, which sold their interests in the TEK-KOL Partnership, the ENCOAL Demonstration Plant, and the Buckskin Mine to Zeigler in late 1992.

Two characteristics of the steaming coal trade in the Pacific Rim that are similar to those of the Powder River Basin have been identified:

- The significant geographic distances between steam coal suppliers in the Powder River Basin (steaming coal exporters in the Pacific Rim) and the utility users in the mid-western United States (the steaming coal importers in Japan, Taiwan, South Korea, Hong Kong, and elsewhere) cause transportation costs to be a determining factor in market share and provide an incentive for upgrading; and

- The growing concern over environmental issues facilitate an increasing reliance on Clean Coal Technologies, especially those such as *LFC* Clean Coal Refineries with their value-added co-products.

Additional incentives are provided by three unique characteristics of the Pacific Rim marketplace:

- The excess of steaming coal supply over demand, with the resulting downward pressure on coal prices provides incentive for marginal producers of low-rank coal to upgrade their resource into products deemed more valuable by the marketplace;

- The high growth rates in East Asia, especially for the developing nations, some of which are dependent on the export of natural resources (e.g., coal and oil) to provide currency exchange to finance internal growth provides incentives for more efficient use of their natural resources for both domestic application and exports is needed; and

- The heavy reliance on imported oil from a politically unstable Middle East, or dwindling domestic reserves of oil in some cases, leads to favorable consideration of the other *LFC* co-product, the *CDL*.

These five factors make the Pacific Rim a geographic region with long-term business opportunities for the application of Clean Coal Refineries using the *LFC* technology. In order to address these opportunities, and to maximize the market potential, SGI has developed a comprehensive business strategy for its operations in the Pacific Rim. This strategy consists of four parts:

1. Test a wide variety of low-rank subbituminous and lignite coals from locations such as Alaska, Australia, China, Indonesia, the Philippines, and Thailand, to determine the technical feasibility of *LFC* processing of these coals;

2. For those low-rank coals that can be shown to represent technically-feasible applications of *LFC* processing, evaluate the *PDF* and *CDL* co-products for yield quantities and market acceptance;

3. Carry out engineering studies, in conjunction with qualified mechanical equipment suppliers and engineering/construction companies, to determine firm construction and operating costs; and

4. Work with potential project owners (i.e., licensees) or joint venture partners to obtain institutional and commercial financing to supplement equity participation, emphasizing the role to be played by one or both of the plant co-products in the export markets.

In the remainder of this paper, emphasis is placed on the first two parts of this strategy, with the country of Indonesia used as an example. Results obtained from testing some thirteen different Indonesian coals from the two primary coal-producing regions of that country South Sumatra and Kalimantan are described. Finally, a hypothetical example of an *LFC* Clean Coal Refinery complex in Indonesia, with both the *PDF* and *CDL* co-products aimed at export markets, is used for illustration.

LFC COAL EVALUATION PROCEDURES

The technical feasibility of *LFC* processing for any particular subbituminous or lignite coal is determined by state-of-the-art testing at the SGI Development Center in Perrysburg, Ohio, and by analytical evaluation of the test results at SGI and Anatech offices in California. Both the test methods and analytical techniques are outgrowths of SGI's research and development programs extending back to the early 1980's. The computer simulations of *LFC* processing were based on adaption of the Sandia National Laboratories MARIAH finite element code [4] capable of calculating the gas velocity and temperature profiles for convective heating and cooling of a porous coal bed. The coal testing program began with bench-scale tests at Davy-McKee Laboratories in Cleveland, Ohio (1981-82), followed by tests in a Process Test Unit at Midland-Ross in Toledo, Ohio (1983-85), and tests in a Process Development Unit at Salem Furnace Company in Carnegie, Pennsylvania (1986-88). The size of these tests scaled from 2 kg batches at bench scale to almost 100 kg per hour for the Process Development Unit operating in a semi-continuous mode. Although these tests varied in cross-sectional area, in all cases the vertical (or coal bed thickness) dimension was represented in full scale. Therefore, since coal particle sizes and convective gas composition are also identical to those in full-scale applications, the areal gas flow rates, pressure drops and temperature profiles replicate those in actual practice.

The SGI Development Center was formed in 1991, and is operated for SGI by Maumee Research & Engineering. Here, the technical feasibility of *LFC* processing is examined through the use of standardized thermogravimetric analysis (TGA) testing to determine accurately the moisture, volatile matter, fixed carbon and ash in the coal. Heating value is also measured in order to complete the proximate analysis. Then, the TGA is coupled to a Fourier Transform Infrared (*FTIR*) spectrometer, in order to measure the gaseous constituents leaving the coal during standardized drying and mild pyrolysis heating profiles. In addition to the weight loss data, a small quantity of char is produced that can be used to estimate an *LFC* processing mass balance. Outside laboratory proximate and ultimate analysis supplement the estimates. These estimated mass balances are not intended to be representative of optimal *LFC* processing, but merely to confirm technical feasibility.

When technical feasibility has been established, larger quantities (500 kg) of the coal are processed in the Sample Production Unit, which operates in a semi-continuous mode. The unit consists of a heater module, a reactor module, and a sample collection module (see Figure 2). The heater module controls the composition of the convective heating gas, its flow rate, and its entering temperature. Drying and mild devolatilization take place in the well-instrumented reactor module, while the sample cooling and collection takes place in the char cooler and Electrostatic Precipitators for the solid and liquid, respectively. Data from the thermocouples and other instruments are recorded in an on-line computer archival and control system. The unit is capable of considerable variation in processing conditions, so that co-products from semi-optimal processing can be obtained. The Sample Production Unit can produce about 4 kg of *PDF* and 1 liter of *CDL* per hour of operation. These quantities are sufficient to permit an early assessment of market acceptance for the co-products.

In addition to co-product yield estimates and preliminary market acceptance, the test data are used to calibrate the *LFC* simulations for plant control system adaptation. These simulations provide a key element in the optimization of co-product quality and quantities. Accurate simulation and control of the *LFC* process requires experimentally verified methodologies, and the models developed at SGI are constructed and verified with data from the Development Center and Demonstration Plant. Production of *CDL* and non-condensible gases (used for supplying the process heat required by the *LFC* process) results from volatile matter removal during the mild gasification step in the *LFC* process. The *TGA/FTIR* experiments provide accurate characteristic data of the candidate coal for constructing robust, empirically calibrated, volatile matter removal kinetics models. The Sample Production Unit experiments provide accurate data of the heat transfer and process time characteristics of an *LFC* plant system for constructing robust plant simulation models. The control system uses these kinetics and plant simulation models in real time analyses to predict *CDL* and *PDF* co-product qualities resulting from current plant conditions and to recommend new process conditions to maintain specified product quality and production levels.

SCOPE OF LFC TESTING PROGRAM

SGI's early coal testing programs emphasized Montana Rosebud, Alaska Usibelli, and Australia (Victoria) Loy Yang coals, primarily because of their potential application to cogeneration projects in the United States and coal-fired electric power projects in Australia. Attention shifted in the late 1980's to stand-alone *LFC* projects in the Powder River Basin of Wyoming, and most of the Process Development Unit test results were based on subbituminous coal from the Buckskin Mine, the site of the ENCOAL Demonstration Plant. In more recent years, the test program has been expanded to include Sample Production Unit testing of Wyoming Buckskin, Alaska Usibelli, North Dakota Knife River, and Montana Sarpy Creek (Absaloka) coals, in order to provide samples of *PDF* and *CDL* for evaluation by outside laboratories under contract to the U.S. Department of Energy. At the same time, SGI has expanded its technical feasibility test program to include a large number of coals from various countries around the Pacific Rim, in accordance with its overall business strategy.

Low-rank coals from Thailand, the Philippines, China and Indonesia have been tested at the Development Center. The Chinese program includes coals from three different provinces Shanxi, Liaoning and Shandong and may be expanded to include Inner Mongolia, Hebei and other provinces with low-rank coal reserves. However, the Indonesian coal testing program, with thirteen different coals tested to date, is the most extensive, and will be used as the prototypical example of SGI's Pacific Rim business strategy.

INDONESIA - THE PACIFIC RIM PROTOTYPE

Indonesia, although not the major steaming coal exporter nor the major coal user in the region (Australia, with some 60 million tonnes of steaming coal export, and China, with some 1.1 billion tonnes of production, respectively, have these distinctions), plays an increasingly pivotal role in the Pacific Rim steaming coal trade. Several important factors combine to emphasize this importance and lead to Indonesia becoming a major coal exporter:

- Large coal reserves - enough for several hundred years of production.
- Largest percentage increase in electrical power demand in Asia.
- Rapidly expanding coal production capacity - exceeding growth of internal demand.
- Close proximity to key Asian markets.

The Indonesian coal reserves are estimated at 37 billion tonnes, as shown in Table 1. [5] Note that approximately 58% of the measured coal reserves are located in Sumatra and 32% are located in Kalimantan.

Indonesia also has the fastest growth rate of electricity consumption in Asia, averaging approximately 15 percent per year over the last decade. This rapid upsurge in demand is a result of higher than expected growth in manufacturing. In fact, the growth in the demand for electricity coupled with more rapidly diminishing petroleum and natural gas supplies will result in coal providing the largest single source of energy in Indonesia by 2021 (See Table 2). The forecasted coal demand through the year 2008 is shown in Table 3.

In 1990, Indonesia had an electric power generation capacity of 8900 MW, of which 1730 MW was coal fired. Perusahaan Umum Listrik Negara (PLN), the Indonesian state utility, plans to add some 2330 MW of new electrical generating capacity, with eight new coal-fired power plants to be built by the end of 1996.

The Indonesian government encourages the use of coal in the power and cement industries in order to diversify demand, thereby releasing oil and natural gas for export. Coal use in the power sector is expected to increase from the current 4.5 million tonnes to 11.5 million tonnes by 1995. After 1995, almost all additional generation will come from coal, with twenty-five new coal-fired power plants scheduled for construction and operation, thereby increasing domestic coal use to almost 30 million tonnes by the year 2004.

Indonesian coal output expanded rapidly from 400 thousand tonnes in 1981 to 10 million tonnes in 1990. Production is expected to reach 25 to 28 million tonnes annually by 1995 and 40 to 50 million tonnes annually by the year 2000. Despite this growth in production, Indonesia's coal reserves are predicted to last for several hundred years. This is considerably longer than the expected lifetime of its gas and oil resources. Furthermore, the growth in production will greatly exceed the growth in internal demand leading to a significant export potential (See Table 4).

Another key aspect of the Indonesian market is its relative proximity to the very large steaming coal markets of Japan, Hong Kong and Taiwan. The southern provinces of China may even become a net importer of steaming coal if the transportation infrastructure problems cannot be resolved within China. All these factors provide the ingredients for opportunities to apply Clean Coal Refineries, which produce both a petroleum substitute and an upgraded, clean coal product from the abundant low-rank coal. Figure 3 shows the principal coal export routes of the world and demonstrates how Indonesia is ideally located to capitalize on the growing need for coal in Asia. Coal is definitely not an energy source of the past, but one for which demand is recognized to be growing internationally. Such growth is absolutely essential - especially in the developing countries of the Pacific Rim - for sustainable growth. Pacific Rim coal demand is expected to rise sharply, primarily for power generation. It is forecast that coal demand in China will rise from 1.1 billion tons a year to 1.5 billion tons a year by 2000, that demand in Korea, Hong Kong and Taiwan will increase from 80 million tons to 120 million tons in 2000, and that demand in the

Southeast Asian nations (including Indonesia, Thailand and the Philippines) will increase from 30 million tons to 90 million tons in 2000. Japan's coal imports are expected to increase from 110 million tons a year to 140 million tons in the year 2000. Figure 4 reflects these trends.

INDONESIAN COAL EVALUATION RESULTS

Using Indonesia as a prototypic example of its Pacific Rim business strategy, SGI has evaluated thirteen different coals from two of the primary coal-producing regions of the country Sumatra and East Kalimantan. Eleven of these coals are from mines or potential mines in the Tanjung Enim district of South Sumatra; the other two are from a potential mine site in the Musi Rawas district of South Sumatra and from the Berau district of East Kalimantan, respectively. Each of the testing programs has a slightly different objective.

Some of the mines in the Tanjung Enim district are operated by the state-owned coal mining company, P. T. Tambang Batubara Bukit Asam (PT TBBA) expressly to supply fuel for the large (1600 MWe) Suralaya power plant complex on the west coast of Java, a power station that is scheduled to expand to 3400 MWe in the next few years. Currently, some 5 million tonnes per year of relatively high-rank subbituminous coal from the Airlaya Mine, supplemented by small amounts of lower-rank subbituminous coal from adjacent Tanjung Enim mines, provide the fuel for the Suralaya station. As the fuel requirement at Suralaya increases to 23 million tonnes per year, the 5300 Kcal/kg (9540 Btu/lb) heating value lower limit will be increasingly difficult to meet without exhausting the Airlaya resources prematurely. Upgrading the lower-rank coals from the adjacent Muara Tiga Besar, Banko, Kungkilan, and Arahan sites would permit both blending of PDF in the interim and eventual firing entirely with PDF in the long term, as sufficient number of Clean Coal Refineries are built.

The other aim, for both the Musi Rawas and Berau projects, is to upgrade the low-rank coals and enhance their characteristics and marketability to the steaming coal markets of East Asia. The Berau Lati mine, in particular, is operated under a Coal Concession Contract (CCC) between PT TBBA and the operator, P. T. Berau, a joint venture between the Japanese trading company Nissho Iwai (40%) and the Indonesian company P. T. United Tractor (60%). The output from the Berau Lati mine, scheduled to be a few hundred thousand tonnes in 1994, is expected to increase to possibly 5 million tonnes per year. *LFC* upgrading will improve the coal characteristics and help the project to achieve its production goals.

The Musi Rawas project, on the other hand, is an Indonesian private mine development activity, under the auspices of P. T. Triaryani. Some one billion tonnes of relatively low-rank subbituminous coal are available at the site, and two potential markets for the out put are being evaluated:

(1) independent power production at or near the mine, with the electric power generation units burning either the existing low-rank coal or upgraded PDF, and the electricity sold to PLN; and

(2) upgrading the coal in *LFC* Clean Coal Refineries and transporting the PDF, by barge and ship, for sale to the Suralaya power station or to other Pacific Rim steaming coal users.

Combinations of the two are also under consideration.

Independent power production, through joint ventures between PT TBBA and private Indonesian or foreign companies, is also an option for the thermal efficiency, and *LFC* Clean Coal Refinery co-product added value, especially for the CDL, will dictate whether raw coal or PDF will be used as the boiler fuel.

In order to determine the technical feasibility of upgrading these low-rank Indonesian coals in an *LFC* Clean Coal Refinery, TGA/FTIR test results, proximate and ultimate analyses by an outside laboratory, and engineering evaluations were used to establish approximate *LFC* process mass balances. Table 5 presents the results of the testing and evaluation effort for the thirteen coals, with a rating based on the estimated CDL yield in kg per tonne of feed coal. As can be seen from the table, at least nine of the coals are rated good to excellent candidates for *LFC* processing. Similarly, the *PDF* co-product can be seen in Table 6 to be significantly improved from the run-of-mine (ROM) coal. The value added by *LFC* processing makes the co-products from these low-rank coals ideal candidates for exporting to the very selective power utilities in Japan, Taiwan and Hong Kong.

LFC CLEAN COAL REFINERY ECONOMICS

The opportunity represented by an *LFC* Clean Coal Refinery complex located in either South Sumatra or Kalimantan can be illustrated by the following example: Four 5,000 tonne per day *LFC* modules are assumed to be located at or near an operating open-cast, subbituminous or lignite coal mine. The coal from the mine has been shown by laboratory testing to be a technically-feasible candidate for *LFC* processing, similar to the findings shown in Tables 5 and 6. Further evaluation of *PDF* and *CDL* obtained from Sample Production Unit (*SPU*) processing at the SGI Development Center, or possibly from processing larger quantities of coal at the *LFC* Demonstration Plant, has shown that the co-products are acceptable in the export marketplace at adequate prices. Staged construction, start-up, and operation of the four modules has confirmed plant cost estimates of approximately $75 per tonne-year (or about $465 million for 6,200,000 tonnes per year of throughput). The *LFC* Demonstration Plant and the staged, modular construction and operation have also enabled plant personnel the opportunity to become trained and familiar with the sophisticated systems that control plant operation.

The Clean Coal Refinery complex, assumed to operate throughout the year at an 85% capacity factor (e.g., 310 days per year at 100% capacity), would produce about 3.5 million tonnes of *PDF* and about 4.2 million barrels of *CDL* for sale each year. If the feed coal price is of the order of $10-12, feedstock costs will be between $60 and $75 million; the revenue from the complex will be on the order of $165 to $195 million per year, including some $65 to $70 million from the *CDL* alone (assuming $14 to $18 oil price per barrel). Estimates for the revenue from the *PDF* will depend on the market value associated with this clean, reactive, high-heating value solid fuel. Conservative estimates of $30 per tonne would yield about $105 million, while $35 per tonne would give over $120 million.

The complex will generate almost all of its energy for drying and mild pyrolysis from combustion of the third co-product, a low-heating-value, non-condensible gas; Electric power requirements will be met by on-site generation, using combustion of coal fines, with some excess power available for export to the Indonesian national grid or to a local user. As a result of these efficiencies, and because of semi-automatic plant control, operating costs will be very low (less than $20 million) and the net revenues from the plant complex would be in the $80 to $100 million range, depending on the payments for any exported electricity. Such an economic opportunity would be very attractive.

Another approach for examining the economic benefits of *LFC* processing, without dealing with any uncertainties in plant construction and operating costs, is based on the increased value of processing an existing asset in this case, subbituminous or lignite coal reserves. Suppose that the existing asset is defined by 300,000,000 tonnes of coal reserves, sufficient for 50 years of production at an annual rate of 6 million tonnes. Suppose that this asset has a current value that is approximately equal to the fixed cost of developing the mine plus variable production and handling costs needed to place the coal in a position for export. If this value is $18 per tonne, the asset has a total value of $5.4 billion. Also, suppose that low quality of the coal and uncertainties with respect to any profit margins permitted by the marketplace prevent the asset from being exploited.

If this low-rank coal is upgraded into two value-added co-products by *LFC* processing, the schematic shown in Figure 5 would apply, based on *PDF* and *CDL* yields for many of the Indonesian coals tested by SGI. In this case, for every two tonnes of coal from this mine processed in an *LFC* plant, about 1.13 tonnes of *PDF* and 1.35 barrels of *CDL* are produced. Both of these co-products will command premium prices in the marketplace because of their desirable characteristics. Because of the added value to the co-products through *LFC* processing, the asset value essentially doubles, to approximately $10 billion. The cost of plant construction and operation to realize this asset value is only approximately 10% of the increase. Again, the economic opportunity offered by upgrading the coal reserve is extremely attractive.

1. Nickell, R. E., "Refining the Art of Coal Upgrading", WORLD COAL Magazine, October, 1993.

2. Frederick, J. P., "Current Status of Design and Construction of ENCOAL Mild Gasification Plant", International Power Generation Conference, October 6-10, 1991, San Diego, California.

3. McCord, T. G., Frederick, J. P., and Farmayan, W. F., "The ENCOAL Project: Status of the Plant and Product Testing", 17th Low-Rank Fuels Symposium, September, 1992, Atlanta, Georgia.

4. Gartling, D.R. and Hickox, C.E. "MARIAH - A Finite Element Computer Program for Incompressible Porous Flow Problems," Report No. SAND-79-1623, Sandia National Laboratories, Albuquerque, NM, August 1980.

Table 1

Indonesian Coal Reserves

Billion Tonnes

	Measured	Probable/ Possible	Hypothetical	Total
Sumatra	2.86	13.41	8.34	24.62
Kalimantan	1.99	5.28	4.23	11.50
Java	0.012	0.029	0.02	0.061
Sulawesi	0.005	0.019	-	0.024
Irian Jaya	-	0.083	-	0.083
Total	**4.87**	**18.82**	**12.59**	**36.29**

Source: Directorate of Coal, May 1993

Table 2

Primary Energy Supply for Uses in Indonesia

10^{15} Joule

	1991		2001		2011		2021	
Oil	1,292	(38.7%)	1,671	(29.4%)	2,335	(25.2%)	4,720	(28.7%)
Natural Gas	711	(21.3%)	1,566	(27.5%)	2,300	(24.8%)	2,977	(18.1%)
Coal and Cokes	194	(5.8%)	790	(13.9%)	2,660	(28.7%)	6,521	(39.6%)
Geothermal & Hydro	142	(4.2%)	419	(7.4%)	544	(5.9%)	535	(3.2%)
Biomass	1,003	(30.0%)	1,239	(21.8%)	1,437	(15.5%)	1,712	(10.4%)
Total	3,342	(100.0%)	5,685	(100.0%)	9,276	(100.0%)	16,465	(100.0%)

Source: BPPT - KFA Studi Markal, 1992

Table 3

Forecasted Coal Demand of Indonesia

Million Tonnes

Users	Year			
	1993	1998/1999	2003/2004	2008/2009
I. Domestic				
1. Power Plant	5.5	28.4	58.6	68.3
2. Cement Industry	3.0	5.5	7.5	9.0
3. Metallurgy	0.5	1.5	2.0	2.5
4. Small Industry	0.5	2.7	6.9	9.4
5. Households	0.5	4.8	13.3	17.7
II. Export	15.0	30.0	45.0	50.0
Total Demand	25.0	72.9	133.3	156.9

Source: State Electricity Co. (PLN), 1992
Directorate of Coal, 1993

Table 4

Indonesian Coal Production & Consumption Predicted (1994-1999)

Million Tonnes

	1994 /95	1995 /96	1996 /97	1997 /98	1998 /99
1. Production	35.20	44.00	52.00	60.00	71.00
• State Owned Coy. (PTBA)	8.50	9.20	10.00	10.85	11.60
• Contractors	24.50	32.30	39.50	46.45	56.20
• Private Nat. Coy.	2.20	2.50	2.50	2.70	3.20
2. Consumption	12.91	16.24	22.36	26.08	31.72
• Electricity	7.21	8.44	11.66	13.88	17.52
• Cement Industry	3.50	4.00	4.30	4.50	4.60
• Metallurgy and Small Ind.	1.20	1.80	3.20	3.70	4.30
• Households	1.00	2.00	3.20	4.00	4.80
3. Export	22.29	27.76	29.64	33.92	39.28

Source: Directorate of Coal, July, 1993
PLN, August, 1993

Table 5

Indonesian Coals Tested

	CDL Yield (kg/tonne)	
Tanjung Enim District (South Sumatra)		
• Air Laya**	155	
• Banjasari**	145	
• Kungkilan, Seam B**	140	
• Kungkilan**	115	
• Muara Tiga Besar Timur**	100	
• South Arahan, Seam B*	100	Wyoming Buckskin Baseline
• North West Banko*	80	
• Kungkilan, Seam A2	60	
• South Arahan, Seam A2	45	
• Muara Tiga Besar Barat (Very High Moisture)	<40	
• Pendopo (Very High Moisture)	<40	
Musi Rawas District (South Sumatra)		
• Sungaimalam*	80	
East Kalimantan		
• P.T. Berau*	95	

** Excellent LFC Candidate
* Good LFC Candidate (Wyoming Buckskin CDL Yield is about 90kg/tonne)

Table 6

PDF Quality Profile

	Powder River Basin		Berau Lati Kalimantan		Air Laya Sumatra	
	ROM	PDF	ROM	PDF	ROM	PDF
HHV AR,kcal/kg	4500	6700	5100	7100	5600	7300
SO_2,LB/MM BTU	1.2	0.8	1.18	0.72	0.48	0.39
H_2O, %wt	30	4	24	5	24	5
ASH, %wt	5	10	3	2	3	5
VOLATILES, %wt	29	19*	33	20*	32	18*
FIXED CARBON, %wt	36	67	40	74	41	77
SULFUR, %wt	0.40	0.44	0.60	0.47	0.24	0.27

* *Variable, Controllable by Process*

Source: SGI Data

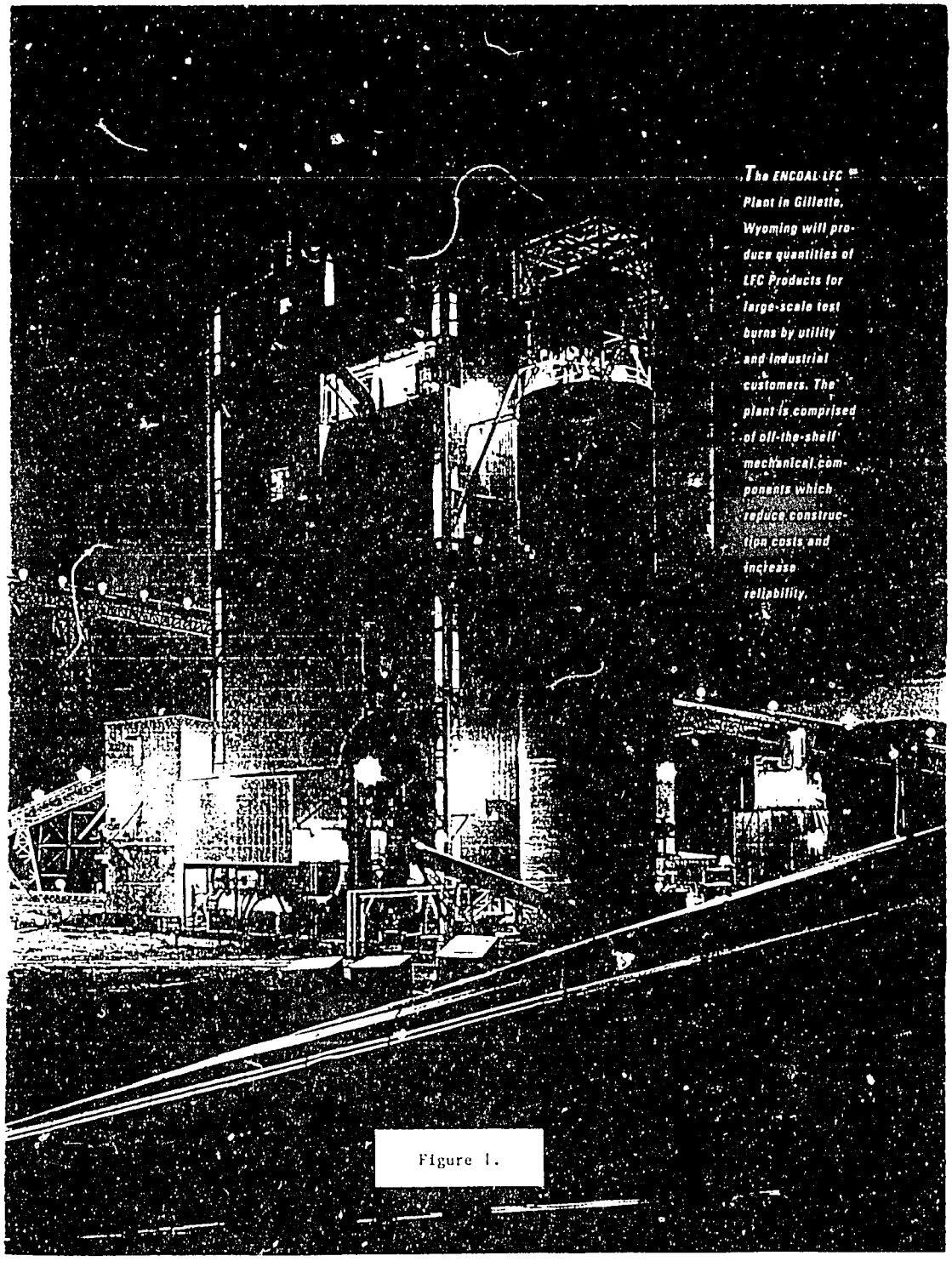
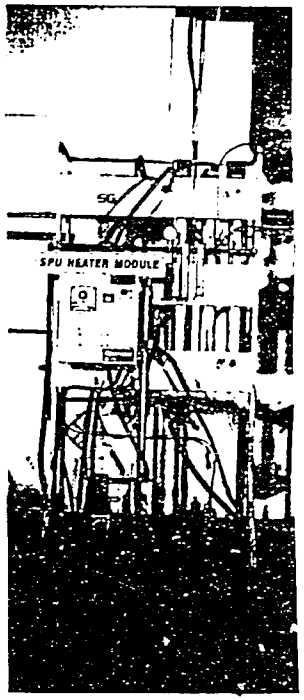
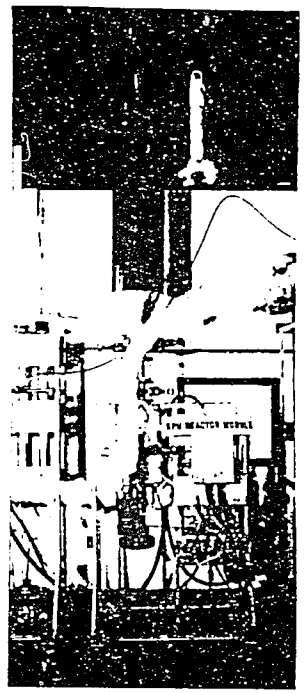

The ENCOAL LFC Plant in Gillette, Wyoming will produce quantities of LFC Products for large-scale test burns by utility and industrial customers. The plant is comprised of off-the-shelf mechanical components which reduce construction costs and increase reliability.

Figure 1.

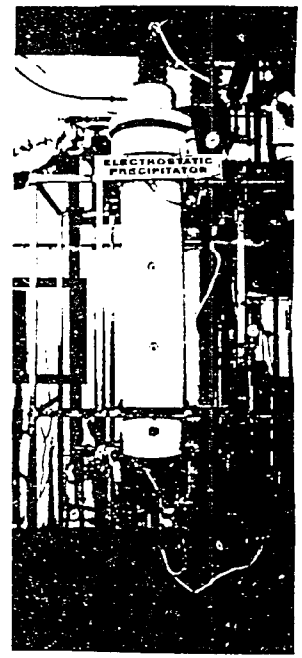
Three Modules Comprise SPU



SPU Heater Module



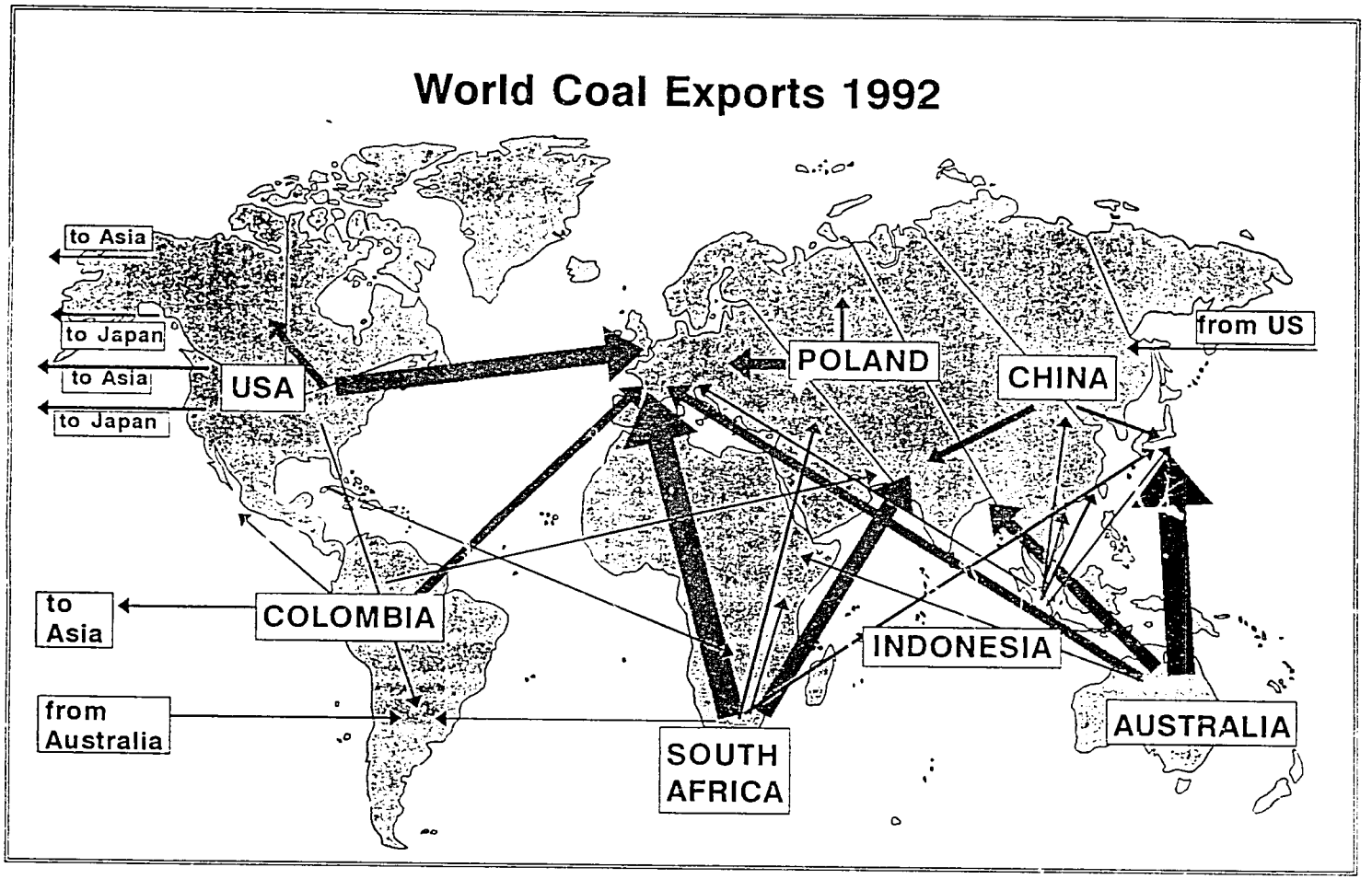
SPU Reactor Module



ESP Module

Figure 2.

Figure 3



Source: World Coal, October, 1992
Indonesia data from "1993 Coal Manual"

Figure 4

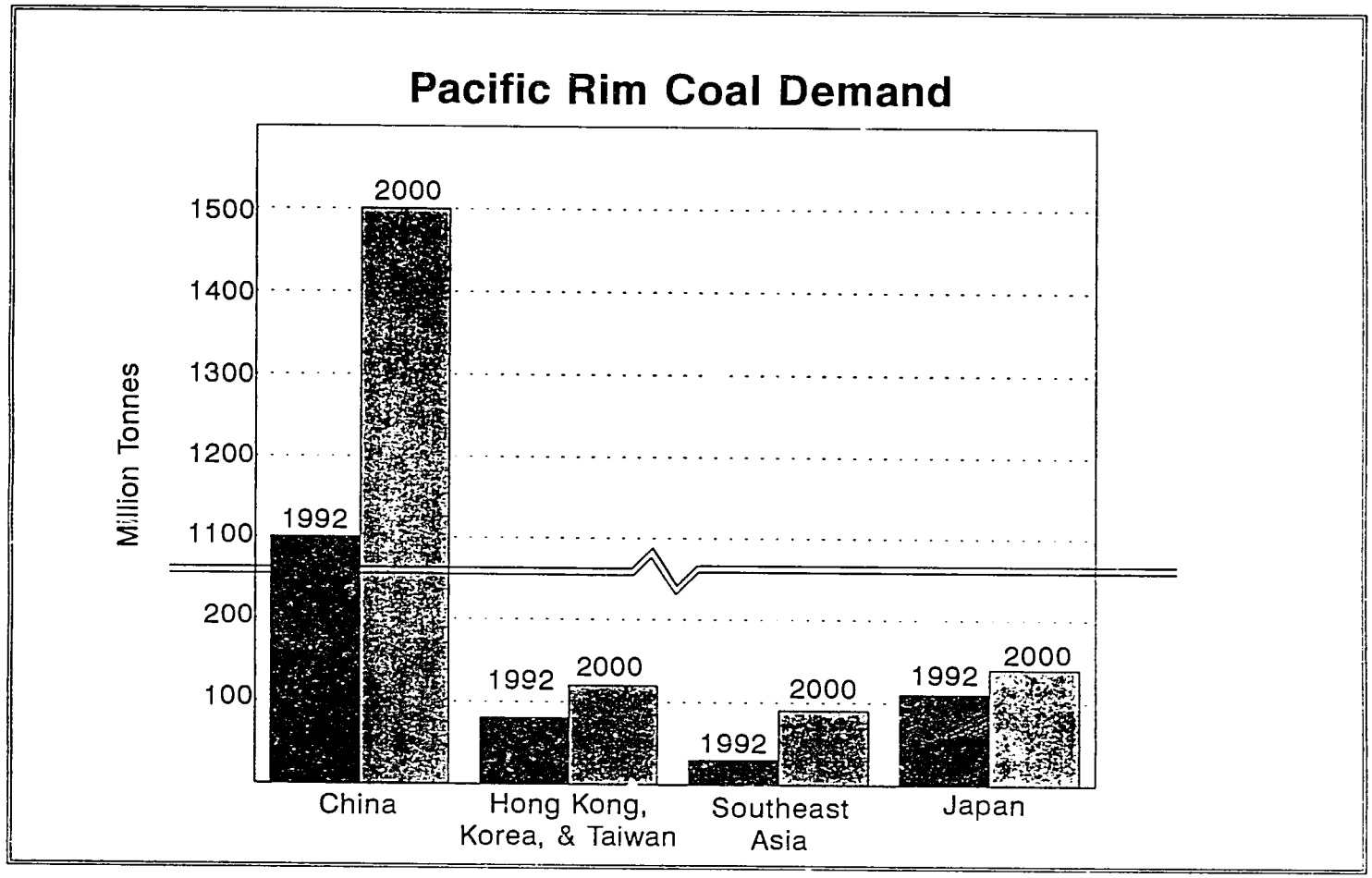
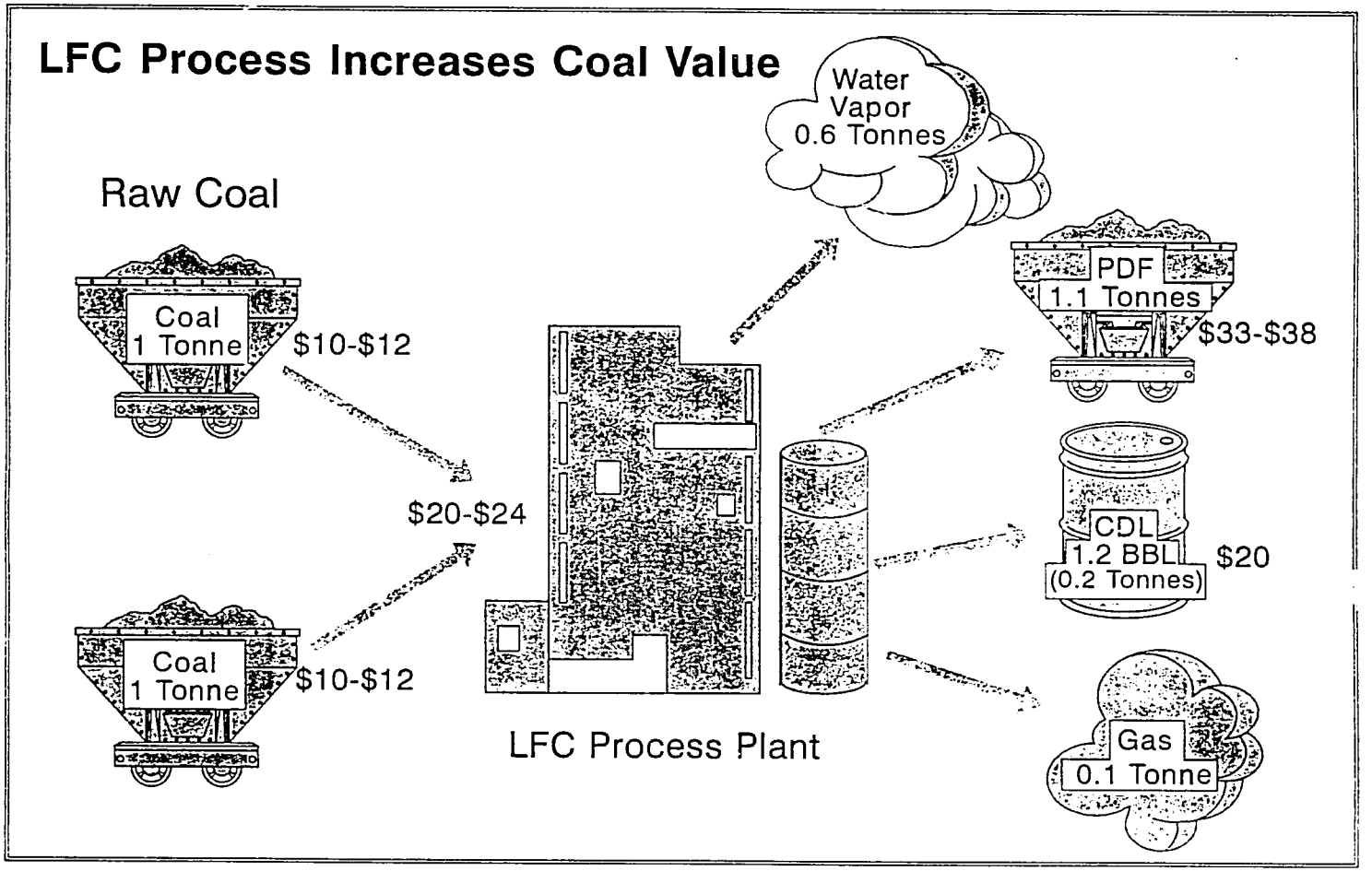

Pacific Rim Coal Demand
Million Tonnes
1500
1400
1300
1200
1100
200
100
1992
2000
1992
2000
1992
2000
1992
2000
China
Hong Kong, Korea, & Taiwan
Southeast Asia
Japan

Figure 5


LFC Process Increases Coal Value
Raw Coal
Coal
1 Tonne
$10-$12
Coal
1 Tonne
$10-$12
$20-$24
LFC Process Plant
Water
Vapor
0.6 Tonnes
PDF
1.1 Tonnes
$33-$38
CDL
1.2 BBL
(0.2 Tonnes)
$20
Gas
0.1 Tonne

COAL LIQUEFACTION IN INDONESIA PROGRAM AND PROSPECT

FOR PRESENTATION AT
SEMINAR ON
CLEAN AND EFFICIENT USE OF COAL AND LIGNITE
ITS ROLE IN ENERGY, ENVIRONMENT AND LIFE
HONGKONG,
30 NOVEMBER - 3 DECEMBER 1993

BY

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AGENCY FOR THE ASSESSMENT AND APPLICATION OF TECHNOLOGY
(BPP TEKNOLOGI)

ABSTRACT

Energy continues to be of strategic importance to Indonesia. Since Indonesia may become a net oil importer in the early of the next century, it would be prudent in this circumstances to consider exploiting its vast coal reserves to offset such import. One possible way is by producing liquid fuels from coal. For that reason, the Indonesian government has decided to promote R&D on coal liquefaction technology in Indonesia. The research program, which has just been established recently, is planned to test almost the majority of Indonesian coals, especially brown coal. Assistance from developed countries, such as Japan, the USA, Germany and Australia, will eventually be needed for the completion of the project.

Because bituminous and sub-bituminous coals are potentially export competitive, brown coal, as a major coal reserves in Indonesia, should be utilized as much as possible for domestic use. However, the nature of this coal has caused difficulties in transportation and storage. Burning this coal in a power generation away from the mining sites will likely be impossible. On the other hand, build a power plant in the vicinity of the mining site combined with a submarine cable network from outside Java to Java (as an island with a major energy demand), economically, still not be possible today. Similarly, ***Brown Coal Liquefaction Technology*** *is also still very expensive at the moment. However, the technology will likely play a very important role on the development of coal utilization in Indonesia in the future, particularly in the transportation sector.*

INTRODUCTION

Energy continues to be of strategic importance to Indonesia. Its availability at sufficient amount, supplied at an economical price is a major requirement for securing the country's economic stability at all times. As Indonesia is commencing its second twenty-five-year national development plan in the early of 1994, it is vital for the country to develop a comprehensive energy master plan for its national development.

In this regard, the government energy policy now is targeted into two main aspects :

1. Securing the domestic energy supply, and
2. Sustaining the export of oil and expanding the export of natural gas.

In order to achieve this, the government has to promote the utilization of its coal resources, which are abundant, as one of its major energy supplies in the future.

Since Indonesia may become a net oil importer in the early of the next century, it would be prudent in this circumstances to consider exploiting its vast coal reserves to offset such import. This can be done by introducing more coal power generation and, if the economy is satisfactory, by producing liquid fuels from coal. Based on that reason, the Indonesian government has decided

to promote R&D on coal liquefaction technology in Indonesia. The research program, which has just been established recently, is planned to test almost the majority of Indonesian coals, especially brown coal which is available more than 70% of coal measured reserves in Indonesia. Assistance from developed countries, such as Japan, the USA, Germany and Australia, will eventually be needed for the completion of the project.

This paper is going to discuss and highlight the need of conducting R&D on coal liquefaction technology, the program and prospect of the technology. Prior to this, coal utilization technologies and previous research activities on coal liquefaction in Indonesia will be reviewed.

THE UTILIZATION OF COAL AND LIQUEFACTION TECHNOLOGY IN INDONESIA : A REVIEW

The utilization of coal in Indonesia, today is limited only to the cement industry and power generation. In fact, many small industries still rely on oil and wood for their primary fuel supply, which actually can be replaced by coal. As with the household sector, there is a great potential to substitute fuels being used today with coal.

Although the use of coal is still limited to several sectors coal demand is rapidly growing, domestically as well as internationally. Since the government adopted a policy to use coal as much as possible, the domestic energy mix has also changed dramatically. In 1979, for example, coal contributed only to less than 1% of the total energy consumption in Indonesia. But ten years later, the use of coal has increased to more than 6%, and at the end of 1994 is projected to reach 8.8%.

From 1984 to 1989, the role of coal in electricity generation has steeply increased; it went up from 0 to 22.5% of the total capacity, and is projected to increase to 25.2% at the beginning of 1994. One of the main reason, as reported by PLN (State Electricity Company), is because the cost of coal power generation is only 54% and 61% respectively of those the costs of power generation from nuclear and geothermal resources.

At the moment there is only one large power plant in operation, i.e. Suralaya power station

in West Java, with a capacity of 4 x 400 MW for supplying electricity demand in Java and Bali. There is another unit of 600 MW in Paiton, East Java which has just been completed and are still being commissioned. It is expected to be in operation at the beginning of 1995. Similar to the one in Suralaya, this power plant will use local coals which are generally clean in terms of low sulfur and ash contents, therefore does not need to be fitted with expensive coal cleaner devices. There is also a plan to install a 400 MW IGCC power plant in Bumi Serpong Damai, Tangerang. This will be the first plant of its kind in Indonesia.

The technology used for existing power plants is the conventional (pulverized) coal-fired system. This technology was chosen as the best possible solution at that time, for meeting energy demand in Indonesia. The selection of technology for the future will certainly depend upon what type of coal will be used for a particular power generation and the financial situation or capability of the Indonesian government and those private sector companies who are interested in building electricity generation plants in Indonesia.

To date, the government is also encouraging the use of coal in households and small industries through the production of coal briquettes, with a target of producing 12 thousand tons this year. It is projected that by the end of the Sixth Five Year Plan (1998/9), the production of coal briquettes will reach approximately 4.8 million tons. The main purpose is to reduce their dependence on kerosine and wood for energy, so that it can substantially reduce the subsidy it applies to domestic oil prices.

In the field of coal liquefaction, few engineers/scientists have attended training or visited the related facilities in several countries such as Japan and Germany. On their return, coal liquefaction research facilities was established to be utilized for the improvement of their expertise and knowledge. There are two coal liquefaction research facilities available, one with the capacity of 5 liter is in MTRDC (Mineral Technology Reserach and Development Center), a government research institution under the administration of the Department for Mines and Energy, and the other (1 liter) is in ITB which is mainly used for research for students who are working on their theses. Coals used in both places are sub bituminous coal from Kalimantan, Sumatra and West Java.

COAL LIQUEFACTION PROJECT

1. Justification of the Project

Why changing coal to oil is important?

1. The rapid increase of oil demand with limited amount of exploitable oil has dictated the need for searching means of substituting oil and diversifying energy resources.
2. Its abundance availability has offered potential continues/stable supply. Today, 127.1 billion BOE of coal reserves in Indonesia are considered to be technically and economically exploitable, almost 4.5 times more abundant than petroleum and gas reserves.
3. To ensure continuous supply of oil and at the same time to conserve oil resources that have played important role in the development of science and technology in this century.
4. To take on the challenge of clean coal technologies, as one of important tools for achieving sustainable growth.

2. Objectives of the study

Short term : a). to enhance the transfer of technology and know-how from developed countries in the field of clean coal technologies, in particular coal liquefaction technology through collaboration or joint research; b). to provide fundamental data of operating conditions of coal liquefaction and the up-grading processes using various Indonesian coals, especially lignite. The data will be used for the selection of the optimum reaction conditions for each type of coal.

Long term : to investigate the overall performance of the coal liquefaction process, reliability, operability and economic viability for the purpose of commercialization.

3. Scope of the Activities

The implementation of the project can be divided into 5 stages :

Stage 1 : ***Coal Analysis and Liquefaction experiment***

Analysis of various Indonesian coals to select the most suitable coals for liquefaction

process will be conducted in Indonesia, and possibly in Japan too, if an agreement on a collaboration research program between the two governments can be signed by the end of this year or early 1994. Through that program or other scholarship schemes, further study in the field of coal liquefaction process in Japanese universities/research institutes and hands-on training for Indonesian scientists and engineers will be carried out. Although the involvement of NEDO (Japan) in these activities is still under consideration, those programs is expected to commence on the beginning of 1994. Coal field studies for the investigation of the present infrastructure conditions will also be conducted during this stage (1993 -1994).

Stage 2 : ***Process Design, Experimentation Methodology and Training***

The objective of this stage is to design and develop an experimental methodology, and to establish a project planning. Assistance from NEDO (Japan) or other developed countries on conducting those activities will eventually be needed. One of the best possible approach in this case is to involve BPPT's scientists/engineers on the research activities being conducted in a particular country. By doing so, there will be a transfer of technology and know-how from foreign experts to Indonesian scientists (mid 1994 - end 1994)

Stage 3 : ***Establishment of a Continuous Laboratory Scale in Indonesia***

Although collaboration with other developed countries remains open, until today there is still an expectation that NEDO under the permission of MITI could assist BPPT in the establishment of coal liquefaction research facility in Indonesia (LSDE, Puspiptek, Serpong) and provide technical assistance in carrying out the research works (beginning 1995 - 1996)

Stage 4 : ***Experimentation and dissemination of the Results***

Fundamental study on Coal Liquefaction using different type of coals such as lignites

from Tanjung Enim, Cerenti, Meulaboh and Asam-asam in the presence of iron sulfide catalyst (for primary hydrogenation) and Mo-Ni with Ca (for secondary hydrogenation), will be carried out. Liquefied coal products under various operation conditions, e.g. temperature, pressure, slurry concentration, amount of catalyst, and ratio of hydrogen /liquid, will be evaluated. Following this, further research to optimize the liquefaction process, and to provide evidence of the advantages and predominance of that process will be needed. Research report will be submitted to countries involved in the joint research. (1996 - mid 1998)

Stage 5 : ***Scale-up, preliminary feasibility study (overall assessment) and further research work***

Development of a conceptual design and flowsheet for commercial plant, overall performance evaluation, preliminary economic assessment, and examination for the necessity of conducting a further research will be carried out during this stage. (mid 1998 - end 1998)

COAL LIQUEFACTION TECHNOLOGY OUTLOOK

Indonesia has total coal reserves of about 34 billion tones with the largest deposits being located in Sumatra and Kalimantan. Figure 1 and table 1 show the distribution of coal reserves in Indonesia. From that amount, only 20-30% of measured reserves are considered suitable for export, while the remaining 70-80% (brown coal) is often considered as non economic coal. Because Indonesian bituminous and sub-bituminous coals are potentially export competitive, logically speaking, brown coal, as a major coal reserves in Indonesia, should be utilized as much as possible for domestic use. However, the nature of this coal, which typically has many holes, and consists of considerable water and high oxygen content that causes self ignition when exposed to air, can cause difficulties in transportation and storage. Thus, burning this coal in a power generation away from the mining sites will likely be impossible due to that difficulties. On the other hand, if the power plant is built in the vicinity of the mining site combined with a submarine cable network from outside

Java to Java (as an island with a major energy demand), economically the technology is still very expensive today. The challenge is, therefore, to seek the best way of utilizing this coal in such clean and safe manner. As a matter of fact, its abundant availability and its critical role in national economic growth and energy security require that special attention be paid in utilizing them as much as possible in ways that can reduce their negative impact on the environment. In this regard, ***Clean Coal Technologies, among others, coal liquefaction technology*** will likely play a very important role on the development of coal utilization in Indonesia in the future.

CONCLUSIONS

Energy continues to be of strategic importance to Indonesia. Since Indonesia may become a net oil importer in the early of the next century, it would be prudent in this circumstances to consider exploiting its vast coal reserves to offset such import. One possible way is by producing liquid fuels from coal. For that reason, the Indonesian government has decided to promote R&D on coal liquefaction technology in Indonesia. The research program, which has just been established recently, is planned to test almost the majority of Indonesian coals, especially brown coal. Assistance from developed countries, such as Japan, the USA, Germany and Australia, will eventually be needed for the completion of the project.

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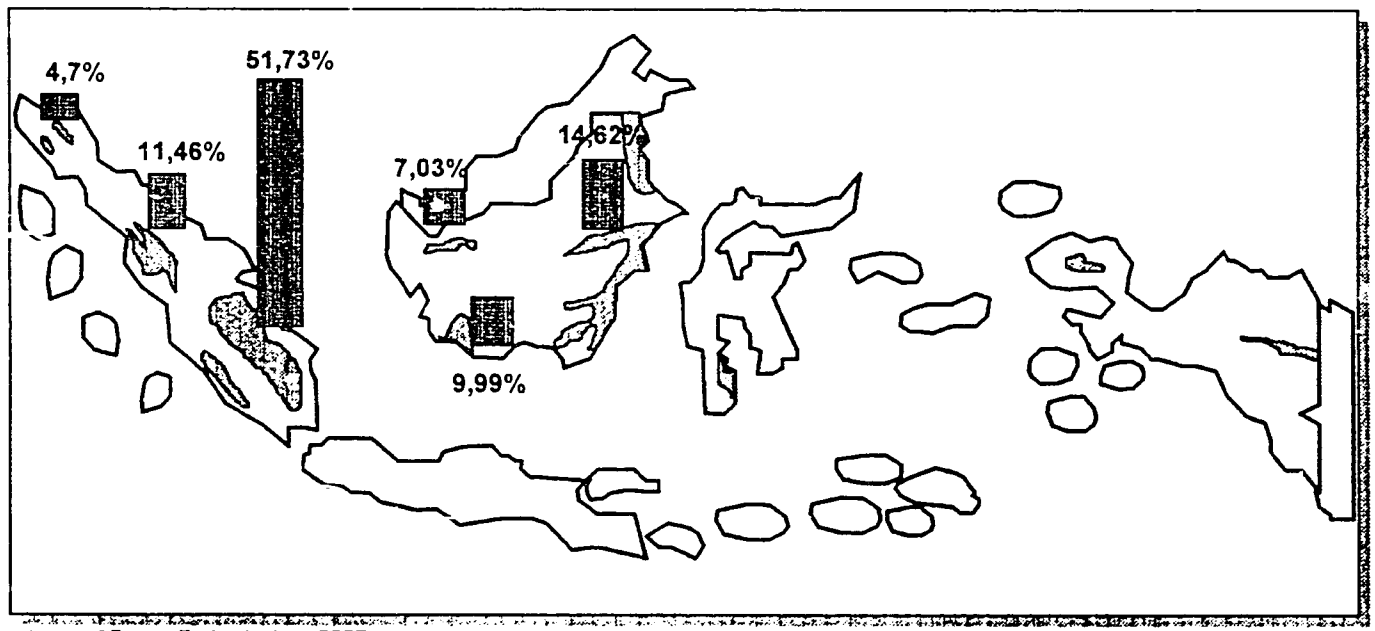
Figure 1 : Coal Reserves Distribution in Indonesia



Directorate of Energy Technologies - BPPT
INDONESIA

Source: Department of Mines and Energy

"Seminar on Clean and Efficient Use of Coal and Lignite its Role in Energy, Environment and Life"

Table 1: Indonesian Coal Reserves As of February 1992

No	Location	Measured	Probable & Possible	Hypothetic	Total	(%)
A	Sumatera	2,887,881.0	13,445,367.0	5,342,990.0	24,676,208.0	72.14
1	North Sumatera	-	1,274,000.0	430,000.0	1,707,000.0	4.99
2	Central Sumatera	717,820.0	2,428,939.0	1,019,000.0	4,165,759.0	12.18
3	South Sumatera	2,243,004.0	9,709,500.0	6,890,990.0	18,843,514.0	55.09
4.	Bengkulu	27,037.00	32,928.0	-	59,965.0	0.18
B	Kalimantan	1,839,613.4	5,213,662.2	2,307,241.0	9,360,516.6	27.37
1.	West Kalimantan	1,801.00	280,398.0	1,837,900.0	2,120,099.0	6.20
2	South Kalimantan	1,112,730.1	2,516,496.0	-	3,629,226.1	10.61
3.	East Kalimantan	725,062.3	2,416,777.9	33,051.0	3,174,890.3	9.28
4.	Central Kalimantan	-	-	436,310.0	436,310.0	1.28
C	Java	12,148.0	28,516.0	19,953.0	60,717.0	0.18
D	Sulawesi	5,475.9	18,785.1	-	24,261.0	0.07
E	Irian Jaya	-	83,114.0	-	83,114.0	0.24
	Total	4,745,118.3	18,789,544.3	10,670,184.0	34,204,846.6	100.00

WORKSHOP A4

REGIONAL NEEDS

IEA Second International Conference on
The Clean and Efficient Use of Coal and Lignite:
It's Role in Energy, Environment and Life.

paper by Mr David Boyd
Executive General Manager, Business Development
Coal & Allied Industries Limited

Integrating Improved Coal Technology Into Regional Energy Systems An Australian Perspective

Hong Kong, November 1993

Australia is now the world's largest coal exporting country and, with over 30 billion tonnes of recoverable coal, is well placed to respond to increased demand for steaming coal in the Asia Pacific region.

There are three reasons for Australia's success in the export coal trade:

- Australia's proximity to the rapidly developing Pacific Rim countries

- The comparative attraction of Australian black coal in terms of reliability of supply, consistent quality, competitive cost, and relatively low environmental impact.

- Major capital investment during the 1980's in large scale opencut and underground mines in New South Wales and Queensland fully integrated with rail transport, stockpiling, shiploading and port facilities.

Competitively priced coal underpins Australia's position as the world's largest coal exporter and given adequate returns on investment is prepared to expand substantially to meet increasing world demand.

The Role of coal is critical in the Asia - Pacific Region Energy Mix

Government and private bodies around the world forecast that over the next decade or two there will be a strong demand growth for steaming coal.

New demand will be centred in the newly industrialising nations of the Asia - Pacific region. Over the past decade the Asia - Pacific region has been growing faster than any other region. Growth in GNP over the past 10 years has averaged 6 percent per annum compared with 2.7 percent for OECD countries.

The economic growth of any nation is fundamentally dependent on the economic supply of energy. Electricity demand in the Asia - Pacific region is projected to grow at 8 - 10 percent per annum over the next decade.

Though there are supplies of oil in the region, it is a net importer of oil. Since the two oil shocks in the 1970's that led to rapid oil price rises and energy security concerns, the region is loathe to rely on oil as its major source of energy particularly for large power stations.

Natural gas is also available in some parts of Asia, however the linkage to oil prices is stronger than that of coal particularly for LNG. Unless converted to LNG natural gas is not easily stocked. However, the abundance of coal reserves worldwide ensures that the international coal market will continue to be subject to strongly competitive pricing, making it among the most economical of all energy sources.

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The wide geographical distribution of coal deposits including the Asia - Pacific region provides consumers with security of access to supply.

These factors dictate that the role of coal will remain critical in the region's energy mix, with an estimated 75 percent expansion in coal consumption in the Asia Pacific region over the 1990 - 2010 period.

The introduction of improved coal technology will be required to reduce the environmental impact of this increased coal use.

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Australia is the World's Largest Exporter of Coal

Since 1984, Australia has been the world's largest exporter of coal achieving record shipments of 126 Million tonne in 1992.

The industry has a proven record of satisfying customer needs for reliable, competitive priced, environmentally preferred coals becoming the largest exporter of thermal coal to the power utilities in Northern Asia as they grew rapidly in the 1980's.

Japan remains the major customer for Australian black coals taking 60 Million tonne in 1992. The other major customers being the Republic of Korea (14 Million tonne), Taiwan (8 Million tonne), and Hong Kong (3.6 Million tonne). Other Asian countries (India, Pakistan, Turkey, Iran and Israel) accounted for 10 Million tonne.

As the world increasingly addresses environmental concerns related to the burning of fossil fuels, demand for Australia's relatively clean coals will escalate.

Australian thermal coals typically have high energy content, moderate ash levels and most importantly low sulphur and other contaminated levels making them suitable for the most environmentally conscious consumer.

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Australia is Committed to Clean Coal Technologies

The Australian coal industry recognises the need to minimise emissions from the combustion of coal. The industries aim is to concentrate on improved and new coal technologies which will increase combustion efficiency as an effective means of reducing CO_2 emissions. Each 1 percent increase in absolute power generation efficiency results in a 3 percent reduction in CO_2 emissions.

Combustion efficiencies in conventional pulverised coal (PC) power stations can be enhanced by using high energy Australian black coals.

According to a number of authoritative studies the most economical means of SO_2 control is to use low sulphur coals. Flue gas desulphurisation (FGD) can meet strict SO_2 emission levels when higher sulphur coals are used. FGD has been installed in over 500 large plants around the world but there is a substantial capital and ongoing operating cost for installation of this technology. The low sulphur content of Australian coal is therefore becoming increasingly important in the selection of fuel supplies particularly by developing countries which may not have the investment capacity to take full advantage of new emission control technologies.

Pulverised coal boilers with FGD and de-NO_x equipment is a proven mature technology. Commitment to this technology underpinned by abundant economical coal reserves and reliable economical supplies involves minimum commercial risk.

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In both pressurised fluidised bed combustion (PFBC) and integrated coal gasification combined cycle (IGCC) acid gas control and particulate collection are integrated into the process so these systems lend themselves to minimal emissions at higher overall efficiency than conventional pulverised coal technologies. Research is currently being funded by the Australian Coal Association into the suitability of Australian coals for these new clean coal technologies. Research is also being undertaken into more efficient coal preparation technologies for the production of superclean (3 to 5 percent ash) and ultraclean (1 percent ash) coal.

However, it will be 1997 - 98 before there is sufficient operational performance data on IGCC systems to support commitment by Power Utilities with an acceptable level of commercial risk.

Pulverised coal will remain the dominant coal boiler technology of choice for Power Utilities well beyond 2000.

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Australian Expertise in Coal Mining, Transportation and Utilisation is of Relevance to the Asia Pacific Region

Australia has developed considerable expertise in coal mining, transportation and utilisation and providing equipment, services, training and technology to the energy sector in Australia and adjoining regions.

Around 80 percent of electricity in Australia is generated from coal. In New South Wales and Queensland over 90 percent of electricity is generated in large pulverised coal power stations. Victoria remains the principle producer of brown coal to fuel power stations generating more than 80 percent of the states energy needs. Australia has been at the forefront in developing state-of-the-art technology to improve power station efficiency and pollution controls.

Of particular relevance to the Asia Pacific region is Australian expertise in coal utilisation including power station design, construction and operation, especially in matching boiler design and emission controls to fuel sources. This expertise compliments experience gained in integration of the coal transport chain from mine by rail and road with state-of-the-art shiploading and blending operations at export coal terminals capable of loading the largest coal vessels used in the international coal trade

The development of new mines together with the related transport and shiploading and blending facilities is a major integrated undertaking requiring long lead times and major capital investment.

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Similarly the expansion and development of client countries coal receival facilities, land transport systems and power stations involve long lead time and major capital investment.

I believe there would be considerable benefit to both coal suppliers and Power Utilities in the strategic integrated planning of the extended coal chain from mine to power stations proposed in the Asia Pacific region. This will become most important to achieve the potential benefits from blending high energy, low sulphur Australian coals with lower rank indigenous coals from various South East Asian countries. Coal & Allied is now commencing blending studies aimed at reducing the effect on the environment of utilising indigenous low rank coals as a fuel for the rapidly growing Asian energy demand. At Australian coal terminals innovative computer controlled stockpile management and loading systems are used to accurately blend different coals to produce the specific composition required by individual customers. These systems have been offered to regional coal importing ports.

Coal & Allied is involved with Ube Industries Limited and Nissho Iwai Corporation of Japan, in developing Ube's Coal Water Mixture Technology which can supply coal in a liquid form suitable for pipeline transportation and storage in tanks which avoids the need for open stockpiling in high population and environmentally sensitive areas.

Australian companies involved in coal mining and manufacture of coal preparation plants are assisting Asian countries in improving coal mining and preparation technologies.

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This is also being enhanced by the Joint Coal Board of Australia arranging UNDP courses for representatives of developing countries in coal technology. The courses cover all aspects of coal mining, handling, preparation and utilisation.

The Australian Coal Trade and Technology Committee (ACTT) brings together coal-related services, research, training, manufacturing and heavy engineering industries. It also provides a focus for liaison with organisations with similar interests in other countries.

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Coal Truly is the Energy Source of the Future

We believe that coal can provide the base load of Asia's energy growth in the 1990's and well into the 2000's economically and efficiently. To ensure this, I am sure there will be on-going research programs by the Australian coal industry targeted at producing, handling and utilising coal in an even more efficient, safe and environmentally acceptable manner.

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IEA Second International Conference on the Clean and Efficient Use of Coal and Lignite: Its Role in Energy, Environment and Life

30 November - 3 December 1993

Regional needs

Asia-Pacific and Europe: comparison of coal prospects/opportunities

Martin Daniel

Head of Supply, Transport & Markets

IEA Coal Research, London

ABSTRACT

Asia-Pacific and Europe are two of the key world markets for the sale of traded coal, mining equipment and coal utilisation technologies. The paper analyses the likely development of coal demand in the two regions to 2010, in the context of overall energy and electricity growth trends. The regions are projected to show considerable differences. Between 1990 and 2010 coal demand could almost double in Asia-Pacific, but fall by over a quarter in Europe.

Power stations will be the main coal market in both regions. By 2010 electricity generation is projected to account for almost 1.9 billion tonnes a year in Asia-Pacific: over half of the region's 3.3 Bt coal requirements. In Europe power plants will account for over three quarters of total coal demand of 0.9 Bt in 2010. Meeting Asia-Pacific needs will require at least 320 GW of additional coal-fired plant by 2010. European additional capacity requirements will be much lower, but the market for replacement plant and environmental upgrading of plant will be substantial.

In Europe coal demand will be met increasingly by imports, which could rise from 153 million tonnes in 1990 to 250 Mt in 2010. European hard coal output will be halved and brown coal output will fall by a third. In Asia-Pacific, by contrast, coal output could almost double over the period to reach 3.2 Bt. Hard coal imports, including intra-regional trade, could rise to 350 Mt in Asia-Pacific by 2010.

INTRODUCTION

Asia-Pacific and Europe are two of the key markets for those involved in the sale of internationally traded coal, mining equipment, and coal utilisation technologies. Between them, the two regions account for over 90% of world coal imports. They produce almost 60% of world hard coal, brown coal and lignite. They consume a similar percentage of world coal, including over half of the coal used in power stations.

Developments in these two regions will clearly influence the overall market prospects for traded coal and coal-related equipment. However, the two regions display many contrasts in their pattern of coal trade, production and use. These differences will continue, and become more marked, over coming decades.

An understanding of the differences is a prerequisite to an appreciation of the particular needs and opportunities presented by countries in the two regions. To this end this paper describes the likely developments in coal demand, output and trade in the two regions over the period to 2010.

CONTENT AND DEFINITIONS

The paper is based on a series of detailed studies undertaken by IEA Coal Research on coal prospects in the two regions. Doyle (1990), Couch and others (1990), Daniel (1991 and 1992), Daniel and Jamieson (1992) and Daniel (1993) are the main studies. The last mentioned report, *European coal prospects to 2010*, was published in September 1993, and forms the basis of the European projections. Asia-Pacific projections partly derive from unpublished work in progress. The paper also draws on recent work by the International Energy Agency (IEA) in Paris.

In the paper Europe is defined as all countries west of (and excluding) Russia, Ukraine and Turkey. Asia-Pacific is defined as all countries east of Iran and south of Mongolia. However, in some of the analysis Australasia is not included. In these instances the text refers explicitly to Asia and not Asia-Pacific.

The main emphasis of the paper is on developments in the power station market. This is the sector where most of the growth in coal demand has occurred in recent decades, and where most future growth will occur. The paper also pays particular attention to the traded coal sector.

All units are given in metric tonnes. Mt is million tonnes. Tonnes of coal equivalent (tce) refers to the international standard of 29.3 Gigajoules (GJ) per tonne. Unless otherwise stated, "coal" refers to all types of solid fuel from lignite to anthracite.

ENERGY BACKGROUND

In 1992 total primary energy consumption in Asia-Pacific was 2.65 billion tonnes of coal equivalent (Btce). European consumption was around 2.4 Btce. Composition of total demand by fuel source varied considerably, although oil accounted for around two-fifths of the total in both regions. Natural gas and nuclear contributions were much lower in Asia-Pacific than Europe. In Europe coal met a quarter of needs but in Asia-Pacific almost half (*see* Table 1).

In both regions coal accounted for by far the largest share of proven fossil fuel reserves (*see* Table 2). In Asia-Pacific the reserves to production (R/P) ratio in 1992 was 53 years for natural gas and 18 years for oil. The R/P ratio for coal was 179 years. Europe had a similar R/P ratio for coal at 173 years. However, the ratio for natural gas and oil in Europe was much lower, at 26 and 10 years respectively (BP, 1993).

Fossil fuel imports met a lower proportion of demand in Asia-Pacific than in Europe. In 1992 Europe obtained two-thirds of oil, a third of natural gas and a fifth of coal needs from third countries. In Asia-Pacific net imports from third countries accounted for a half of oil, a third of natural gas, but only 4% of coal supplies

FUTURE GROWTH IN ENERGY DEMAND

Primary energy demand has grown very fast in Asia-Pacific over the past decade. Between 1982 and 1992 the region experienced growth of almost 5% a year. European growth started from a higher base and was much lower, increasing by 0.8% a year over the same period.

These divergent trends will continue for several reasons. The population of Asia-Pacific will continue to grow substantially over coming decades. The World Bank anticipates that the population of the region will increase by 1.3% a year. By 2025 the Asian population could exceed 4.4 billion people. In Europe, by contrast, the population will remain almost stationary at around 0.5 billion people (World Bank, 1990).

Population growth will inevitably lead to rising energy consumption in Asia. This factor will be compounded by the low level of per capita energy consumption in the region. At present per capita energy consumption in East Asia is 1.3 tonnes of coal equivalent (tce) a year. The level in South Asia is only 0.4 tce a year. European consumption is over ten times higher at 4.7 tce - in spite of the low levels of consumption in some eastern European countries.

Asian per capita energy consumption may thus be expected to grow much faster than in Europe. This will in part reflect the higher rate of economic growth anticipated in the region. A recent IEA analysis of future world energy supply assumed that economic growth in Europe would average just over 2% a year from 1990 to 2010. In Asia the assumed growth levels were much higher. Growth in China was anticipated at 7.6% a year. East Asian growth was put at 5.8% a year, and South Asian growth at 5% a year over the period (IEA, 1993).

Primary energy requirements in Asia-Pacific will thus rise substantially (*see* Table 3). The IEA projected growth in Asia-Pacific primary energy demand of 3.6% a year from 1990 to 2010. In the latter year total primary energy demand could stand at around 5 Btce.

European primary energy demand is projected to increase much more slowly. Western European energy demand may rise by 1% a year to 2010, but eastern European demand may barely exceed 1990 levels by 2010. Between 1988 and 1993 eastern European energy demand fell by over a third as economic output slumped. The collapse in eastern European gross domestic product will have been reversed well before 2010. However, economic restructuring will result in a trend towards less energy intensive economic activity. Combined with much more efficient energy use this will offset the impact of renewed economic growth on energy consumption. By 2010 European primary energy demand is projected at just over 2.9 Btce.

ELECTRICITY DEMAND PROSPECTS

An increasing proportion of total primary energy supply is devoted to the generation of electricity in both regions. In Europe over a third is used in this way, and in Asia-Pacific just under a quarter. However, in Asia-Pacific there are substantial differences between countries. In China, for instance, electricity production accounts for only 15% of total primary energy supply, whereas in Japan the figure is 39%.

It has already been noted that the composition of primary energy supply by fuel source differs between the two regions. This applies to electricity supply as well (*see* Table 4). However, at present the differences are less marked. In both regions coal provides two-fifths of electricity output and renewables just under one-fifth. The main difference is in the relative shares of hydrocarbons and nuclear power. The latter accounts for 30% of electricity production in Europe, but only 12% in Asia-Pacific. The proportions met by hydrocarbons are reversed. The low percentage of hydrocarbon usage in Europe will, however, change in future years.

The past decade has seen very fast growth in electricity demand in Asia-Pacific and a much more moderate increase in Europe. These trends will continue. The rapid growth in Asia-Pacific primary energy demand will be paralleled, and in large part driven, by the growth in electricity demand. Asia-Pacific electricity demand is projected to grow at almost 5% a year between 1990 and 2010. In the latter year electricity output in Asia-Pacific could exceed 6,360 TeraWatt hours (TWh). This would represent over 30% of world electricity supply, compared with the 21% recorded in 1990 (IEA, 1993).

European growth in electricity demand will be much lower. In 2010 European electricity output has been projected by IEA Coal Research at 3,592 TWh (Daniel, 1993). This represents growth of only 1.4% a year over the period from 1990. As with energy demand the effects of economic restructuring and improved efficiency in eastern European electricity use will be mainly responsible for restraining growth in demand.

COAL DEMAND - ASIA-PACIFIC

The substantial growth anticipated in Asia-Pacific energy and electricity demand will be primarily fuelled by coal. Coal accounts for just under half of total primary energy supply in the Asia-Pacific region today. In 2010 the level is likely to be similar. Coal use in that year is projected to reach 2.25 Btce (or 3.3 Bt) - almost double the 1992 level.

Most of the increased demand will occur in power stations, almost all of which will operate on base load. Coal-based electricity output is projected to grow by nearly 6% a year in Asia-Pacific, taking the fuel's share of total electricity output from 42% in 1990 to over 50% in 2010. Coal-based power production would thus more than triple, exceeding 3,270 TWh in 2010. To put it in perspective: coal-based power output in Asia-Pacific would then almost equal total electricity output in Europe.

An increase of this magnitude will require enormous investment in power station capacity. An additional 320 GW or so of base load plant, excluding replacement capacity, will be needed between 1990 and 2010. Much of the additional plant will be required in India and China. In India net additional coal-fired capacity of up to 99 GW is planned by 2010 (WEC, 1992). In China some 70 GW of additional capacity is being sought between 1993 and 2000 alone.

Large tranches of new capacity will also be required in countries such as Japan, South Korea, Thailand, Indonesia and the Philippines. By 2000 an additional 50 GW could be in place in these countries (Doyle, 1993).

These are, however, only projections. The amount actually built will in all cases be constrained less by demand than by available capital - much of it derived from foreign investors. Annual capital expenditure on coal-fired plants in Asia-Pacific to meet these plans could easily exceed $20 billion over the period. Capital will be directed primarily to those countries with liberalised electricity systems and prices. Without guaranteed returns much of the planned capacity may not be built.

Power station coal use could thus rise substantially over the period. In 1990 some 380 Mtce (or 622 Mt) of coal was consumed in Asia-Pacific power plants. By 2010 annual consumption could exceed 1.1 Btce (almost 1.9 Bt), if capacity is added as planned. Coal demand in other market sectors will rise more slowly, with most of the growth occurring in the industrial market. Household and transport use will suffer a relative decline. As a result power station coal use could rise from 37% of total coal use in 1990 to well over 50% in 2010. This will follow a well established trend (*see* Table 5), but would still be a much smaller proportion than in Europe, where power stations already account for over three quarters of total coal demand.

COAL DEMAND - EUROPE

In Europe there will be a decline in both overall and proportional coal use. IEA Coal Research projects that overall coal use will fall from 1,198 Mt in 1990 to 835 Mt in 2010. The share of European electricity output met by coal will fall from 38% to 31% over the same period. Nevertheless solid fuels will remain the largest single contributor to European electricity supply (Daniel, 1993).

The projected decline in European coal demand can be attributed to several factors. The low growth anticipated in energy and electricity demand has already been noted. So, too, has the collapse in economic output and energy use in eastern Europe. Energy and electricity supply in eastern Europe were heavily dependent on coal - especially brown coal. Collapsing energy demand has thus mainly affected coal.

However, economic revival in eastern Europe in future years will not result in renewed coal growth. Improved efficiency of energy use, environmental taxes and concerns, and the incursions of natural gas will constrain coal demand. These factors will have an impact on coal demand throughout Europe - especially in power generation. Natural gas use in power stations is projected to more than double by 2010. Nuclear output will also increase. In some countries coal-fired plants will not operate on base load. As a result electricity production from coal is projected to grow by only 0.4% a year from 1990 to 2010 (*see* Table 6). With coal use in other markets projected to decline, European coal use in 2010 will thus fall by a quarter, to 0.9 Bt.

Falling demand does not mean that Europe will offer no opportunities for sales of coal and coal-related equipment. It is true that commissioning of additional coal-fired capacity will be limited:- especially when compared with the prospects in Asia-Pacific. However, the stock of

European power stations is much older than that of Asia-Pacific (Daniel, 1991). A significant portion - up to a half, or 115 GW - will need refurbishing, modifying or replacing before 2010. This especially applies in eastern Europe, where most power stations are old, inefficient and environmentally inadequate (Couch and others, 1990). The cost of modernising eastern Europe's energy sector was recently quantified by the US Secretary of State for Energy at US$200 billion. Much of this cost relates to expenditure on coal-fired power plants.

COAL PRODUCTION AND TRADE

Coal demand will thus almost double in Asia-Pacific. In Europe it will fall, but still remain a substantial component of energy supply. In both regions a significant part of demand will be met by imports, which will rise substantially from the 379 Mt recorded in 1992 (*see* Table 7).

IEA Coal Research has projected that in Europe net hard coal imports could rise from 153 Mt in 1990 to over 200 Mt in 2000, and reach 250 Mt in 2010. All the growth will occur in the thermal coal sector, with coking coal imports remaining stagnant over the period. Most growth in thermal coal demand will come from power stations (Daniel, 1993). This forecast is in line with other recent projections, certainly up to 2000 (*see* Table 8).

The growth in European demand for coal imports will mainly reflect the replacement of indigenous output, rather than the creation of additional markets (Daniel and Jamieson, 1992). European hard coal output is projected to halve, falling from 376 Mt in 1990 to under 190 Mt in 2010. By the latter date imports will thus substantially exceed European hard coal production. Brown coal and lignite output will also decline by a third, to 446 Mt, between 1990 and 2010. Loss of markets, high costs and, in cases, relatively poor quality will militate against indigenous output at a time when Europe will be undergoing increasing economic liberalisation.

Asia-Pacific gross coal imports will also increase substantially. However, net imports into the region will rise much less significantly because of the export roles of Australia, China and Indonesia. By 2000 imports (including intra-regional imports) could reach 250 Mt a year, comprising around 150 Mt of thermal coal and up to 100 Mt of coking coal (*see* Table 9). By 2010 imports could easily exceed 350 Mt, with most additional sales being thermal coal to power stations.

This import figure relates to a projection of Asia-Pacific coal production of over 2.1 Btce (or 3.2 Bt) in 2010 - almost double the 1992 figure of 1.7 Bt. A large part of the growth would occur in China, India, Australia and Indonesia. Chinese output plans envisage production of 1.4 Bt a year by 2000 with substantial growth thereafter to 2 Bt a year in 2010. Indian output in 2010 has been projected at between 550 and 650 Mt (WEC, 1992). Australian production could exceed 330 Mt by 2010. Production at these levels would, however, require both large scale investment in power station capacity - as already described - and in the mining industry. Without these investments Asia-Pacific output in 2010 could stand at 2.5 Bt or less.

CONCLUSIONS

Coal demand in Asia-Pacific could rise to around 2.25 Btce (3.3 Bt) in 2010. Over half of the demand would arise from the power generation sector. Achieving this level will require massive capital investment in at least 320 GW of new coal-fired power station capacity.

Coal production in Asia-Pacific could grow from around 1.7 Bt a year in 1992 to around 3.2 Bt a year in 2010. This total would include over 0.2 Bt of intra-regional coal imports. A further 0.1 Bt or so of coal imports from third countries would be required by 2010. All these projections are, however, dependent on substantial investment, which will in turn require guaranteed returns through realistic electricity and coal prices.

In Europe coal demand will fall by over a quarter to 0.9 Bt in 2010. Slow growth in energy and electricity demand, environmental concerns, and competition from natural gas, will constrain coal use even in the power station sector - the main market for coal in Europe. Nevertheless coal will remain the largest single supplier of European electricity output, with up to half of the region's power station stock requiring replacement or environmental modification in the period to 2010.

European coal production will fall because of lost markets, high costs and environmental problems. Hard coal production will be particularly hard hit, falling to half of its 1990 level by 2010. Coal imports, by contrast, will rise from around 150 Mt in 1990 to 250 Mt by 2010. At that stage imports will substantially exceed indigenous hard coal production in Europe.

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IEA Second International Conference on the Clean and Efficient Use of Coal and Lignite: Its Role in Energy, Environment and Life

Workshop A(4) - Regional Needs

Regional Analysis and Architecture of the Whole Energy System

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Introduction

In June 1990, the Chairman of the United States Energy Association (USEA), the United States Member Committee of the World Energy Council (WEC), chartered an Energy Research Committee that included a representative of the Energy Council of Canada, the Canadian Member Committee.* This Energy Research Committee was tasked to examine advanced technology and development required to address concerns regarding global climate change, comment on research and development demonstration programs in the United States, and contribute to U.S. and Canadian member committee involvement in the 1992 World Energy Congress in Madrid. The committee, of which this author was chairman, produced a report(1) upon which this paper is based.

The committee began its deliberations in a conventional way in order to come to grips with investigating the range of research activities under way and commenting on them. Because of the multi-fuel industry and technology representation on the committee, it became apparent that a conventional (parochial) approach would not yield more than the usual catalog. We came to the conclusion that a long-term global view starting with local and regional short-term priorities was necessary and chose 2100 as the target year.

Electing the long-term approach enabled us to get above short-term difficulties and intra-national, regional, resource, fuel, or technology competition issues, and thereby critically examine the general direction of governmental energy research, development and/or demonstration (RD&D). We found that there was a need to make RD&D prioritization and planning more pertinent and responsive to long-term needs. Though regional views may not show global priorities in the short-run, they will in the long-run.

* Committee Members: S. W. Gouse, Chairman, Bruno Brodfeld, John Casazza, J. Edward Cichanowicz, John Clarke, Peter Dyne, Thomas Gillette, William Harris, Richard Hilt, Feenan D. Jennings, Dolores M. Kern, Date E. Klein, Thomas Leuchtenburg, Edward K. Levy, Thomas H. Magness, Robert C. Marlay, Robert McFarren, Richard H. McMahan, Loring E. Mills, Frank C. Schora, Irving J. Solomon, Michael Tinkleman, David O. Webb, Jay Willer, Richard H. Williamson, Barry K. Worthington, Fred H. Zerkel.

Energy, A Future of Fundamental Change

The most recent cyclical activity in energy RD&D began with the oil embargo in 1973 and has weathered two price shocks, a major surplus of natural gas, and current real prices of oil below those at the start of the period, with current reserves of all fossil fuels at record highs. Over the past two decades, energy policy concerns have focused largely on the security of supply. This concern has been dominant due to growing world dependence on oil, with the concentration of oil reserves in areas of potential instability.

During this period, exploration and finding techniques have improved, strategic oil reserves have been established, and RD&D efforts have been directed toward expanding the capability to use previously untapped or underutilized energy resources. In addition to increasing supply options, energy research of this period has led to major advances in the development, demonstration, and application of technologies to increase the efficiency of energy use and thus reduce potential demand growth from all sources.

The period started with price instability and a fear of running out. It has ended with an understanding of the vast amounts of resources available, the ability to deal with the short term instabilities, and a growing realization that true long-term issues revolve around the increasing density and standard of human activity, increasing population, and the greatly increasing level of residuals of all types being placed in the environment. In particular, emerging concerns with respect to global climate change and the role that fossil fuel use may have in accelerating or decelerating this phenomenon are major emerging uncertainties effecting the choices available to us in the future.

Our target year was 2100. Several studies became available during deliberations. Table 1 is a summary of their projections. When the time into the future and the varied approaches are considered, the agreement is remarkable. The lower numbers have allowed for continued efficiency improvement of the type that have been historically embodied in economic development. In the year 2100, the annual requirement will be at least three times that of today, and that the resource base exists to supply this without major reliance on renewables. The total level of economic activity in the world will be considerably higher than today. In the year 2100, the level of economic well being of today's less developed world is likely to exceed that of Italy today. The residuals produced in providing for these energy demands will be of consequence and their nature will vary according to the kinds of primary resources, conversion, and end use systems that will be deployed. Because of the evolution of technology and the different stages of energy system infrastructure investment and development around the world, actions in the future will vary by region even though the commercial energy forms employed are likely to be similar.

Table 1: Estimated Future Global Energy Requirements (Exajoules/yr) 1986 = 317

↓Source/Year→	2060	2100
Holdren 1990(2)	834	1246-1577
Starr, et al. 1990(3)	810	
MITRE 1992(4)	709	1100
Greenpeace 1993(5)		987

Most of us, when working at or thinking about parts of the energy system, come at it from the point-of-view of elements of the system. However, the real issues are more fundamental, global, differ in detail regionally, and will have a profound effect on what ultimately will be deployed in the future.

The principal constraints to change facing us are economics, the time constants associated with the energy infrastructure, both in conversion and in end use, and the fact that many of the effects and impacts of energy conversion and use are not borne directly by the individuals responsible for a particular phase of the system. A primary aspect of the decision problem facing all involved in the energy system is that one can go from virtually any primary resource through various commercial energy forms to an ultimate end use. There is rarely a one-to-one correspondence. The system is richly redundant and the choices overwhelming—not only today, but for the future as well. However, careful analysis linking energy, the environment, and economics must be the norm if we are to afford the future.

The Job Ahead of Us—We Need an Architecture

In the year 2100, total primary energy consumption will be at least three times today's level. This requires an energy system infrastructure at least three times larger than what exists today, and allowing for infrastructure lifetimes, perhaps two to three replacement cycles of equipment. This is a staggering prospect and calls for an evolvable system. Because of the increased density of activity around the globe, this system will be subject to more considerations than were taken account of in our energy system evolution to this stage.

We use the term energy system to refer to the integrated set of primary energy resources through end use function provision systems and devices that are necessary to provide for our energy enabled services—defense; goods and services; lighting; production of food; space conditioning; and transportation; etc.—in the various regions of the world. Between resources and end use lie the various extraction, refining, conversion, storage, transmission, and delivery systems and processes. It is recognized that a focus on the integrated system is necessary in order to understand the economics, evolution, and performance of future energy systems. We felt that the energy system is often construed too narrowly. As a result, the phrase "architecture of the whole energy system" was adopted to emphasize the idea that an energy system is more than a collection of devices, processing plants, resources, etc., that satisfy the energy demands of the economy.

Architecture is the art or science of designing the system in accordance with principles determined by practical or functional considerations. For structures in which people live and work, etc., there is a general understanding of what architecture means with respect to the location of activities, the movement of goods and people into, out of, and within a structure, the illumination, maintenance, provisioning, remodeling, sewering, space conditioning, etc. In addition, building codes, zoning laws, and esthetics considerations are understood and accepted. There is an analogy to almost any system including energy systems. All systems need an architecture that deals with all their functions and interfaces and provides for evolution of function and technology.

For the energy system, the architecture is an organized arrangement of development locations, flows, physical facilities, storage depots, transmission links, and their interaction with accessibility, climate—existing population centers, cultural differences, economic development centers, stage of development—resource distribution, water supplies, etc. Were it to be designed by an accepted architect, all could be laid out in advance. However, we do not have that luxury or possibility. We have a non-uniform global distribution of various resources, including the renewables. We have existing population density and economic activity plus embedded first and second derivatives or rates of change, etc.

For the energy system this means the distribution of all resources to be employed, the choice and location of various intermediate steps of benefaction, conversion, delivery,

extraction, refining, storage, transmission, transport, etc., of commercial energy forms through enabling end use functions. including accounting for appropriate actions with respect to all effects, requirements, and impacts and ultimate disposition of all residuals and spent system hardware. We need a full understanding of the paths we are on, as well as the paths we must follow into the long-term.

The effects, inputs, requirements, etc., will vary geographically. However, because of the specifications surrounding the production of commercial energy forms (fungible commodities), independent developers can produce devices and subsystems for various parts of the system including end use devices. There will be need for a great deal of local, regional, and global discussion about coal ports (loading, unloading), LNG terminals (shipping, receiving), major plant locations, nuclear waste repositories, pipe lines, refineries, solar converters, transmission lines, wind farms, etc., all with new and more stringent standards and requirements coming into being (some retroactively) with respect to various environmental effects; occupational, health, and safety effects; residuals; etc.

The issues are: how does one examine the choices and arrive at conclusions or figures of merit as to what combination of non-uniformly distributed primary resources and intermediate, as well as perhaps changing with time, commercial energy forms leads to the overall most beneficial way to meet service needs in various regions of the world when the location and life-cycle of all elements and outputs of the system are considered. This has not been society's approach. Generally, the focus has been on relatively small pieces of the system, e.g., a new refining technology, a new automobile engine, or an alternative fuel. Over the past 450 years, a vast world energy system has evolved without conscious attention to many of its affects. We believe this energy system has reached a scale that demands attention to its architecture to determine where and how the system might be changed, how that change could be accomplished, and what the resulting impacts and effects might be. We need to develop a process to study the architecture of the whole energy system (AWES) to allow all effects of arrangements for various architectures to be evaluated on a consistent basis.

Current RD&D Planning

We believe that most governments have a relatively short-term myopic process for looking at energy RD&D. The programs look like catalogues of resources, technologies, devices, etc. Little attention is given to real success, that is research results that lead to large-scale implementation of a technology. We believe that the planning of government RD&D aimed at developing new energy technologies, components of tomorrow's energy system, should be based on a broader analysis and longer-term criteria with evolutionary system requirements. Considering only the existing regulatory structure and standards is not adequate. The combination of increasing population and continuous economic development have effects that seem tolerable at the outset, unacceptable later. These large-scale activities can include things that were thought unimportant or neutral but become critical, such as the chloroflourocarbons in the atmosphere.

Thus, a new approach is needed. Today, many environmental challenges are being confronted locally or regionally. However, they will generally all become global. Some already are. Because of the enormous flexibility before us, choices for RD&D investments will require developing a new planning system. Such a system must allow tracking of all the effects—positive, negative, and neutral—as if the RD&D were successful and the product implemented on a large-scale. This is not a simple task. The present global energy system is huge, complex, and evolving. How it evolves is effected by many factors, such as the finding of new reserves, changing end use requirements; new extraction, conversion, and delivery

technical capabilities; geographic, environmental, and social constraints and regulation; changing economic ground rules; national security considerations. Furthermore, most of these factors can and do change more rapidly than the energy system infrastructure.

The technical and economic lifetimes of major energy facilities are 30 to 50 years or more. These facilities represent an immense imbedded investment of capital and other resources. The future expansion of the energy system, and especially the incorporation of new technologies, will pose an equal or greater requirement for capital and technical resources. The result is a tremendous inertia that allows only gradual changes from existing technology in the developed world.

Since the rate of economic development is increasing more rapidly in less developed countries and since their current infrastructure investments are small compared to future requirements, these regions will have opportunities (from a long-term perspective) to employ better technologies. The developed world is mostly in the replacement business, rather than in the new installation business. We must take advantage of this.

This is especially true when one considers our habitat structures where many buildings have lives in excess of a century or two, and, where ordinary housing runs close to a hundred years. Dealing with the complexities of an evolving and expanding energy system and its increasing effect on the environment due to the scale of activity will require fundamental changes that will take a long time to be fully realized. Achieving substantial changes in the structure of the global energy system will also require decades, thus the long-term view.

This is a conclusion that raises a number of practical questions. Is it possible to perform a valid analysis of our

The Inertia of Energy Systems: An Example

Homes can be built to require far less energy for heating or cooling than is today's norm. However, the energy-efficient house illustrates the problem of the inertia of energy systems. Houses built today will be heated and cooled for close to the next 100 years. From an energy systems viewpoint, what are the consequences, the advantages or disadvantages, of not building as many houses as possible today? What would be the preferred method of heating (in, for example, the northeast) or cooling (in the southwest) with the majority of all dwellings being built to current standards?

How is electricity to be provided to these homes? A large portion of domestic services (lighting, air conditioning) require electricity; cooking and heating can be serviced with electricity or with natural gas. Are houses best served by centrally generated electricity, as today; by some combination of central and locally generated electricity; or by wholly decentralized systems? If electricity is provided by central generation, is the heating load so low that an additional natural gas distribution system would be uneconomical? How would heat pumps affect the seasonal load patterns of the utility or a reduction in electricity demand?

Suppose further that photovoltaic panels existed with the cost and performance projected for 20 years hence. How would they interface with electrical supply systems? Would they be better deployed in large central facilities, or decentralized, sited with each home? What are the technical problems and costs involved in interfacing a low-voltage DC source with the conventional 110 V AC supply or with the higher voltages in longer-distance transmission systems? How does such a supply vector, periodic and variable with respect to the sun, affect the utility's load management? For the utility, what are the better ways of providing reserve capacity for a succession of cloudy days? Is the fully decentralized, stand-alone system a possibility? There are some environmental questions as well. Energy-efficient houses require carefully controlled ventilation. Is indoor air quality adequate? What must be done to recycle defective photovoltaic cells, which, if based on heavy metals, may cause difficulties?

Dealing with issues of such complexity requires a time horizon that precludes all but the most gradual changes.

requirements a hundred years in the future? In some ways, the long-term is less uncertain in its global characteristics than is the short-term. In the absence of surprises or miracles, the population growth already in place and the fundamental forces causing economic development will lead to numbers of primary energy resource requirements as shown in Table 1. Even the lowest number may cause unacceptable stressing of the global environment. It is clear that in the far distant future only renewable or non-depletable resources will be able to meet our needs. While they appear attractive today, it is highly likely that as we get to know them and understand all of their effects and requirements, they too will have their share of problems. It is important to understand the shortcomings of renewables as soon as possible, even if we cannot assess their net cost or benefit at the present time.

A New Approach: Analysis of the Architecture of the Whole Energy System (AWES)

In a simplified form, the two phases of the world energy system are depicted in Figure 1. Phase I starts with primary energy resources, either depletable*, such as fossil, geothermal, nuclear, etc., or non-depletable, such as agricultural waste, biomass, gravity, ocean thermal, solar, tidal, wave energy, wind energy, etc. The primary resources with inputs are then refined and/or converted into commercial or manufactured energy forms—butane, chemical feedstocks, diesel fuel, electricity, gasoline, heating oil, jet fuel, natural gas, propane, etc., leaving residuals and producing emanations. In Phase II, commercial energy forms are then employed in a variety of devices and processes with perhaps additional inputs to enable services and functions, such as agriculture, food preparation, lighting, manufacturing, minerals extraction, national defense, space conditioning, transportation, etc., also leaving residuals and producing emanations.

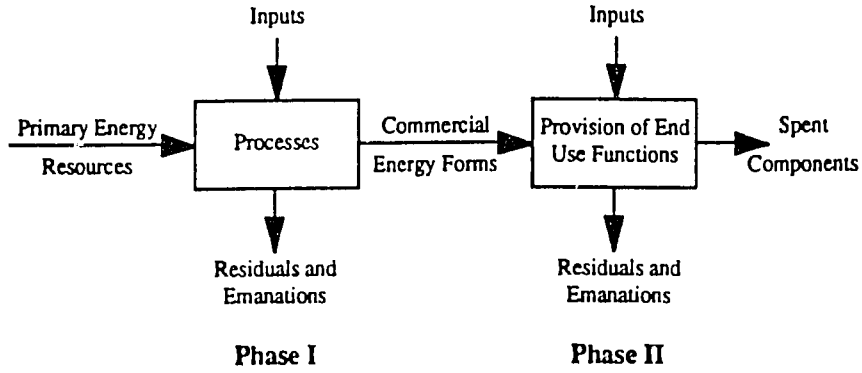


Figure 1: World Energy System

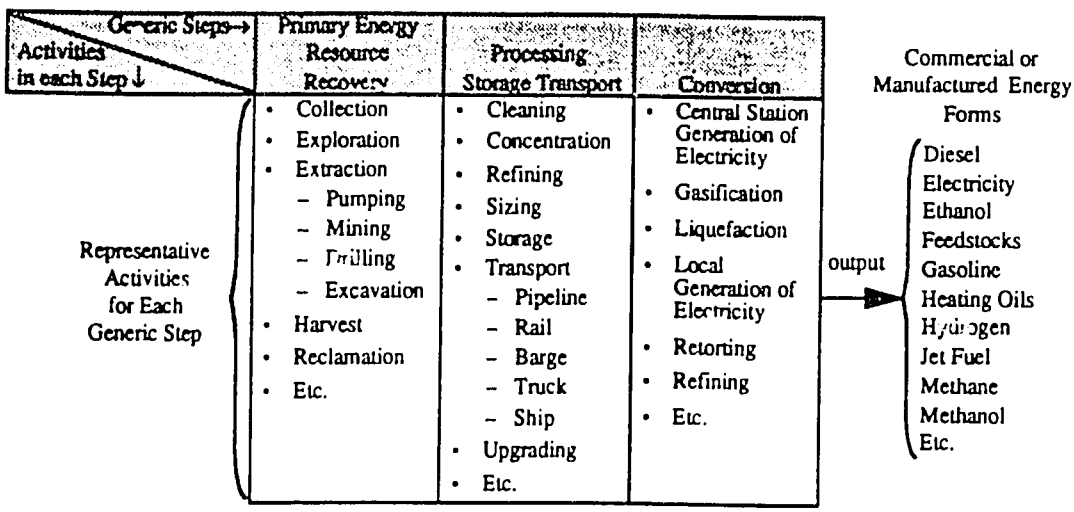
The end use functions are rich in their range and choices, e.g.: transportation can be of people or goods; on land, sea or in the air; long distance or short distance, slow or fast, in an automobile, in a mass transit vehicle; etc. Even a particular choice like an automobile can be powered by several fuels in various types of engines, on or off the vehicle, etc. It is indeed a complex system. It is useful to become more systematic in viewing such a system, if for no

* The question of depletable or non-depletable (non-renewable/renewable) is one of time—fossil fuels can be renewed but very slowly; nuclear can be extended far to the future with breeders; geothermal is depletable at a particular site, but will be somewhere as long as the earth lives; etc.

other purpose then counting. Within each of the general functions there are, of course, many subdivisions.

What follows is a description of one way to keep track and identify all the effects, impacts, requirements, etc., of going from any primary resource to the provision of a function in such a way that it would be possible to compare the merits of choices on appropriate scales.

Figure 2 shows the generic steps and production of commercial energy forms from primary energy resources in Phase I of the energy system. The primary resources are solids, liquids, gases of the fossil nature, nuclear materials, renewable resources based on the sun and gravity, etc. There can be quite a geographic range of distribution of the steps from resource recovery through processing, storage, transport, and conversion. All could be located at a particular site, such as a mine mouth central station electric plant, or the final refining could be on the other side of the world from the extraction of an oil from the ground, i.e., the generic steps are not as simple as depicted.



There can be multiple processing, conversion, transport, storage, etc., steps—depends upon particular resource (e.g., gas—solid), location (e.g., surface—underground, relation to demand centers), conversion process, and commercial energy form.

Figure 2: Phase I of Energy System Generic Steps in Production of Commercial Energy Forms from Primary Energy Resources

Figure 3 shows the assessments, effects, requirements, impacts for the generic steps in the production of commercial energy forms, which are necessary to identify all costs, benefits, externalities, currently neutral effects, etc. It is important that common units or measures per unit of commercial energy form be employed here. The means for identifying the requirements, i.e., in land use (the number of acres of land), the length of time of the land is sequestered or out-of-service for other uses (e.g., acre years/megawatt year), must be comparable for various paths from nuclear, fossil, and renewable resources to different commercial energy forms. Disposition of spent systems, components, and other residuals have to be identified. In the past, we have not paid sufficient attention to dismantling and disposition of old plants and spent fuel. This has become particularly important with nuclear power plants, but it is equally important with all chemical processing devices and even with the

Generic Steps→ / Effects, etc. in each Step↓	Primary Energy Resource Recovery	Distribution Storage Transmission	Conversion
Capital			
Disposition of Spent Systems Component and Other Residuals			
E-M Fields			
Gaseous Effluent			
Land Use			
Liquid Effluent			
Market Potential			
Nuclear Radiation			
Operations and Maintenance			
Occupational and User Health and Safety			
Process Inputs			
RD&/orD			
Security			
Solid Effluent			
Thermal Radiation			
Water Use			
Etc.			

Commercial or Manufactured Energy Forms

- Diesel
- Electricity
- Ethanol
- Feedstocks
- Gasoline
- Heating Oils
- Hydrogen
- Jet Fuel
- Methane
- Methanol
- Etc.

Figure 3: Phase I—Assessments, Effects, Impacts, Requirements for Generic Steps in Production of Commercial Energy Forms

disposal of working fluids, e.g., refrigerants or toxic substances in batteries and other components. These things may not be a problem—if you are dealing with small numbers—but in the growing global energy system, the numbers are large.

Figures 2 and 3 can be combined in the matrix shown in Figure 4. This matrix, for each primary energy resource, if fully expanded with the generic steps for each particular application allows one to identify all effects, impacts, judgments, requirements, with respect to a particular path from a resource to commercial energy forms and allows comparison with any other path

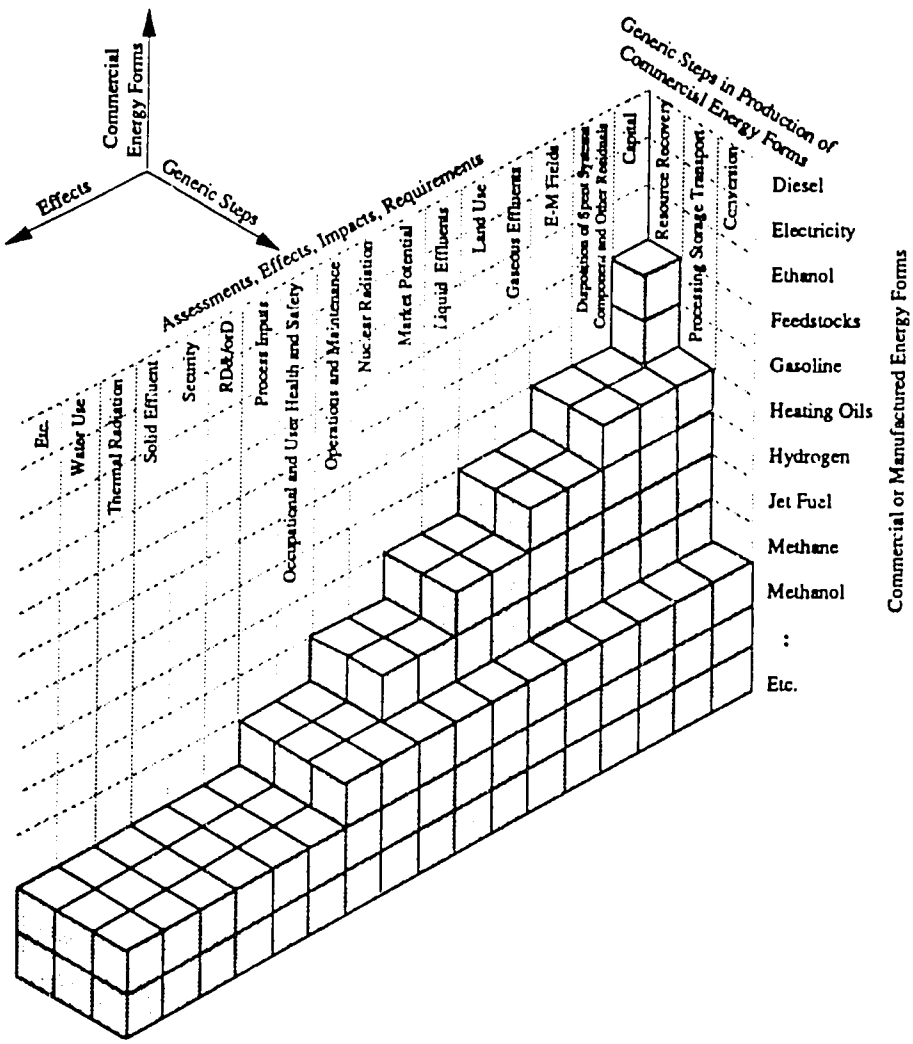


Figure 4: Matrix for Inventory of Attributes of Elements of the System to Produce Commercial Energy Forms from a Primary Energy Resource

for other resources. All possible commercial energy forms have not been shown in Figure 4. There are new reformulated gasolines becoming available, as well as new ultra low sulfur diesel and jet fuels. Other changes such as this may come in the future.

Commercial energy forms are what are available in the marketplace to enable various end use functions. Figure 5 is an aspect of Phase II of the energy system. It depicts generic steps enabling end use functions, showing how commercial energy forms enter the distribution storage or transmission system ending up in enabling generic end uses. This system can be more complex than that shown, in the sense that there can be several transmission and storage steps between refineries, storage yards, retailers, etc. There is an analogous figure in Phase II to that shown in Figure 3, where one must track the effects in each generic step. These can then be combined as shown in Figure 6.

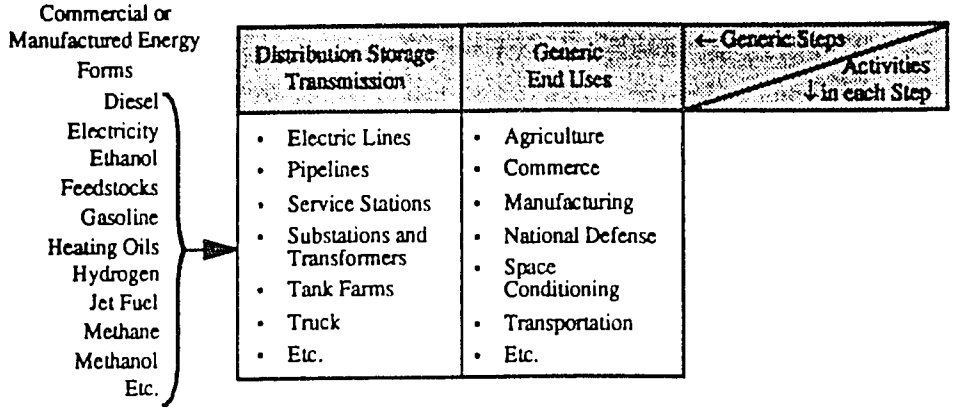


Figure 5: Phase II—Generic Steps in Enabling End Use Functions

Figure 6 is a matrix for an inventory of attributes of elements of the system to enable end use for a given commercial energy form. The combination of Figures 4 and 6 is the total energy system for each resource, but since they are actually separable at the commercial energy form interface, it is convenient to work that way as each of the commercial energy forms are fungible commodities.* One can see that given the knowledge base available to us today, the number of paths from various resources, renewable and non-renewable, through provision of end use functions is staggering. The system is rich and redundant, a strength and a weakness.

It is precisely because of the richness of the existing and the potential global energy system that we need to be more deliberate about being systematic in identifying appropriate architectures, e.g., which resources are best suited for various commercial energy forms, which commercial energy form is best suited for various end use functions. What is the best means of shipping and storage, etc.? Where should operations be located? The best is likely to vary for different regions of the world, but in all cases will be under ever more stringent requirements with respect to environmental, etc., effects.

* One could, in principle, stack the matrix for each primary energy resource one upon the other—all the renewable and unrenewable resources—in order to have the entire energy system in one matrix. However, it is cumbersome to look at it in that form.

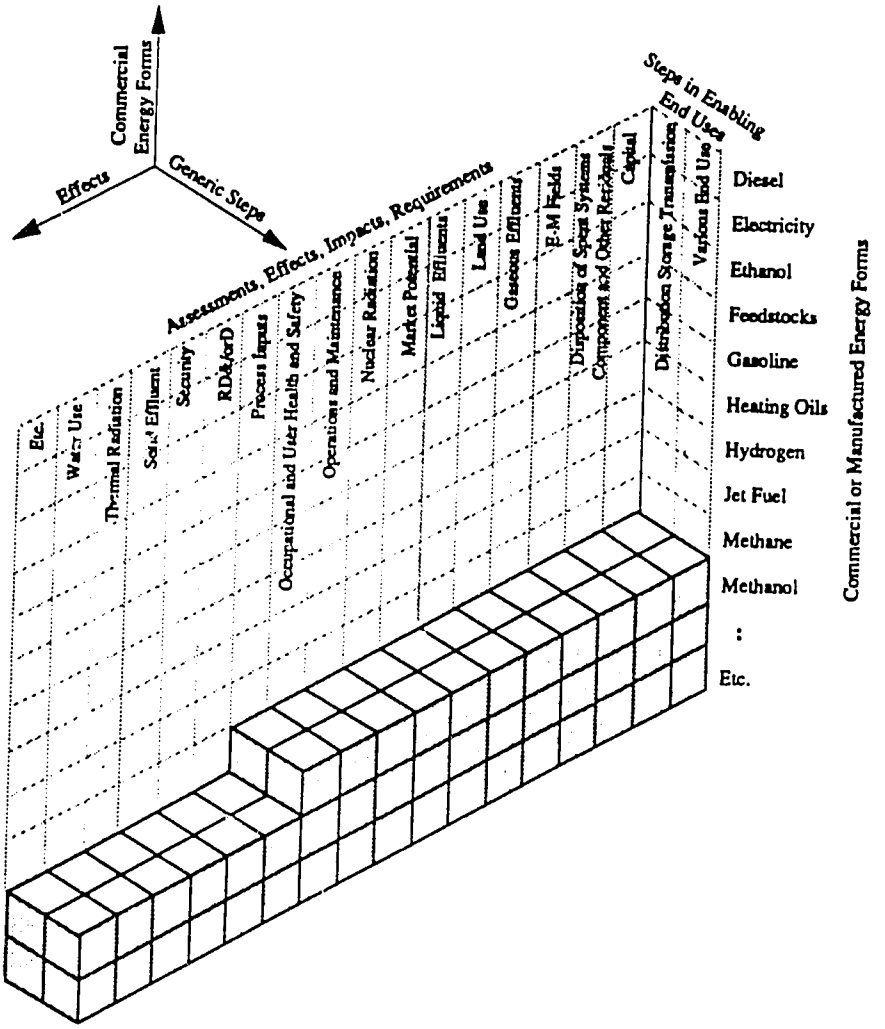


Figure 6: Matrix for Inventory of Attributes of Elements of the System to Enable End Use for a Given Commercial Energy Form

Preparation of an analysis that would permit real comparisons of alternate choices will be a multi-disciplinary process and must identify all of the effects and how they will be dealt with over the whole life cycle of the system. In many cases, the data will not exist or will have conflicting values, in which case uncertainty bands must be included in our system description. The work should begin at the local level, grow into a regional analysis, and then be integrated on a global basis with feed back.

Because technology and regulations change, with time, the analysis must be dynamic in the sense of dealing with the evolutionary and transition issues of going from where we are today to where we might be, with allowance for the time constants in the infrastructure and end use

hardware, especially central station, habitat, and transportation infrastructure. It is unreasonable to believe that in the absence of compelling forces, we will abandon useful capital equipment and structures.

With all the models that have been developed, the computational, database, and graphics display technologies available, the rapidly emerging global multi-media communications systems, it should not be difficult to begin describing the system. It must be done in such a way that objective comparisons can be made between alternate paths and choices and that the form of the comparison be understandable and credible to the decision makers in the process. This includes the public.

While it is important to deal with regional differences with respect to resource availability, history, state of economic development, cultural preferences, one must also deal with the emerging global economy. Because of rapid spread of information and multi-national companies, the infrastructure and end use function technologies are not likely to be that different, even though there will be strong competition among providers. Also, of the commercial energy forms, the fraction used as electricity increases as development proceeds. The number of other commercial energy forms that are likely to be used on a global basis may be limited. So while there will be regional differences, there will also be global similarities.

The basic purpose of an analysis is not to provide a solution, but to display the choices in such a way that they can clearly be compared. This permits more rational decisions about preferred architecture or ways in which commercial energy forms and end use functions are to be supplied and how that will vary over time in different regions. The basic building of the information should be technically based in order to avoid value judgments that are best treated in the political arena. This does not mean that externalities should not be internalized where there is an agreed upon basis to do so, but many effects can only be quantified as to amount, strength, size, etc., not valued. Much research needs to be done in order that there be an agreed upon way to internalize costs of externalities. This would be one of the dynamic evolutionary features of AWES. As society comes to terms with values for effects, the costs can be put into the analysis as a technical factor. Where there is not an agreement on values, effects must be identified, and the various political processes will assign values. Because of the consideration of scale of implementation, most important is the identification of all effects that emerge. Scale will identify significant effects that are often overlooked on a short-term small-scale basis.

The conduct of such an analysis would suggest basic, as well as applied energy research activities that could point the way to beneficial modification of the global energy system architecture. It would provide a methodology for assessing the potential value of new applied energy technology. We believe that with improved insights and understandings, there could be major improvement in the planning and prioritization of public and private energy RD&D programs and the allocation of available energy RD&D resources. The analysis would inform national planners and policy makers of the potential effects of economic, environmental, and other regulatory changes in the evolution of the energy system. It would allow anticipation of broader policy issues that might arise from the longer-term consequence of changes in the architecture of the system. AWES analysis would also bring about a broader foundation for improved international dialogue and coordination of energy and environmental issues among the world's planners and policy makers.

Implementation

To begin such a process, we need broad participation. However, the home for the collection and inputting of information and data for the comparative aspects of various architectures of the energy system ought to be an objective, analytical organization—perhaps a new one, perhaps an offshoot of the United Nations, the International Energy Agency, or the World Energy Council. Advocates, of course, must be allowed and encouraged to have full access with their ideas and information, but some group without predilection towards a particular solution will have to evaluate the data, assign uncertainty ranges, and raise the appropriate questions. Advocates are optimistic and need to be, for if they were not, there would be very little new. However, the comparison of alternate paths on a regional and global basis to produce the commercial energy forms to provide for end use functions needs to be objective, and comparison of future systems must have appropriate uncertainties incorporated.

We have used a set of figures and a matrix organization to describe the energy system. This is not the only way. However, it does have elements that are useful. The matrix boxes provide for a database structure for computer storage and access of information. This organization can also be easily visualized and readily expanded for new conversion and processing technologies or effects in either Phase I or Phase II of the energy system. The important elements are completeness; standard units for comparison for effects in relation to inputs and outputs; and standard ways of presenting uncertainties, risks, and unknowns. Probably much of the information needed exists. Data that is not available for pathways otherwise attractive identify priority research areas.

For example, today we see much about the hydrogen economy, using that form of energy carrier to enable our end use functions because of the low pollution resulting from the combustion of hydrogen. This, in fact, may be the way to go. However, unless one looks at how the hydrogen is produced, it is not clear that making storable hydrocarbon liquid from water and the carbon in the atmosphere is not a better way to go. It is only by a complete resource to commercial energy form to ultimate end use analysis that one can understand all the requirements, effects, etc. Similar questions can be raised with respect to concurrent programs to encourage the use of alternate fuels in various transportation applications—natural gas, ethanol, methanol—as well as reformulated gasoline. Then one must look at the total resource through end use to understand which in fact is the more desirable.

Institutional Framework

As already indicated, one needs an objective home for this work; for without objectivity and hopefully, credibility, it will not be of sufficient value to warrant the effort. Therefore, we must somehow be creative in getting this done. Since the energy system and technologies are global, though built up of local and regional activities, there ought to be an agreed upon framework of units and system description, so that analysts from various locations can readily access and provide information. The technology to provide access from anywhere in the world is more or less in place and improving rapidly. What is important is to have the information put together to be used by various types of decision makers understandable and available.

Complex political processes will arrive at the decisions. However, to enable those responsible for overall architectural choices and major investments, etc., we need to implement something like the system described earlier in this paper, that is a systematic way of accounting for everything including associated uncertainties. Because the energy system will be huge, and even if developed with appropriate regard for "externalities," it will not be without effects or riskless.

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EFFICIENT USE IN INTEGRATED REGIONAL ENERGY SYSTEMS

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1. THE IMPORTANCE OF TECHNOLOGICAL DEVELOPMENT

Technological development for sustained progress involves a vast gamut of technologies, some already existing and others currently undergoing development. While technological development related to clean coal utilization is obviously an extremely effective tool for solving energy supply and demand as well as global environmental problems, future technologies for coping with energy and global environmental problems involve high-grade and complex systems, which require long lead-times to be made practicable. Hence, it is very important to conduct technological development with a long-term perspective and full consideration of the related systems' characteristics in the community level.

In terms of energy supply, the development of technologies related to the assurance of stable electric power supply is very important.

With regard to energy demand, the time has come to direct our environmentally-friendly energy vision toward the community level and maximize the introduction into urban areas of clean energies, such as solar energy and full utilization of waste heat from small scale coal-fired power stations. One very important feature of rationalized energy utilization at the community level is the promotion of cascaded energy utilization systems, as well as garbage and natural-resource recycling systems.

The research phase of CO_2 recovery from coal combustion and utilization is expected to be completed around the year 2010, when the technology is to become practicable, albeit costly. Developments should thus be made in technologies incorporating CO2 recovery and utilization into the above-mentioned systems.

As it has been previously mentioned, the systematic integration on a regional level of these individual technologies toward improving the quality of our environment is of paramount importance for the future.

2 AN INTEGRATED APPROACH TO URBAN ENERGY SYSTEMS

Energy and environmental problems in the 21st century will inevitably have a global character, which means that energy and environment measures developed to meet the needs of specific countries, such as Japan, will be of use and necessity to other countries as well. If the related technologies are thought of as International Public Property, it becomes necessary to establish an open-door international cooperation system from the research and development stage, and to actively promote technological transfer so as to broaden the dissemination of R&D results. Such international cooperation will make it possible to tackle global environmental problems on a world-wide level and ensure mutual benefits to all countries involved.

2.1 CLEAN ENERGY LARGE NATIONAL PROJECTS IN JAPAN

Japan now accounts for 5% of the total world energy consumption and, next to the United States, is the world's second largest user of energy. A plentiful, inexpensive supply of petroleum enabled Japan's consumption of energy to increase swiftly as it did during the early 1960's. Since then, however, all of this petroleum has been imported and, as demand increased, self-sufficiency in energy fell from 76% in 1955 to only 19% today.

With this background, the *Sunshine Project* was initiated in 1974, with the aim of securing solutions to basic energy problems and at harmonizing energy utilization with the need to protect the environment. This project is the first large-scale, long-term technological development effort which deserves to be designated as a national project. It has as its object all aspects of new energy technology, with the exception of nuclear power technology.

Major development targets have been set in four fields:

◊ Solar Energy,
◊ Geothermal Energy,
◊ Gasification and Liquefaction of Coal,
◊ Hydrogen Energy.

Research and development also include alternative energy sources such as wind ocean, etc.

Another large national project, nicknamed *Moonlight Project*, was launched in 1978 as an R & D program for developing advanced energy conservation technology, now being carried out by the Ministry of International Trade and Industry's *Agency of Industrial Science and Technology*. Under the *Moonlight Project*, R & D on energy conservation is conducted systematically by national laboratories, private firms and universities working in cooperation.

The name *Moonlight Project* was chosen because energy conservation technology should enable the efficient use of even small amounts of energy, as the moon shines by reflecting light from the sun.

Recently, five large-scale projects have been carried out:

◊ Advanced Battery Electric Power Storage System,
◊ Fuel Cell Power Generation Technology,
◊ Super Heat Pump & Energy Accumulation System,
◊ Superconducting Technology for Electric Power Apparatuses,
◊ Ceramic Gas Turbine Project,

The *Research and Development Project for Environmental Technology* includes studies on carbon dioxide fixation by artificial photosynthesis, separation of carbon dioxide, and biodegradation of chemical compounds.

These projects, which have been carried out in parallel, have lead to the accumulation of a substantial technological stock for effectively coping with energy constraints.

The global environmental consequences of energy use are now calling for a comprehensive approach in paving the way for sustainable economic growth by overcoming energy and environmental constraints simultaneously. In response to this urgent need, MITI has established *The New Sunshine Program* (R&D Program on Energy and Environmental Technologies) by integrating the *Sunshine Project*, the *Moonlight Project* and the *Global Environmental Technology Program*. Through the integration of these R&D activities, effective and accelerated achievement of R&D in the field of energy and environmental technologies is expected by means of co-utilization and supplementation of various technologies common to new energy, energy conservation and environmental protection.

2.2 The New Sunshine Program

The *New Sunshine Program* comprises the following three technological systems.

[1] Innovative technology development: The development of innovative energy and environmental technology is accelerated to implement the *Global Warming Prevention Action Plan*, while focusing on important subjects in the course of progress.

[2] International, large scale collaborative research: An international, large scale collaborative research program is prompted to implement *Earth Regeneration Program "New Earth 21"*.

[3] *Collaborative R&D on Appropriate Technology*: A collaborative research and accelerated development program is promoted for fitting energy and environmental technology to the conditions of the partner country to ease energy restrictions and address environmental concerns in neighboring developing countries.

Figure 1 illustrates the concept of the *New Sunshine Program*. The development of innovative technology will contribute to the *Global Warming Prevention Action Plan* of Japan, while the collaborative R&D on appropriate technology will contribute to innovation in neighboring developing countries. The results of these two projects as well as international, large-scale collaborative research will contribute to the *Earth Regeneration Program*.

Figure 2 shows the contribution of the *New Sunshine Program* to the *Earth Regeneration Program*, while Figure 3 shows the increasing contribution of the *New Sunshine Program* to the domestic energy supply and to the reduction of carbon dioxide emissions.

Among the many subjects in the new energy and energy conservation technologies that have been studied in the *Sunshine Project* and the *Moonlight Project*, solar cells and fuel cells show a "positive circulation", or favorable synergistic effect. The development of technology for these led to an increase in demand and a reduction in cost, which was triggered by major recent technological innovations. Nevertheless, full scale introduction of the technology still requires lead time to establish sufficient production capacity and develop adequate marketing. Therefore, research and

development of solar cells and fuel cells must be accelerated to maximize their supply potential and realize the supply of energy alternatives to oil for the *Global Warming Prevention Action Plan*.

Figure 4 shows a cost reduction scheme for these two technologies. Accelerated promotion of the *New Sunshine Program* will reduce the cost of electricity from both technologies to ¥20/kWh by the beginning of the year 2000. Innovative technologies are expected to contribute markedly to the solution of energy and environmental restrictions in the medium to long term.

Three innovative technological subjects were initiated with the *New Sunshine Program* in addition to the continued, accelerated implementation of research and development of subjects such as solar cells and fuel cells from the *Sunshine Project* and *Moonlight Project*. These new subjects were derived from the results of the *Sunshine Project* and *Moonlight Project* and are expected to yield significant medium to long term benefits:

[1] Broad area energy utilization network system technology (Eco-energy City System),
[2] International Clean Energy Network using Hydrogen Conversion (*World Energy Network: WE-NET*),
[3] Economically and environmentally compatible combustion system (Lean burn de-NOx catalyst system).

Coal is expected to show a drastic world-wide increase in demand. The *New Sunshine Project* deals with coal conversion technology in response to the increasing request for its use under environmentally friendly conditions. Coal conversion technology that has long been under study is integrated with hydrogen production technology using renewable energy and lean burn de-NOx technology to develop the *Environmentally-Friendly and Economically-Viable Coal Conversion Complex Technology*. These technological development issues are outlined below:

◊ *Broad area energy utilization network system technology (Eco-energy city system)*, Figure 5.

Outline: Advanced cascaded and combined thermal energy recirculation system based on innovative technology that recovers waste heat from facilities and transports the recovered energy efficiently to remote urban consumption areas.

Breakthroughs: [1] Key technology developments: heat recovery technology with a maximum utilization of sensible heat and with temperature lifting technology; heat transport and storage technology using chemical reactions; and multi-functional heat supply technology.
[2] Structuring and optimizing the total system by matching multiple and wide-area heat sources to the energy demand.

Expected results: When unexploited energy in coastal industrial regions near major urban areas is used to the maximum extent, Japanese energy consumption can be reduced by 6% and CO_2 emissions can be reduced by 9%.

◊ *International clean energy network using hydrogen conversion (World Energy Network: WE-NET)*, Figure 6.

Outline: World-scale clean energy system based on innovative technology from production and transfer to consumption using hydrogen as the medium.

Breakthroughs: [1] Development of elemental technologies relating to hydrogen utilization: high efficiency and large scale hydrogen production technology; high density hydrogen storage and transfer technology; and hydrogen turbine technology.
[2] Structuring and optimizing world-scale systems related to production, distribution and utilization.

Expected results: When fully implemented, the system will contribute to the reduction of world-wide CO_2 emissions by 10% in 2030 and 20% in 2050.

◊ *Economically and environmentally compatible combustion technology (lean burn de-NOx catalyst technology)*, Figure 7.

Outline: Exhaust gas de-NOx catalyst technology applicable to diesel engines and lean burn engines aiming at the improvement of vehicle fuel costs and the simultaneous reduction of CO_2 and NOx emissions.

Breakthroughs: Development of elemental technologies related to new catalysts: analysis of material and structure, heat resistance, corrosion resistance, and improvement of catalysts' life in atmospheres with high oxygen concentration.

Expected results: Compared to conventional systems, the technology contributes to reducing Japanese energy consumption by 2%, and reducing CO_2 emissions by 2% and NOx emissions by 40%.

◊ *Environmentally Friendly and Economically Viable Coal Conversion Complex Technology*

Outline: Coal liquefaction complex technology aiming at drastic reductions of product cost and CO_2 emissions by combining a hydrogen production system employing renewable energy and a de-NOx lean-burn combustion system.

Breakthroughs: [1] Establishment of key technologies related to coal liquefaction.
[2] Integration of hydrogen production and lean-burn catalyst technologies with coal liquefaction technology

Expected results: Reduction of CO_2 emissions by 2%; reduction of product cost from $35/bbl to $25/bbl.

3. THE NEED FOR AN INTEGRATED APPROACH TO URBAN ENERGY SYSTEMS

In general, energy conservation has been largely concerned with the improvement of elemental technologies, like the quality of heat insulation or the efficiency of individual machines such as exhaust-heat boilers or heat pumps. Although unquestionable achievements have been made in these domains, we have now reached a stage where furtner improvements call for a more systematic and functional approach to energy utilization.

Several measures can be taken in this direction; from an engineering perspective, this includes rationalizing the utilization of energy in its multiple forms and creating complex energy systems that encompass heat utilization and power recovery with maximized exergetic efficiency. The following systems deserve attention, as representative of effective energy-conserving technologies.

1. Cascaded Energy Utilization Systems;
2. Co-Generation Systems;
3. Unexploited Energy Utilization Systems.

The systematic combination of these three technologies enables the creation of large-scale centralized electric power generation plants for a highly efficient and stable supply of heat, electricity and power. The fact that both cascaded energy utilization and co-generation systems cannot materialize without an efficient utilization of mid to low temperature waste heat further emphasizes the social importance of unexploited energy utilization systems, particularly from a long-term perspective.

3.1. CASCADED ENERGY UTILIZATION IN REGIONAL INTEGRATED SYSTEMS

The cascaded use of energy, i.e., multi-stage use of energy with consideration given to its quality, is extremely rational from a thermodynamic viewpoint. This concept is applicable to thermal energy (multi-stage use by temperature level) as well as heat-and-power (co-generation) and electricity (combined cycles and re-powering).

Future cogeneration systems are expected to greatly benefit from an extensive use of fuel cells.

Fuel cells are electrochemical energy conversion devices for direct conversion of fuel chemical energy into electric energy, which feature high efficiency, low pollution, multi-fuel capability, ease of location and are expected to be applicable to a wide range of power generating systems, such as large-scale centralized, suburban, on-site and other types. In Japan, fuel cell technology development has been proceeding with comprehensive R & D on fuel cell types such phosphoric acid, molten carbonate, solid oxide and others.

For the phosphoric acid fuel cell, two different types of 1000 kW power generating systems and 200 kW on-site systems are being developed. The former has undergone a successfully rated output run in fiscal 1987 and the latter, expected to be put into practical use in the near future, is undergoing R & D on applications to isolated islands and commercial utilization.

The molten carbonate fuel cell is characterized by a higher efficiency in comparison to the phosphoric acid type and can be utilized with coal gas. 10 kW class stacks have been developed for fiscal 1986, and the accomplishment of 1000 kw class power generating systems is expected

for fiscal 1995. The solid oxide fuel cell, which may be the most efficient in the future, is undergoing development on elemental technologies.

In order to apply the concept of cascaded heat utilization, efforts should be made to form the ideal energy flow among industrial processes classified by their temperature levels, including lower temperature levels below environmental conditions, such as LNG. In Japan, LNG is stored at the temperature of -160°C and usually evaporated by sea water, but this exergy should be recovered by industrial processes at its highest efficiency limit.With this point of view, the author suggests a representative example of ideal exergetic utilization with a cascade form as shown in figure 8.

An effective utilization of this system requires the incorporation of co-generation, heat-pump and energy storage technologies. Predicted rises in electricity demand coupled with difficulties in long-distance heat transport further enhance the merits of this system. Figure 8 , needless to say, assumes the existence of a base-load supplied by a a large-scale, centralized electric power plant. The current need for effectively utilizing the vast amounts of waste heat that result from electric power generation may make it necessary to scale down power plant sizes to a certain extent, and locate them in the vicinity of areas with high heat-and-electricity demand. Typically, co-generation systems are broadly divided into topping cycle and bottoming cycle, the former involving direct generation of electricity by fuel combustion with gas-turbines or fuel cells, and the latter consisting of power recuperation from waste heat.

In the case of Japan, topping cycle co-generation has rapidly diffused into the industrial sector, while an expansion into the commercial/residential sector requires support by regulatory provisions and technological advances in areas such as heat-electricity ratio control and freedom from maintenance. Another important element regarding the energy utilization situation in some countries is the distinction made by the government between primary energy supplied for Electricity Generation and that for purposes Other Than Electricity Generation. In Japan, 37% of the primary energy (nuclear, geothermal fossil fuels and others) is utilized for electricity generation, and the remaining 63% is used for purposes other than electricity generation, as shown in Figure 9 (a). If energy utilization is to be rationalized by adopting co-generation and cascaded use technologies, however, this parallel distinction between energy for electricity and other purposes must be thoroughly reformulated .

The basic concept of cascaded energy use involves fully harnessing the heat generated by fuel combustion, from its initial 1800°C down to near-environmental temperatures, with a thermal "downflow" of heat analogous to the downward flow of water in a cascade. One obvious example of such utilization is the use of cogeneration systems where a heat engine generates power and converts it into electricity, and the exhaust heat is utilized in industrial processes and/or in heating,cooling and hot water supply systems for the commercial/residential sector. Such systems, where both heat and power/electricity are generated and used, can only be fully efficient if electricity and heat are managed not in the conventional "parallel" way, but in a "serial" manner. As cascaded use and cogeneration systems such as fuel cells become more widespread, the cases of simultaneous heat and electricity generation at the same location tends to increase.

While heat demand in industries and hotels, for example, has hitherto been met by using boilers, the advent of cascaded energy use will require the use of engines instead of heat-only generating boilers, which are no longer a thermodynamically sound option. A more widespread use of engines as heat sources will mean more electricity generated as heat is produced, which will require careful reformulation of the future energy supply structure to accommodate these much-needed changes

As has been mentioned earlier, a highly important task from now on consists of determining how unexploited energy, including low to mid temperature waste heats can effectively be utilized within such systems. Significant developments in energy conservation by waste heat recovery can be achieved if near-environmental temperature waste heats can be effectively utilized as heat sources for heat pumps. While heat pump technology has an enormous potential in terms of carbon dioxide reduction, developments in bottoming cycle co-generation are also highly important for effectively utilizing large amounts of industrial waste heat. A systematic combination of heat pump and co-generation technologies is thus highly desirable from the view point of establishing a free interchange of energy between different economic and geographic sectors.

The author firmly believes that we are now at a time when energy utilization must not confine itself to one specific sector, but rather be functional as a system, in an organic combination

where mutual profits are ensured to a multitude of corporations. Positive action in promoting the development of new integrated industrial/commercial community projects is essential in the establishment of new environment friendly communities with minimized exploitation of energy resources.

Furthermore, if future needs for carbon dioxide fixation and recycling are considered, as shown in Figure 10, the development of poly-generation systems may contribute not only to energy conservation but also to environmental preservation. Figure 9 (b~f) outlines possible cascaded systems for utilizing energy in a serial flow manner.

4. UNEXPLOITED THERMAL ENERGY UTILIZATION IN THE REGIONAL COMMUNITY LEVEL

Among the energy systems shown on figure 8, one aspect which deserves particular attention is the rational utilization of near-environmental thermal energy to meet the heat demand of the commercial/residential sector as shown in Figure 9 (f).

In the case of Japan, for example, the growth in heat demand for HVAC and hot water supply systems in this sector has been exceeding twice the national growth rate of energy consumption. It must be noted, however, that most of this demand can be met by heat sources of relatively low temperature, below 100 °C. Hence, rather than using high-grade energies as heat sources it can be very appropriate, also from a thermodynamic viewpoint, to construct systems capable of utilizing hitherto overlooked and unexploited low-grade energy sources.

If one looks at urban areas with high heat demand, one will find that this demand can be met and even exceeded by utilizable yet unexploited nearby energy resources which include not only waste heat from electric power generation and garbage incineration plants but also river and sea water—whose temperatures differ from the atmospheric throughout the year—as well as sewage, for example.

High-temperature heat supply, which utilizes steam or other latent-heat media and has a broad application range, is generally regarded as the most desirable heat transport system. If, however, heat demand in the non-industrial sector is emphasized, from a different perspective, it becomes possible to meet most of the demand with low to mid-temperature waste heat. Moreover, by making extensive use of absorption and super heat pumps, it is possible to broaden the range of unexploited heat utilization and effectively use low-temperature heat sources and heat sinks at near-environmental temperature, such as river and sea water.

In an effort to construct district heat supply systems utilizing unexploited energy sources, the Japanese government (MITI) has been promoting R&D on large-scale, high-efficiency machines, heat transport technologies, large-scale heat storage, and the planning/operation of optimized systems combining these technologies. An expansion of district heat supply systems through dramatic increases in the efficiency of unexploited energy utilization systems is expected to assist in reducing and optimizing energy consumption, and hence in peak-shaving the electric power demand, particularly by the residential/commercial sector. An example of a development project incorporating these concepts is shown in figure 11. The project is scheduled for implementation between 1991 and 1997. Design and manufacture will be completed by 1994, and verification studies will be conducted beginning in 1995.

4.1 REQUISITES FOR THE UTILIZATION OF URBAN UNEXPLOITED ENERGY

Difficulties in long-distance heat transport make it desirable to have heat supply networks in areas where demand exists within relatively short distances. From this viewpoint, emphasis can be placed on urban areas where heat demand is concentrated.In particular, the recent trend for more amenity-oriented lifestyles has brought very rapid increases in heat demand for building climatization and hot-water supply in the non-industrial sector, thus making it very important to rationally utilize low to mid-temperature waste heats.

The potential for unexploited heat utilization in the Tokyo metropolitan area has been surveyed by the Agency of Natural Resources and Energy, and unexploited energy was found to be available in excess of the heat demand. Thus, the construction of unexploited energy utilization systems as part of the social infrastructure, with due consideration to various factors such as temperature level and geographic distribution of heat sources, can result in substantial benefits to urban areas, where the demand for energy is highly concentrated.

This concept of unexploited heat utilization systems requires fulfillment of a number of conditions for implementation, namely:

- ◊ As a pre-requisite, there must be heat supply networks within each specific area. The inter-connection of several such decentralized, relatively small-scale networks will then originate a large-scale heat supply network.
- ◊ There must be a consensus that heat supply pipelines constructed over wide areas are part of the social capital and that the provision of a stable and efficient supply of heat is the responsibility of local governments.
- ◊ Also, a consensus must be built among the citizenry with regard to legally enforcing the shift from decentralized heating and cooling to centralized systems utilizing unexploited heat.

The planning and establishment of such unexploited energy networks as part of the social infrastructure requires the solution of several problems, many of which are of technical nature. These technological improvements must not be restricted to the establishment of criteria for standardization and the development of elemental technologies, but must also involve a better understanding of overall system performance improvement by means of empirical experimentation. In particular, substantial contributions to the diffusion of unexploited heat utilization systems can derive from standardization and the resulting hardware cost-reduction, provided that the temperature levels of collected and discarded heat are adequately matched upon the planning and establishment of such broad networks.

4.2. Actual Examples of Energy Transfer Between Industrial and Commercial-Residential Sectors

A few examples of energy transfer between the industrial and commercial-residential sectors implemented in Japan are the use of COG from coke processing plants as sources of town gas, the recovery of heat from Japan Synthetic Rubber's coke combustion ovens for use in a hot water distribution pipeline in the early 1970's, and also the use of waste heat recovered from Japan Heavy Chemical Industry's ferro-alloy combustion ovens for hot water supply to governmental official buildings and old people's homes in an adjacent town (70°C, 30 t/h). Although in the latter case crude oil savings of up to 1000 kl were made possible, examples of industrial heat utilization by the commercial/residential sector in Japan are still rare. Since energy conservation by using unexploited heat is highly desirable as a means of reducing emissions of greenhouse gases, the promotion of energy transfer between the industrial and commercial/residential sectors is highly recommendable.

One such recent example which will be presented here is the use of residual heat from a cement factory for district heating and cooling in Hitachi city (figure 12). This system, which started operation in December 1989, is being run by the Hitachi Thermal Energy Co., established in march 1988 with joint capital from Tokyo Electric Power Co. and Hitachi Cement Co.. Within a total area of 12.5 ha, 107,000 m^2 are to be serviced by the DHC system, which has a maximum supply capacity of 7.682 Gcal/h (8.934 GW) of heat and 10.29 Gcal/h (11.927 GW) of cooling. The serviced facilities include Hitachi's civic center, hotels and offices.

The main heat source of this system consists of industrial waste heat from the cement kilns of the adjoining Hitachi cement factory, which is used to supply hot water and to drive absorption chillers. Residual heat is recovered from a four-stage NSP kiln for the production of 9.4 t/h of steam at 8 kg/cm^2; a plate-type heat exchanger is used to supply hot water at 60°C and a volume of 1560 m^3 is provided for chilled water storage. The factory has a production capacity of 150,000 t of cement per month and requires a heat input of 98 Gcal/h (113.97 GW) into its cement baking ovens. 22% of this heat input is discharged as pre-heater waste-heat gas, of which 6.5 Gcal (7.56 GW) or 6.6% of the total heat input are re-utilized as heat input for the residual-heat boiler. Since the required temperatures are 360°C at the pre-heater's exit and 270°C for clay drying, the intermediate temperature level is utilized by the residual-heat boiler.

One noteworthy feature of this system is that when DHC load fluctuations result in a surplus of heat in the residual heat boiler, the excess heat is used to generate electricity with a T&M-driven, 373 kWh generator. Seasonal and daily load fluctuations in the DHC system are hence absorbed, while the stability of a round-the-clock operation of the kilns throughout the year is ensured by a constant supply of steam. At present, 60% of the residual boiler's heat output is used by the DHC

system and 40% for electricity. As can be seen by this example, due to seasonal and daily load fluctuations only about half of the industrial waste heat can be utilized for DHC, but by it coupling with electricity generation an effective use of energy can be realized.

An example of integration of a steel manufacturing plant into a regional community is shown in Figure 13 , where waste heat generated from the coal-intensive steel manufacturing plant is utilized for supply into the community energy network. While the amount of waste heat recoverable from a 4 million ton steel manufacturing plant is about 7.7 Tcal/day, the heat demand from a city of 500,000 people is about 1.9 Tcal/day, so that thermal energy available from the steel works easily outstrips demand from the community.

5. CONSTRUCTING ENVIRONMENT-FRIENDLY URBAN ENERGY SYSTEMS

By utilizing both new and unexploited energies with maximized efficiency, one can break off the connection between amenity-oriented lifestyles and increased energy consumption with resulting augmentations in CO_2 generation. Hence, a substantially large impact can be achieved in terms of accomplishing the goals of global warming prevention plans.One problem which must be overcome for practical implementation to be achieved is the mismatch between heat sources and heat demand in terms of location, time and temperature level. This mismatch cannot be overcome without the provision of large-scale pipeline networks, heat pumps, heat storage tanks, etc. Many countries, such as Sweden, France and others, have hundreds of kilometers of heat pipeline networks as part of their social capital, in district heat supply systems which meet most of their urban heat needs.

In the case of Japan, however, this is a domain in which there is still much to be done: increasing affluence and a shift toward more amenity-oriented lifestyles will require substantial public investment for the provision of a comprehensive energy infrastructure, which is imperative to efficiently meet the surging demand for heat by the commercial and residential sectors.

It is essential that eco-energy be the guiding concept behind the provision of these urban energy systems, whereby early-stage integration with transportation and sanitary networks in urban planning will enable us to bequeath a high-quality energy infrastructure to future generations. Growing heat demand due to urban re-development, water front development and new town construction projects, in particular, calls for joint efforts between the public and private sectors in the establishment of an energy infrastructure making use of unexploited thermal energy.

The concept of rationalized urban energy systems, proposed by the author, is illustrated in figure 14. It can be seen that this urban energy vision encompasses not only the residential and commercial sectors, but also includes conveniently located industries in the surroundings, consisting altogether of greenery, water, commercial, residential and industrial areas. This holistic approach to district development must be actively pursued as, for example, in the creation of towns in the surroundings of existing large urban areas.

These newly-developed areas should be provided with both radial and concentric transportation networks and also with an energy infrastructure capable of recovering waste energy from the industrial sector and transferring it to the residential/commercial sector. The promotion of such integrated industrial/commercial communities should be actively promoted as a means of enabling the free transfer of new and unexploited energies. Furthermore, from an eco-energy perspective, the provision of underground LNG supply and electric power generation facilities can be very effective in terms of cold, gas and electricity supply. It is also very important to effectively use greenery to promote natural air recycling within local areas, thus integrating urban energetic metabolism with material recycling.

Future integration of energy recycling systems and CO_2 fixation facilities into the urban system can also be highly significant from the viewpoint of environmental preservation. For the realization of such functionally integrated systems, it is highly important to have integrated technological development, combining maximized utilization of renewable energies with highly efficient energy conservation. Such a holistic approach can bring about rationalized urban energy configurations that will contribute to global environment preservation.

In conclusion, the author wishes to stress that the widespread use of such a network by a multitude of industrial and commercial/residential entities can result in mutual benefits to all parties, and the active promotion of such new regional development projects can create communities of higher environmental and social quality, with minimized use of primary energy resources. This will result in materialization of the ultimate environment-friendly energy systems.

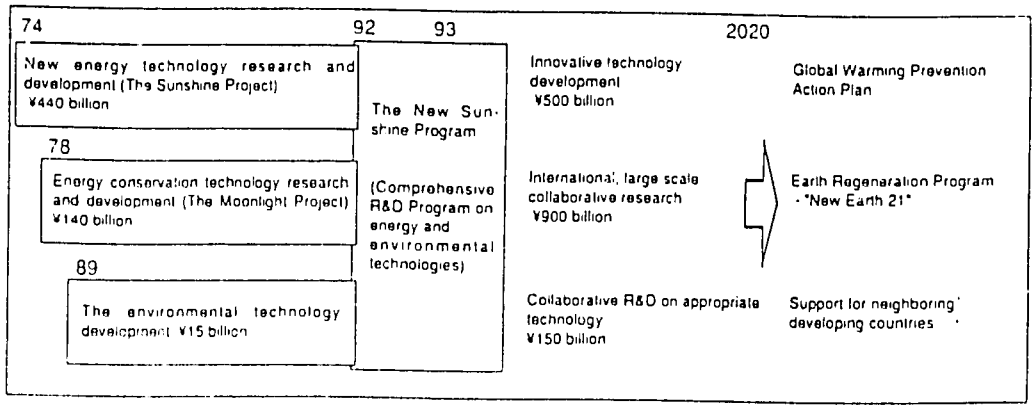


Fig.1 The New Sunshine Program system

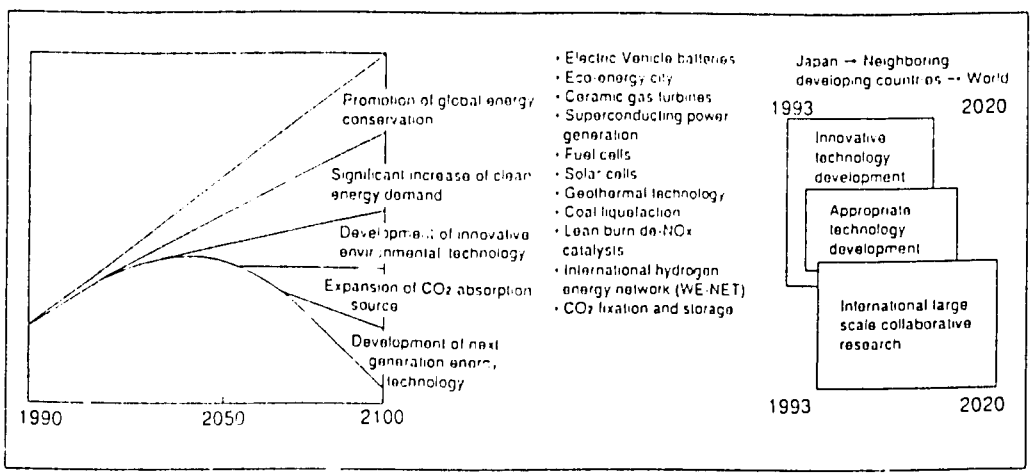


Fig.2 Contribution of the New Sunshine Program to the Earth Regeneration Program

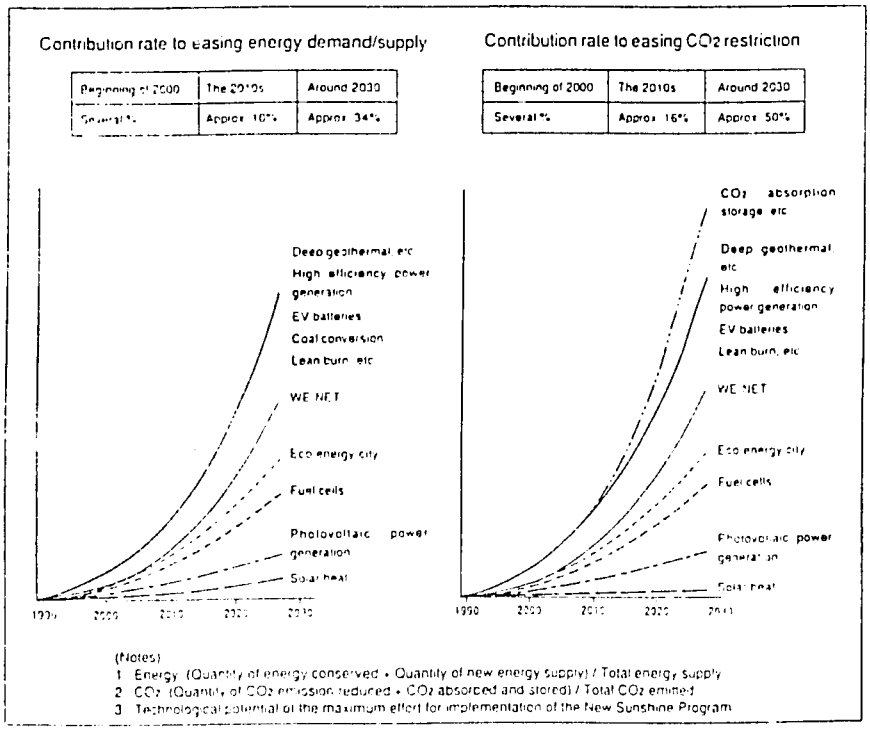


Fig.3 Contribution of the New Sunshine Program to easing energy demand/supply and CO_2 restrictions

1) Solar cell

Improvement of conversion efficiency, mass-production, cost reduction technology

	At the end of FY'92	At the beginning of 2000
Total system	Approx. ¥450/W	Approx. ¥220/W
Cell	Approx. ¥330/W*	Approx. ¥150/W
Peripheral equipment	Approx. ¥120/W	Approx. ¥70/W
Power generation cost	Approx. ¥40/kWh*	Approx. ¥20/kWh

* As of 100 MW/Y plant of production scale

2) Fuel cell

Cost reduction, compacting technology, validation operating study

	At the end of FY'92	At the beginning of 2000
Total system	Approx. ¥800/W	Approx. ¥300/W
Cell	Approx. ¥240/W	Approx. ¥90/W
Peripheral equipment	Approx. ¥560/W	Approx. ¥210/W
Power Generation Cost	Approx. ¥40/kWh	Approx. ¥20/kWh

Fig.4 Expected accelerated promotion of research and development and resulting cost reductions

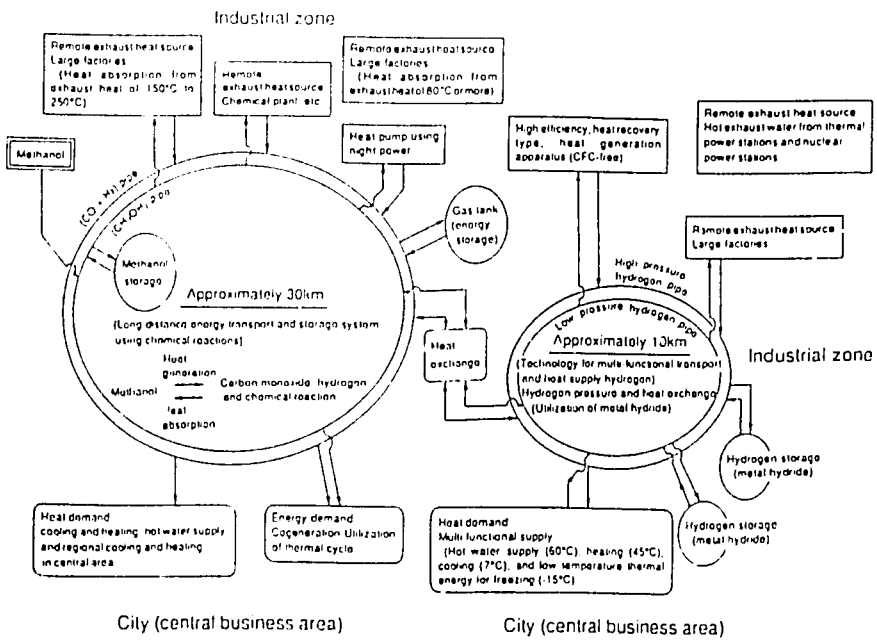


Fig.5 Schematic of the broad area energy utilization network system

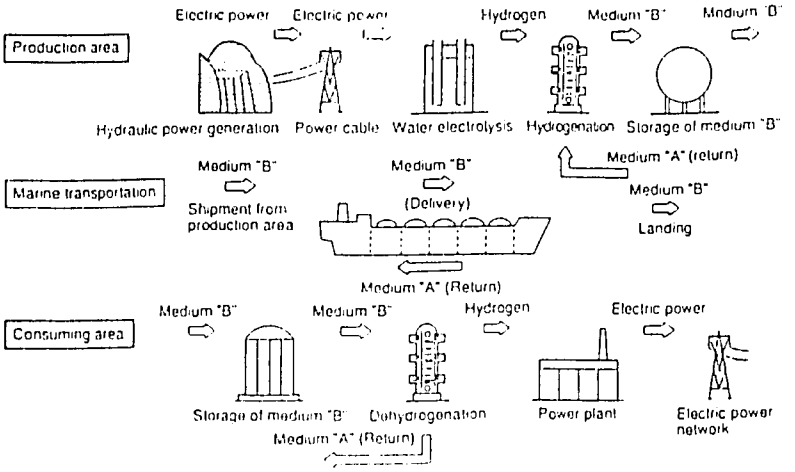


Fig.6 Concept of WE-NET

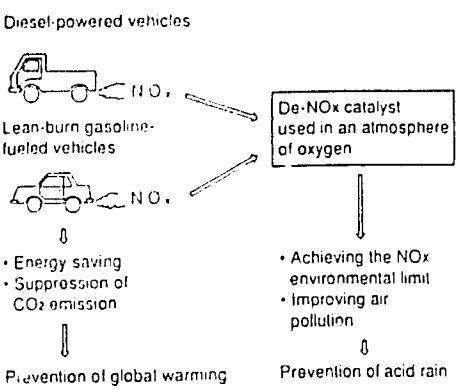


Fig.7 Concept of exhaust gas de-NOx catalyst technology for lean-burn engines

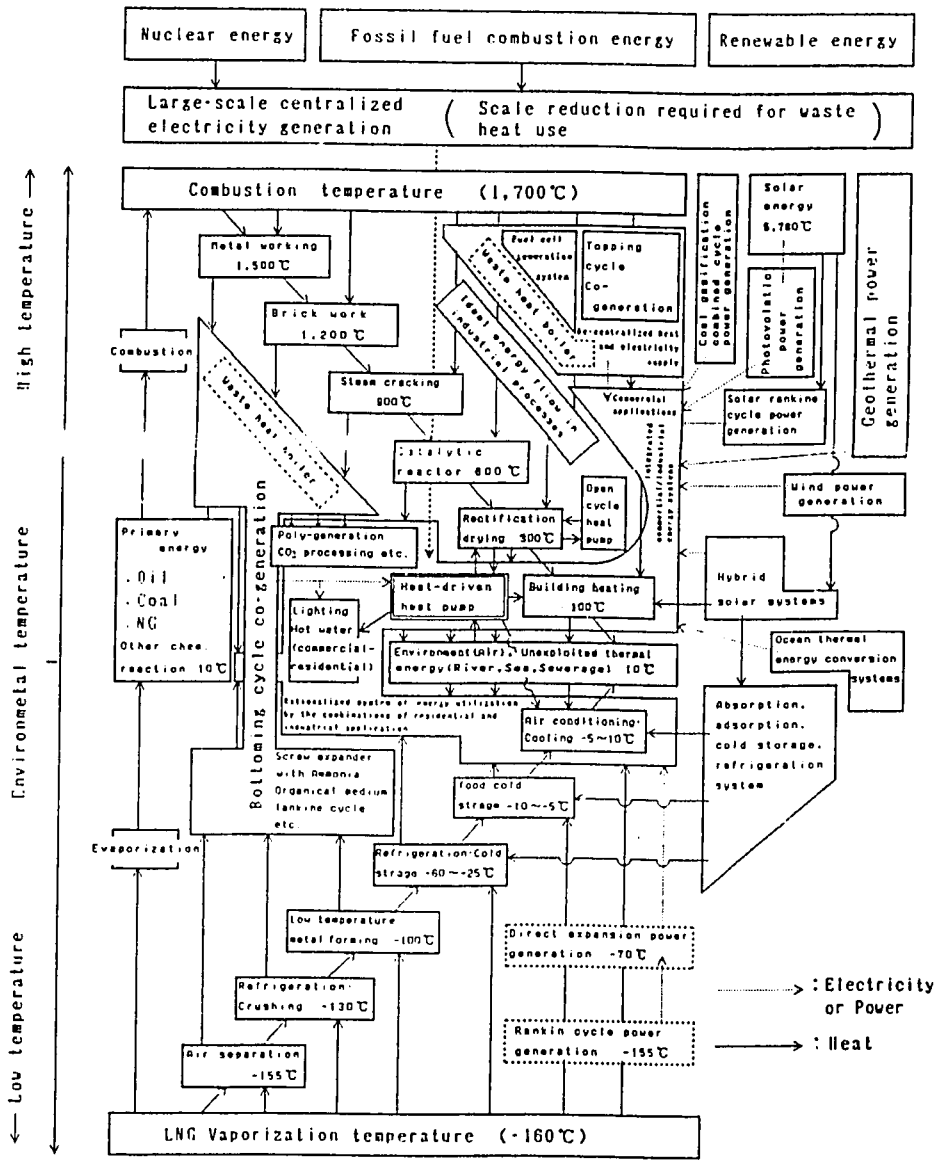


Fig.8 Cascaded energy utilization concept and systems integration

Fig. 9d
Facilities for electric power generation from wastes
Stimulate the use of heat from waste-incineration, which traditionally has not been harnessed as energy.

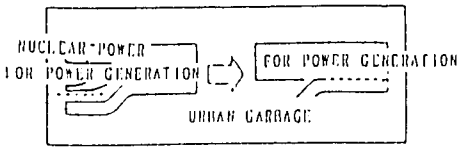


Fig. 9b
Large-scale district supply of cogeneration heat
Expand the use of waste heat from power-generation by locating cogeneration systems in the vicinity of areas with large heat demand

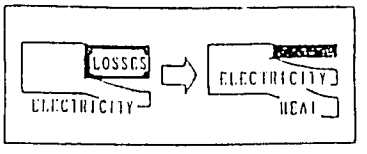


Fig.9a Flowchart of energy supply and consumption in Japan (F.Y. 1986)

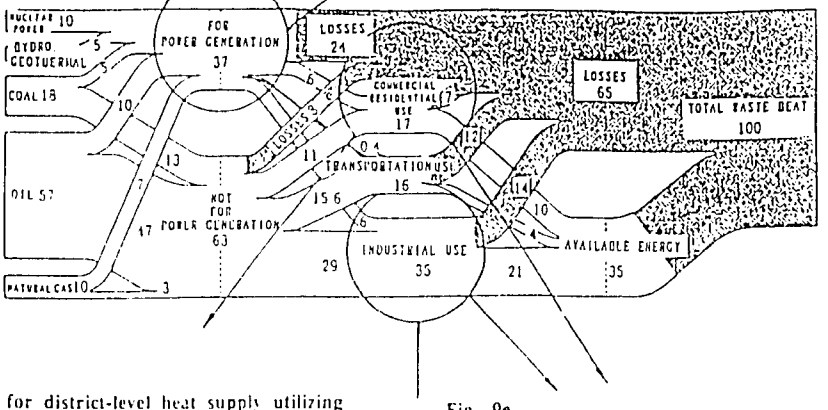


Fig. 9f
Facilities for district-level heat supply utilizing unexploited energy
Reduce the input of new energy by utilizing unexploited energies such as temperature differences in river and sea water, as well as urban waste heat from subways and other sources.

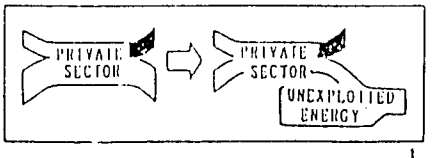


Fig. 9e
Facilities for supplying surplus energy from power plants and factories
Reduce the input of primary energy by effective utilization in the commercial-residential sector of waste heat not suitable for industri use

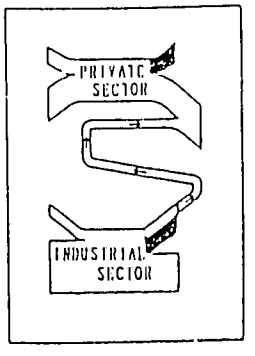
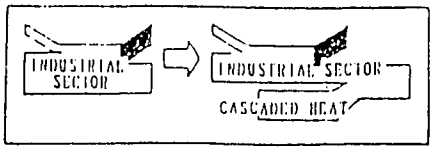


Fig. 9c
Industrial complexes with cascaded energy utilization
Reduce the total input of primary energy into industries by promoting the multi-stage utilization of heat.



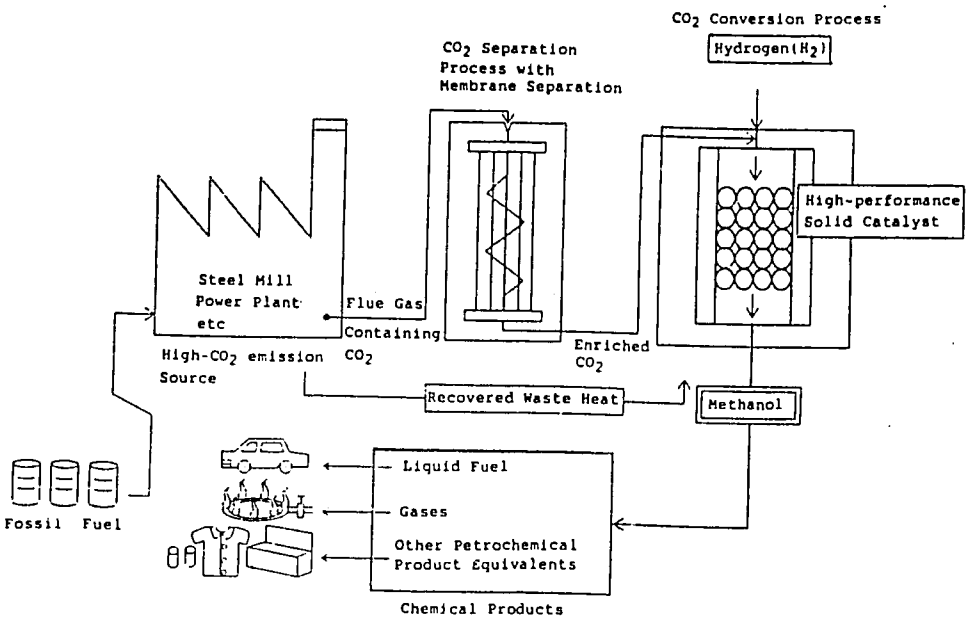


Fig.10 CO_2 fixation and re-utilization technology: catalytic hydrogenation

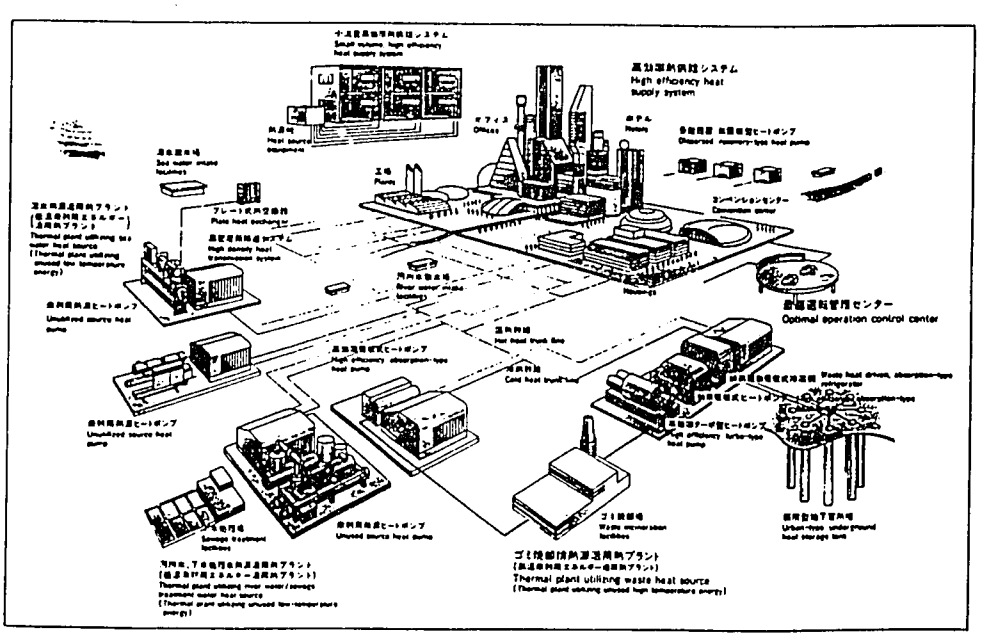
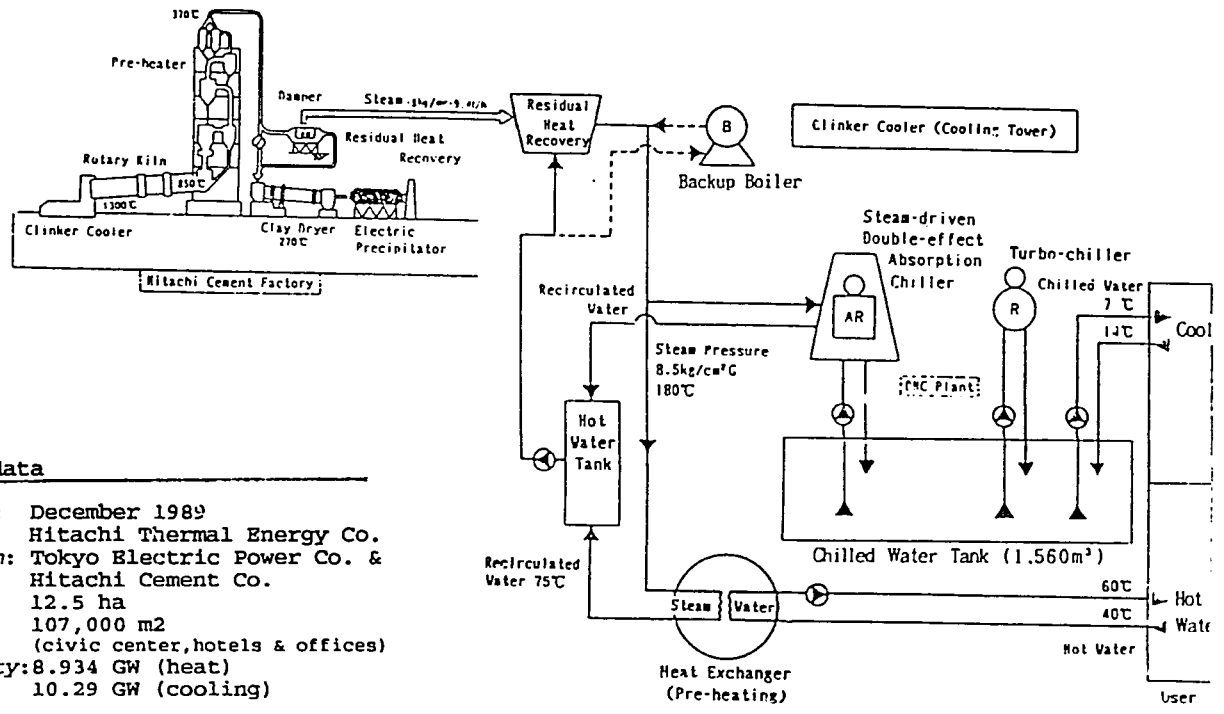


Fig. 11 Load-levelling air-conditioning system using unexploited energy



Hitachi city DHC data

Operation started:	December 1989
Operated by:	Hitachi Thermal Energy Co.
Joint capital from:	Tokyo Electric Power Co. & Hitachi Cement Co.
Total area:	12.5 ha
DHC-serviced area:	107,000 m2 (civic center, hotels & offices)
Max.supply capacity:	8.934 GW (heat) 10.29 GW (cooling)

Fig. 12 Industrial surplus heat utilization and DHC plant system outline

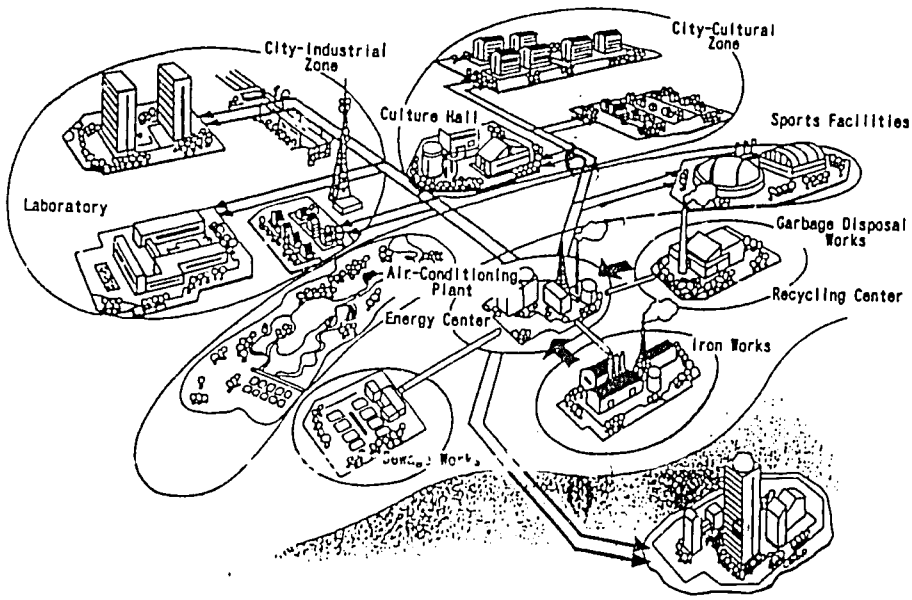


Fig. 13 Integration of a steel manufacturing plant into a regional community

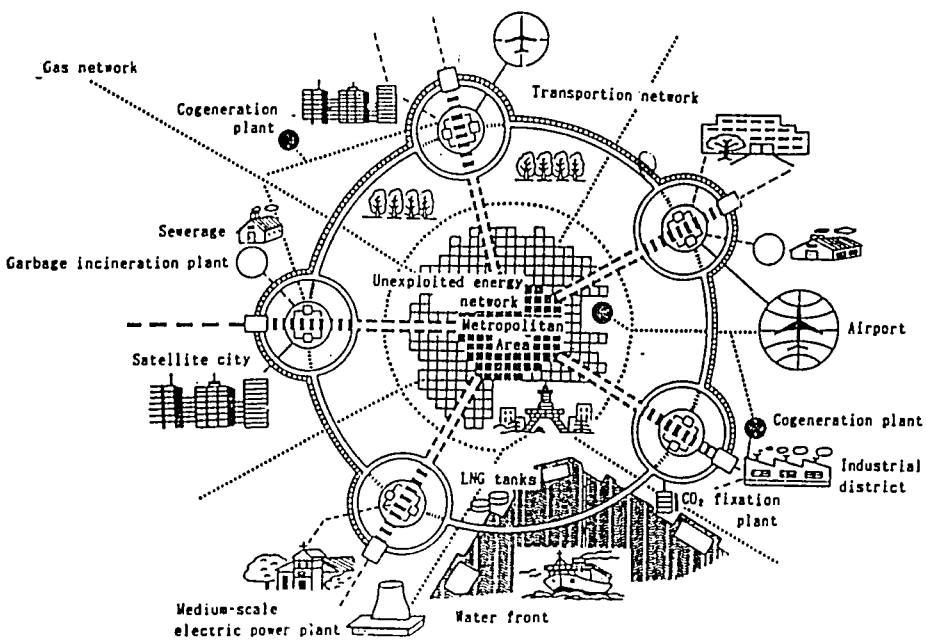


Fig. 14 Concept of integrated industrial and commercial/residential urban energy systems

30TH NOVEMBER - 3 DECEMBER, 1993.

THE ROLE OF COAL IN THE DEVELOPMENT OF PAKISTAN

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ABSTRACT

The Coal Mining Industry in Pakistan took birth in the Eighteenth Century. Originally the coal was being used in the Railways and later in the Brick-kiln industry after the oil had replaced its use in the Railways. The Coal of Pakistan at places is of sub-bituminous as well as of Lignite in nature, possessing high percentage of Sulphur and Ash. However, the Coal has been able to find its diversified use in Industry having the Projects in early sixties. With the popular use of oil and gas in the Fertilizer and Cement Industries the use of coal has been pushed out with the result that it is now again confined to the Brick-kiln Industry. The use of Lignite Coal through Fluidized Combustion beds have given an impetus to the use of coal in the Industry world-wide. Currently the Pakistani coal is also used in Thermal Power Plants for the generation of electricity. The contribution of coal in the generation of electricity is upto 5.6 percent of the country requirements and hopefully by the end of this century, the contribution in this sector shall rise to 20 percent in the total energy mix-up.

The recent discovery of coal in Thar (Sindh) is 8 billion tons proved reserves while 22.4 billion tons are probable reserves. These additional reserves have given a substantial hope that the role of coal shall be adequately increased in the Thermal Power Generation so as to reach to the level of 20% in the tota energy generation.

The other uses of coal in the Brick-kilns, Fertilizers, Cement and Briquettes for house-hold purposes is finding much favourable markets.

The Increased use of coal in the overall development of industry in Pakistan is highly anticipated.

BEST AVAILABLE DOCUMENT

IEA Second International Conference on Clean and Efficient Use of Coal and Lignite: Its Role in Energy, Environment and Life

30 November - 3 December 1993

Lignite Mining in Germany

Workshop A (4) Regional Needs

"Changes in German Lignite Mining: Just the Effects of the Reunification?"

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Abstract:

Reunified Germany now has to cope with the effects of integrating two rather different energy sectors. Consumption of energy in East Germany dropped since 1989 by 45%, which reflects not only the collapse of entire industries, it also marks the correction of an enormous waste of resources. With respect to mining, the lignite reserves are probably the most sizeable plus for the German economy after the reunification. But irresponsible mining in the GDR caused a damage of 19 billion US $ and left 600 square kilometres devastated land and a groundwater deficit, that will take almost 100 years to refill. To manage this 'inheritage', about 1 billion US $ will be allocated yearly for a rehabilitation and recultivation program. The highlights of the policy in the East German federal states are: coping with the ecological damages of the past; establishing a supply structure that is based on the fulfilment of modern environmental and social standards on equal footing to economic requirements; reducing environmental impacts through increased performance efficiency and emission control.
But the integration of both German energy sectors is not without disputes. In times of shrinking markets competitors are not everywhere welcome. An open market for power supply, as demanded by the German Government and the EC-Commission, is not yet fully established. But the unique chance of a new beginning in the East should be taken up.
With the energy policy for the new "Bundesländer" the foundations are laid to a modern competitive energy structure that shoulders the responsibility for the environment and the quality of life.

Changes in German Lignite Mining: Just the Effects of the Reunification?

After more than 4 decades of being devided, East- and West Germany became almost unexpectedly reunified in 1990. During those years of separation, both states have gone through a dynamic social and economic development. But their path of development did not lead in the same direction. This was also true for the mining and power generating industry. Reunified Germany now has to cope with the effects of integrating two rather different energy sectors. What are the consequences and what is achieved three years after reunification ?

The Structural Context

It is hard to say, whether the reduction in German energy consumption of 3 % in the first quarter of 1993 (compared to the first quarter 1992) is more an indicator of recession or largely caused by improved efficiency. The disengagement of energy consumption from economic growth has been one of the remaining 'achievements' in energy policy after the oilprice explosion in the late 70's. In West Germany it led to a situation where energy consumption in the last two years was at the same level (408 - 410 mill. tons of hard coal equivalent) as it was in 1979, having been constantly lower in the years inbetween, although the GDP had risen by 30 % during this period.

The German reunification did not change this trend. But due to other reasons it rather enhanced it. Before reunification the GDR statistically belonged to the top group of industrial nations with one of the highest energy consumption per capita (much higher than West Germany). Since 1989 energy consumption in East Germany dropped by 45 %.

This dramatic reduction reflects not only the collaps of entire industrial complexes, particularly of heavy industry, it also marks the correction of an enormous waste of resources.

The fortunate geological blessing with - even on world scale - large lignite deposits tempted the political leaders to build up a monostructured energy supply, that did not consider appropriately the environment, the natural balance, ecological consequences, health or quality of life in the region.

Looking on the particular background of East Germany, it is surprising that its impact on the all German energy structure after reunification is rather minimal. On one hand this is due to the small share of East German consumption which is only 15 % out of total energy consumption in Germany. On the other hand it is due to the dominating share of lignite in East Germany that is now compensating for a shrinking proportion of hard coal in the western part of the country.

The same is true for a balance between the growing consumption of mineral oil in the east and a slight reduction in the west. East German position in natural gas is too weak to make any measurable impact on the total energy balance and no nuclear power plant was added to the German supply from East Germany.

Energy structure in West Germany had developed until the late 80's according to a 1-2-3-4 formular (10 % nuclear energy, 20 % natural gas, slightly less than 30 % for coal, and 40 % for mineral oil).

This formular is also arrived at in the energy balance of reunified Germany (11 % nuclear power, 22 % natural gas, 28 % coal (half hard coal and half lignite), 37 % mineral oil, whereas the remaining 2 % are for hydroelectric power and other renewable energy sources.

These figures indicate a comfortable supply structure with a wide ranged energy mix. Looking from the outside, it is most probably hard to understand the current political discussions about a German energy consensus. The dispute is interestingly not based on a classical shortage in supply, or on new positions in the environmental policy, but rather on the question how a longer period of over-supply can be handled. The fight for a good share in an energy market, that became tight through successfull energy savings, is the background for the current energy disputes.

This is the context for the currently rather slow process of integration of the East German into the all German energy industry.

Inherited Problems: a Challenge

The aggressive form of lignite mining in the GDR has left deep scars in the environment. In contrast to legal obligations according to the GDR mining law, the companies did not recieve the funds to rehabilitate and recultivate the dumps, heaps and tailings of the mining operations. The result:

A damage estimated at 30 billion DM (19 billion US Dollars) and an area of 60.000 hectares (600 square kilometres) devastated land including 1000 illegal waste dumps with unknown content, and a groundwater deficit of 16,5 billion m^3 that will take almost 100 years to refill.

With utmost urgency, action programs have to be implemented for safety, protection from landslides, waterregulation, clean up of toxic waste dumps, rehabilitation and recultivation.

East German federal states can not afford the required funds, and the government in Bonn, as the legal heir of GDR's state companies, has to take up responsability. So a financial treaty was signed on December 1st, 1992 that covers - as a first step - the period of five years. According to this treaty 1,5 billion DM (just under 1 billion US Dollars) will be allocated yearly from the government, federal agencies and the concerned four 'Bundesländer'.

Besides the goal of rehabilitation and recultivation, this program also supports the labour market as the funds will secure 15'000 jobs. These jobs are, on the short run, primarily for the people that are dismissed from the mining companies.

Particularly the federal states of Brandenburg and Saxony, that have the largest areas of devastated mine lands, are eager to combine the work on the inherited ecological problems with a structural policy for the future. So it is planned to integrate the areas recovered after completion of recultivation into the concepts of the regional structural planning. According to those planning concepts conditions should be created, where work, housing, and cultural life should take place in an environment that is not burdened anymore by inherited ecological problems and that is in a natural balance.

In contrast to the capital stock of industrial plants, that are in a very poor state and burdened with ecological problems of the GDR past, the lignite reserves are probably the most sizeable plus for the German economy after the reunification. Even if lignite mining in the East will be reduced by two thirds from their traditional level (from 300 Million t/y to 70 - 90 mill t/y in the late 90's) the brown-coal represents a considerable addition to energy reserves in the reunified Germany.

The most important benefit of East German lignite mines is, that they are competitive to imported coal and are operating profitably without governmental subsidies (as the hard coal miners depend on in the Ruhr district).

German Brown-Coal Industry
(before and after reunification)

I. Lignite Mining (million tons per year)

Year	1989	1990	1991	1992	1993*
West G.	109.8	107.6	111.7	112.3	105.0
East G.	300.8	248.9	167.7	129.4	117.0
Total	410.6	356.5	279.4	241.7	222.0

* projection

II. Employees in Lignite Mining

Year	1989	1993*
West Germany	17'900	16'000
East Germany	132'000	41'000
Total	149'900	57'000

* projection in 9/93

New Policies

In order to facilitate and support the "growing together" of east and west energy sectors, the five East German federal states have worked out guidelines for the energy policy.

The states of Brandenburg and Saxony, as the major lignite producers, put a stress on the following major policies:

- disintegration of the monostructure; opening of markets and building up of a modern supply system with a wide spread energy mix.
- coping with the ecological damages of the GDR energy industry.
- setting up a future supply structure that is based on the fulfilment of modern environmental and social standards on equal footing to economic requirements.
- reducing environmental impacts through increased performance efficiency and emmission control.
- a market share in power generation for a reduced amount of subsidy-free East German lignite.
- support for research and development for a long-term energy structure that is leaving maximum room for renewable energy sources.

The turning away in East German energy policy from reckless lignite mining with too little responsability for man and nature towards an opening of energy markets and improved efficiency in power generation is hightlighted by two major postulates:

- not more lignite mining than absolutely necessary for a secure economic energy mix
- minimization of land consumption and social impacts.

Although there is no alternative to a turnaround in East German energy policy, it creates severe problems in the labour market. Like in all other labour intensive industries, the political change had the effect of major cutbacks in the employment structure of the mining industry.

Since 1989, when 132'000 people were employed in the eastern mining industry, more than 90'000 miners lost their jobs (see Table II on page 3). Early next year, in the context of privatisation another 10'000 - 15'000 employees will have to be dismissed. That means, that only within five years over 100'000 people lost their jobs in the East German mining industry.

In comparison: in the West German hard coal mining district similar structural changes needed more than 20 years.

This example demonstrates the dramatic change in the East German energy sector, where the negative impact on the living conditions in the mining region cannot be overestimated as job alternatives are still scarse.

Taking up the Chances

Dealing with the economic, environmental, and social aspects of the structural change in mining will be incomplete, if not at the same time also the chances for new developments and new economic activities are considered.

The policy to cope with the ecological damages of the past is already in the phase of implementation. Because of financial and technical constraints it will not be possible to restore completely the pre-mining conditions, and it is in many cases not even desirable.

After the devastation of the landscape now the unique chance of a new beginning to create an environment, that fulfils the different needs of a modern society, should be taken up.

The implementation of an energy policy to create a modern structure of energy sources stimulates a variety of job creating effects. So, as an example, led the development of logistics and marketing for the mineral oil business to the creation of thousands of small and medium sized companies that did not exist in the old system.

The building up of urban and regional public utility companies for power generation in combination with heat supply, is apart from the benefit of improved energy efficiency of those plants also a sizeable employment program.

As all companies require goods and services from other branches and sectors the restructuring process creates major investments and safeguards employment also in other sectors.

In the next five years 28 billion DM (17.7 billion US Dollars) will be invested in the eastern energy sector. About half of this amount will be for large powerplants.

So special employment effects will also be created by the implementation of investment-projects in lignite power plants. In the context of privatisation of the East German mining and power generating industry, there will be three new plants (with 1.600 MW each) set up with a higher net efficiency rate of over 40 % and with the 'state of the art' in emission control. Two plants (with 3'000 MW and 1'000 MW) will be refitted to comply with the German laws for emissions.

Each new power plant will create or guarantee between 5'000 and 10'000 jobs. There will be jobs for the construction, jobs for regional suppliers that should get a share of 60 % out of the total investment volume, jobs in the open-pit mines that supply the plants with coal, and jobs to recultivate the mining area.

Those examples should demonstrate the positive effects on the labour market of new East German strategies in energy policy.

But it would not be honest to say that integration of both German energy sectors is without disputes. So is the appearance of the East German lignite coal in the energy market of reunified Germany not welcome everywhere. Like elsewhere in the world, a competitive newcommer in the light of shrinking markets is looked upon with scepticism. Even the macroeconomic benefit of generating power from national low-cost lignite coal from the east is not generally appreciated. On the other side there is limited acceptance to the take-over of the East German electric power grid system by a West German cartell like consortium. It is feared that the cartell might prevent third party access to the power distributing system.

The German Government as well as the EC-Commission would like to see more competition in the energy market in order to put pressure on costs and prices. It is important to note that the German consumers have to pay the highest prices for electricity in the European Community. More competition in the German energy sector would be achieved if the power generation and power distribution would be generally separated. The concerned companies reject that and claim, that they need secure markets to protect their major investments from risks. As a compromise to introduce more competition, the companies are now suggesting a new tendering procedure for new power plants among the major energy companies.

International competitiveness requires cheap, subsidy-free energy in the framework of an open market. Protectionism and market constraints will not be the adequate tools to build up a healthy reliable energy sector for the reunified Germany.

With the energy policy for the new "Bundesländer" the foundations are laid to a modern energy structure that shoulders the responsibility for the environment and the quality of life for <u>all</u> concerned people, those who consume electric power and are interested in low prices as well as for those who are directly affected by the mining operations.

SOME CONSIDERATIONS ON IMPORTED COAL AND THE ENVIRONMENT IN MOROCCO

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October 1993

ABSTRACT

THE SCARS MADE ON THE NATUREL ENVIRONMENT BY ECONOMIC ACTIVITY HAVE BECOME THE FOCUS OF UNIVERSAL CONCERN.

NEVERTHELESS POVERTY AND OVER POPULATION IN DEVELOPING COUNTRIES CONSTITUTE AN OTHER SOURCE OF DEGRADATION FOR THE ENVIRONMENT.

ENERGY IS FACTOR OF GROWTH BUT WHEN IT IS OVERUSED THE ENVIRONMENT WAS INVOLVE.

THE APPROACH ENERGY-ENVIRONMENT HAS SUMMONED UP INTERNATIONAL EFFORTS IN ORDER TO COUNTER THE "WARMING UP" DANGER.

MOROCCO IS CONSIOUS THAT THIS A SERIOUS PROBLEM HE CONTINUOUSLY CONDEMNS THE DAMAGES MADE ON ENVIRONMENT AT A VARIOUS OCCASION.

IN DEED THE ENERGY FIELD OF ACTIVITY IN MOROCCO IS KEEN ON THE PROTECTION OF ENVIRONMENT AT THE DIFFERENT LEVEL OF THE CONCEPTION AND USE OF PRODUCTION UNITS OR AT THE LEVEL OF THE USE OF ENERGY.

A JUDICIOUS PROGRAMS WAS BEEN ESTABLISHED WHICH INSURE THE ENERGY SUPPLYING OF THE COUNTRY WHILE TAKING INTO CONSIDERATION FACTORS WHICH MIGHT AFFECT THE ENVIRONMENT. THIS PROGRAM IS GEARED MAINLY TOWARDS LOWEST COST PROJECTS AND IMPORTED COAL.

THE INTRODUCTION OF IMPORTED COAL HAS BEEN ACCOMPANIED BY A FEW ACTIONS TO LIMIT COAL POLLUTION.

SOME CONSIDERATIONS ON IMPORTED COAL AND THE ENVIRONMENT IN MOROCCO

I) GENERAL INFORMATION ON MOROCCO

A) GEOGRAPHY, CLIMATE AND POPULATION
B) NATUREL RESOURCES
C) EVOLUTION OF ENERGY CONSUPMTION
D) NATIONAL ENERGY PROGRAMME

II) THE COAL AND THE ENVIRONMENT

A) OVERVIEW OF MOROCCO'S COAL SECTOR
B) INFRASTRUCTURE

III) GENERAL SITUATION OF THE ENVIRONMENT IN MOROCCO

A) THE CURRENT FRAMWORK OF ENVIRONMENTAL MANAGMENT IN MOROCCO
B) ACTIONS OF THE ENVIRONMENT PROTECTION

I) GENERAL INFORMATIONS ON MOROCCO

A) GEOGRAPHY, CLIMATE AND POPULATION

MOROCCO STRETCHES OVER 710.850 km², WITH 3.250 km OF COASTLINE OF WHICH 2.500 km ON ATLANTIC OCEAN AND 750 km ON THE MEDITERRANEAN SEA.

THE TOTAL POPULATION IS ESTIMATED AT 25 MILLIONS PEOPLE. TWO MAJOR MOUNTAIN RANGES, THE RIF IN THE NORTH AND THE ATLAS IN THE MIDDLE NORTH DIVIDE THE COUNTRY INTO:

-THE MEDITERRANEAN ZONE IN THE NORTH,
-THE ATLANTIC PLAINS IN THE WEST,
-AND THE SUB-SAHARAN AND SAHARAN ZONES IN THE SOUTH.

FROM THE SOUTH TO THE NORTH, THE CLIMATE VARIES FROM ARID, SEMI ARID AND WARM TO MILD.

AVERAGE ANNUAL RAINFALLS ARE ESTIMATED BETWEEN 35 mm IN THE MOST ARID ZONE AND 900 mm IN THE NORTH OF THE COUNTRY.

THE ANNUAL TEMPERATURE AVERAGES 21°C IN DAKHLA, 19°C IN CASABLANCA, 18.5° IN RABAT AND 20°C IN MARRAKECH.

B) NATUREL RESOURCES

MOROCCO IS BESTOWED WITH IMPORTANT NATUREL RESOURCES INCLUDING MINERALS, VEGETATION AND ANIMALS. ITS PHOSPHATE RESERVES ACCOUNT FOR 2/3 OF THE WORLD'S RESERVES IN ADDITION TO A HOST OF METALLIC AND NO METALLIC MINERAL ORES.

WITH REGARD TO AGRICULTURE, MOROCCO POSSESSES 9 MILLIONS HECTARES OF ARABLE LANDS, IN IRRIGATED AND RAIN-FED AREAS.

C) EVOLUTION OF ENERGY CONSUMPTION

PRIMERY COMMERCIAL ENERGY CONSUMPTION IS ABOUT 6.904.000 TOE IN 1992. PETROLEUM PRODUCTS WITCH ARE OBTAINED BY LOCAL REFINING OF IMPORTED CRUD OIL, REPRESENT 77,5 % OF THE WHOLE CONSUMPTION

EVOLUTION OF CONSUMPTION

1000 TOE	1988	1989	1990	1991	1992
PETROL	4.513	4.821	5.027	5.095	5.524
GAZ	56	47	43	29	18
COAL	1.029	1.143	1.104	1.261	1.107
HYDROELECTRICITY	243	301	317	329	255
TOTAL	5.841	6.312	6.491	6.714	6.904

LOCAL PRODUCTION AMOUNT TO 1.110 TOE COMPRINSING:

HYDOELECTRICITY : 440.000 TOE
COAL (anthracite) : 550.000 TOE
OIL AND GAZ : 120.000 TOE

SO, THE ENERGY DEPENDANCE RATE IS PARTICULARLY HIGH REACHING 84 %

D) NATIONAL ENERGY PROGRAMME

IN ORDER TO LIMIT THE BAD IMPACT OF THIS SITUATION TO IMPROVE AS FAR AS POSSIBLE THE ENERGY BALANCE, MOROCCO HAD IMPLEMENTED A NATIONAL ENERGY PLAN WITH THE MAIN OBJECTVES:

a. TO ENSURE THE ENERGY SUPPLY OF THE COUNTRY AND THE BEST CONDITION OF TECHNICAL QUALITY AND COST.

b. TO REDUCE THE ENERGY DEPENDANCE THROUGH A WIDE MOBILISATION OF LOCAL RESSOURCES:

- HYDROELECTRICITY POTENTIEL DEVELOPMENT, IT CAN PRODUCE ABOUT 1.5 MILLION TOE.

- REINFORCEMENT OF OIL EXPLORATION, WITH A NEW EXPLORATION CODE WICH IS PARTICULARY ATTRACTIVE BECAUSE STATING THAT THE INTERESTING COULD BE, UNDER SOME CONDITIONS OF EXPLORATION PROGRAMME STRENGTHING, 65 % FOR THE COMPAGNY AND ONLY 35 % FOR THE STATE.

- RENEWABLE ENERGY POTENTIEL DEVELOPMENT, THIS POTENTIEL WAS STUDIED AND EVALUED AT:
    * 3.000 H/YEAR OF SUN
    * A MEDIUM WIND SPEED OF 4.5 m/s ON THE LONGEST PART
    * BIOMASS

c. DIVERSIFICATION OF SORTS OF ENERGIES USED AND THE SUPPLYING SOURCES.

d. IMPLEMENTATION OF A NATIONAL ENERGY MANAGMENT PLAN.

II) THE COAL AND THE ENVIRONMENT

A) OVERVIEW OF MOROCCO'S COAL SECTOR

1) NATIONAL COAL:

THE COAL ZONES ARE IN THE NORTH EASTERN PART OF THE COUNTRY, JERADA IS THE ALONE MINE WORKED IN THE NORTH OF AFRICA.

EVOLUTION OF ANTHRACITE PRODUCTION

10^3TONS	1988	1989	1990	1991	1992
ANTHRACITE	637	504	526	552	576

95 % OF THE PRODUCT OF JERADA CONSOMED IN THE THERMAL POWER STATION OF JERADA (3 * 55 MW).

2) IMPORTED COAL:

THE ENERGY FIELD OF ACTIVITY IN MOROCCO HAS ESTABLISH AJUDICIOUS PROGRAM WHICH INSURE THE ENERGY SUPPLYING OF THE COUNTRY WHILE TAKING INTO CONSIDERATION FACTORS WHICH MIGHT AFFECT THE ENVIRONMENT. THIS PROGRAM IS GEARD MAINLY TOWARDS LOWEST COST PROJECTS SUCH AS THE IMPROVEMENT OF ENERGY SAVINGS, THE VALORISATION OF RENEWABLE ENERGIES AND INTRODUCTION OF IMPORTED COAL.

THE ENERGY FIELD OF ACTIVITY ENCOURAGES LOCAL INDUSTRIES TO TAKE A MAXIMUM ADVANTAGE OF DIVERSITY OF THEIR SUPPLIES BY BUYING A CHEAPER ENERGY WHILE KEEPING IN MIND THE PRESERVATION OF NATURE.

IN DEED, THE CONSUMPTION OF IMPORTED COAL IN MOROCCO OF FIVE YEARS AGO.

TONS	1988	1989	1990	1991	1992
ELECTRICITY	1054.260	780.150	618.282	699.263	577.075
CEMENT INDUSTRY	409.036	458.341	544.808	925.233	656.576
SUGAR REFINERIES	35.870	48.832	45.101	77.328	32.640
SMELTING WORKS	17.450	16.575	17.725	15.096	18.536
TOTAL	1516.625	1303.898	1225.916	1416.920	1284.877

WITH THE NEW THERMAL POWER STATION NEAR THE JORF LASFAR HARBOR (3* 330 MW) THE PREVISIONS OF THE IMPORTED COAL ARE:

1000.TONS	1993	1994	1995	1996	1997
ELECTRICITY	600	1.420	2400	2.735	2.880
CEMENT INDUSTRY	560	680	695	700	710
SUGAR REFINERIES	33	37	41	45	49
SMELTING WORKS	17	18	19	20	21
TOTAL	1.210	2.155	3.155	3.500	3.660

B) INFRASTRUCTURE

PORTS,ROAD AND RAIL NETWORKS CONSTITUTE A SUFFICIENT INFRASTRUCTURE TO ASSURE THE COAL IMPORTATION.

SINCE CASABLANCA BIG PORT, WHERE A HUGE COMMERCIAL EXCHANCE IS CARRYED OUT WITH OTHER COUNTRIES, IS NO MORE ABLE TO STAND GREATER TRADE FLOWS, ANOTHER BIG PORT IN JORF LASFAR IS RECENTLY BEING BUILT 130 Km SOUTH OF CASABLANCA.

JORF LASFAR IS ONE OF THE BIGGEST PORT OF AFRICA AND A NEW ECONOMIC DEVELOPMENT CENTRE IN THE COUNTRY. IT IS GOING TO MAINLY BE SPECIALIZED IN IMPORTING COAL AND EXPORTING PHOSPHATE.

THE DISTRIBUTION OF IMPORTED COAL BY PORT IS:

PORT / 1000 TONS	1991	1992	1993	1994	1995	1996
CASABLANCA	955	798	750	740	780	800
AGADIR	142	182	180	190	192	200
NADOR	242	227	210	235	245	250
TANGER	3	41	30	40	38	40
JORF LASFAR	58	19	40	950	1.900	2.210
TOTAL	1.400	1.267	1.210	2.155	3.155	3.500

NEAR THAN 80 % OF THE COAL IMPORTATION IS FROM U.S.A, THE PRICE (1991) IN CASABLANCA PORT IS ABOUT 48 $/TON.

III- GENERAL SITUATION OF THE ENVIRONMENT IN MOROCCO

MOROCCO CONTINUOUSLY CONDEMNS THE DAMAGES MADE ON ENVIRONMENT AT THE OCCASION OF VARIOUS INTERNATIONAL OR REGIONAL EVENTS. THIS AWARENESS HAS BECOME STRONGER SINCE THE OCCURING OF ECOLOGICAL DAMAGES WHICH HAVE INVOLVED MOROCCO.

THE MOROCCAN PUBLIC OPINION IS CONSCIOUS OF THE RISKS PRESENT IN ENERGY, INDUSTRY AND URBAN POLLUTION.

TO AVERT ANY SERIOUS ENVIRONMENTAL DAMAGE, THE GOVERNMENT HAS CARRIED OUT A SET OF PROGRAMMES DESIGNED TO ACHIEVE AN IN-DEPTH KNOWLEDGE OF POLLUTION PHENOMENA, BRING ABOUT A GREATER AWARENESS OVER THESE ISSUES AND ENSURE A SOUND MANAGEMENT OF THE ENVIRONMENT IN TERMS OF REGULATIONS, ORGANISATION AND TECHNICAL ASPECTS.

MANY PRIVATE ORGANISATION HAVE BEEN CREATED IN MOROCCO. THEIR OBJECTIVES ARE THE FOLLOWING: THE PROTECTION AND IMPROVEMENT OF THE ENVIRONMENT.

A) THE CURRENT FRAMEWORK OF ENVIRONMENTAL MANAGMENT IN MOROCCO

THE FIRST REGULATIONS RELATING TO THE ENVIRONMENT IN MOROCCO DATE BACK TO 1914 WHEN A LAW ON UNHEALTHY, INCONVENIENCING OR HAZARDOUS FACILITIES WAS PUBLISHED.

SUBEQUENTLY, THE REGULATIONS GOVERNING NATUREL RESOURCES DEVELOPMENT GAVE A NOTABLE PLACE TO ENVIRONMENTAL ISSUES, IN PARTICULAR: SEA RESOURCES CONSERVATION, PROTECTION OF WATER RESOURCES, WOOD-LAND, NATIONAL PARKS, PUBLICS ROADS AND SO ON.

AS FAR AS THE ADMINISTRATIVE STRUCTURES ARE CONCERNED, THERE EXISTS A STATE DEPARTMENT OF ENVIRONMENT IN THE MINISTRY OF INTERIOR.

FURTHERMORE, MOROCCO HAS, OVER THE LAST TEN YEARS, ESTABLISHED A NATIONAL ENVIRONMENT COUNCIL WITH BRANCH OFFICES.

THE NATIONAL COUNCIL, WHICH IS MADE UP OF TWENTY MINISTERS OR SO, IS ENTRUSTED WITH THE MISSIONS OF PRESERVING AND IMPROVING THE ENVIRONMENT BY INDERTAKING THE FOLLOWING ACTIONS:

* PRESERVE THE ECOLOGICAL BALANCE OF THE NATURAL HABITAT
* AVERT AND FIGHT AGAINT POLLUTIONS AND NUISANCES
* SEE TO IT THAT THE NATUREL RESOURCES ARE SOUNDLY MANAGED AND CONSERVED
* IMPROVED THE LIVING FRAMEWORK AND CONDITIONS

IN THE FIELD OF R&D, MANY UNIVERSITIES AND PRIVATE RESEARCH INSTITUTES WORK ON THE ENVIRONMENT.

B) ACTIONS OF THE ENVIRONMENT PROTECTION

ENERGY IS IMPORTANT IN THE SOCIO-ECONOMIC DEVELOPMENT IN MOROCCO. FOR THIS REASON THE COAL FIELD ACTIVITY IS KEEN ON THE PROTECTION OF THE ENVIRONMENT, ALTHOUGH THERE IS A LACK OF COHERENT AND RESTRICTING LEGISLATION FOR THE PROTECTION OF NATURE.

THE SPECIFICATIONS OF THE COAL USING IN THE THERMAL POWER STATIONS AND THE CIMENT INDUSTRY IN MOROCCO ARE;

* TOTAL MOISTURE.....: 8 - 10 %
* ASH .....: 10 - 15 %
* VOLATILES .....: 22 - 28 %
* SULPHUR.....:1,4 -1,5 %
* GROSS C.V.....: 6.400 kcal/kg

MOROCCO TRIES TO APPLY THE REGULATIONS ENFORCED IN THE MEDITERRANEANS COUNTRY, TAKING INTO CONSIDERATION THE LIMITED MEANS OF MOROCCO IN THE PROTECTION OF THE ENVIRONMENT. HOWEVER, THE INTRODUCTION OF IMPORTED COAL BY THE NATIONAL OFFICE OF ELECTRICITY AND THE INDUSTRY SECTOR HAS BEEN ACCOMPANIED BY A FEW ACTIONS RELATED TO THE PROTECTION OF THE ENVIRONMENT, SUCH AS:

- THE PROHIBITION OF EXPANDING THE COAL HARBOR OF MOHAMMADIA, IT WAS DECIDED TO RESERVE THIS HARBOR TO THE ONLY IMPORTATION OF HYDROCARBONS SO AS TO LIMIT THE POLLUTION OF THE SUMMER RESORTS OF THE AREA.
- THE IMPORTATION OF COAL COMES TEMPORARILY INTO THE HARBOR OF CASABLANCA FOR THE MOHAMMADIA THERMAL POWER STATION, IN THE MEANTIME THE COAL TERMINAL OF THE JORF LASFAR TAKE OVER THE IMPORTATION OF COAL FROM 1994 WITH 950.000 TONS.

- THE SITTING UP OF FILTRING DEVICES FOR THE ISOLATION OF DUSTS AND OF SULPHUR IN THE THERMAL POWER STATION OF MOHAMMADIA AND CASABLANCA WHICH ARE LOCATED IN AREAS VERY CLOSE TO URBAN ZONES.

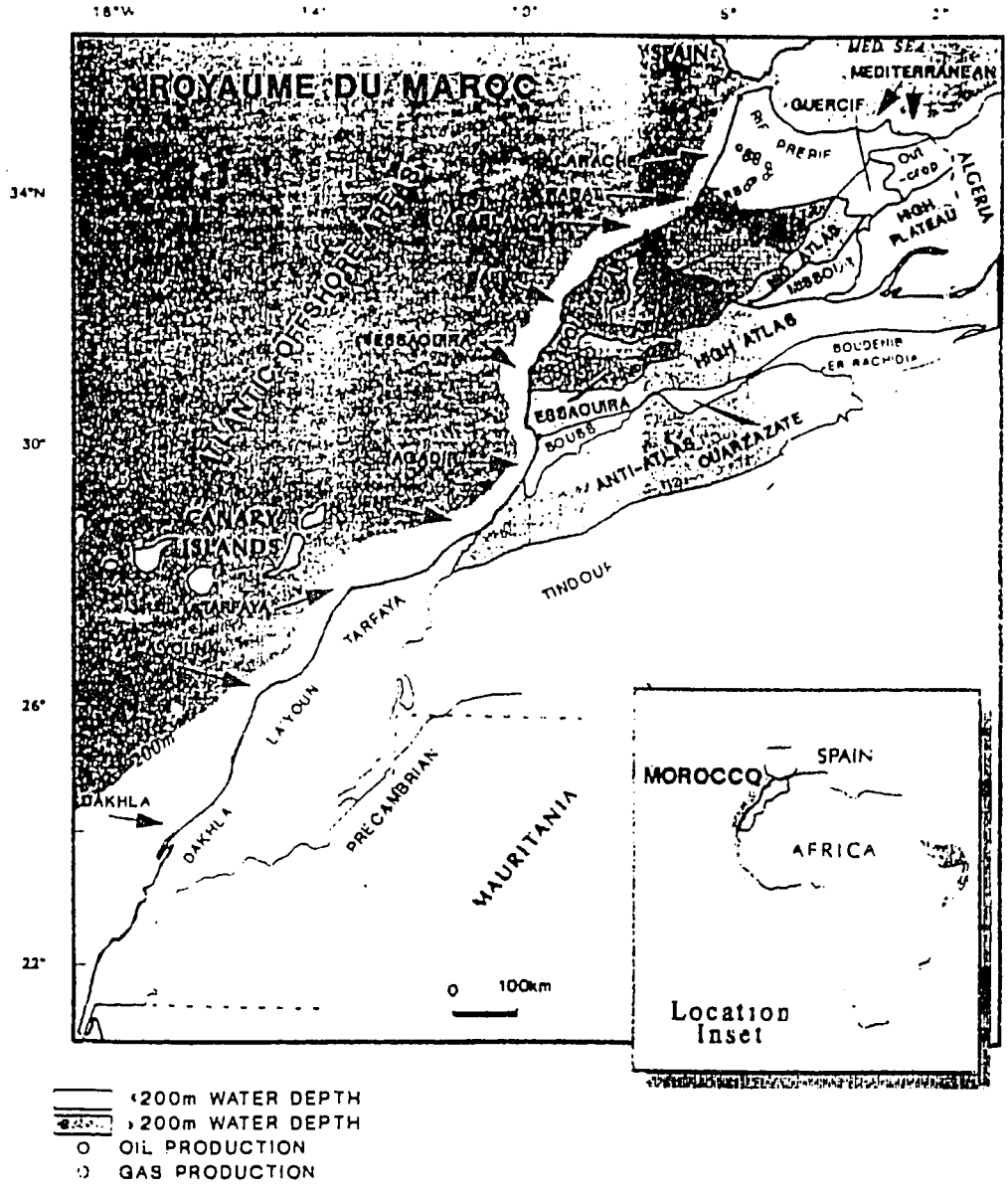
- THE NEW COAL THERMAL POWER STATION IN JORF LASFAR (3 * 330 MW) RESPECTFUL OF THE NORMS SET BY THE NATIONAL OFFICE OF ELECTRICITY (O.N.E), THE PROCESS OF JORF LASFAR SITE SELECTION HAS ALREADY TAKEN INTO CONSIDERATION FACTORS WHICH HAVE A BEARING ON THE ENVIRONMENT.

SIMILAR ACTION HAVE BEEN TAKEN BY THE CEMENT INDUSTRY CERAMIC INDUSTRY AND SUCAR INDUSTRY IN MOROCCO. THE LATTER DEMAND FROM THEIR SUPPLYERS A QUALITY OF COAL CONFORMED WITH THE CRITERIA DEFINED BY THE CONSTRUCTOR, SO AS TO REDUCE THE POLLUTING EMISSIONS IN THE ATMOSPHERE.

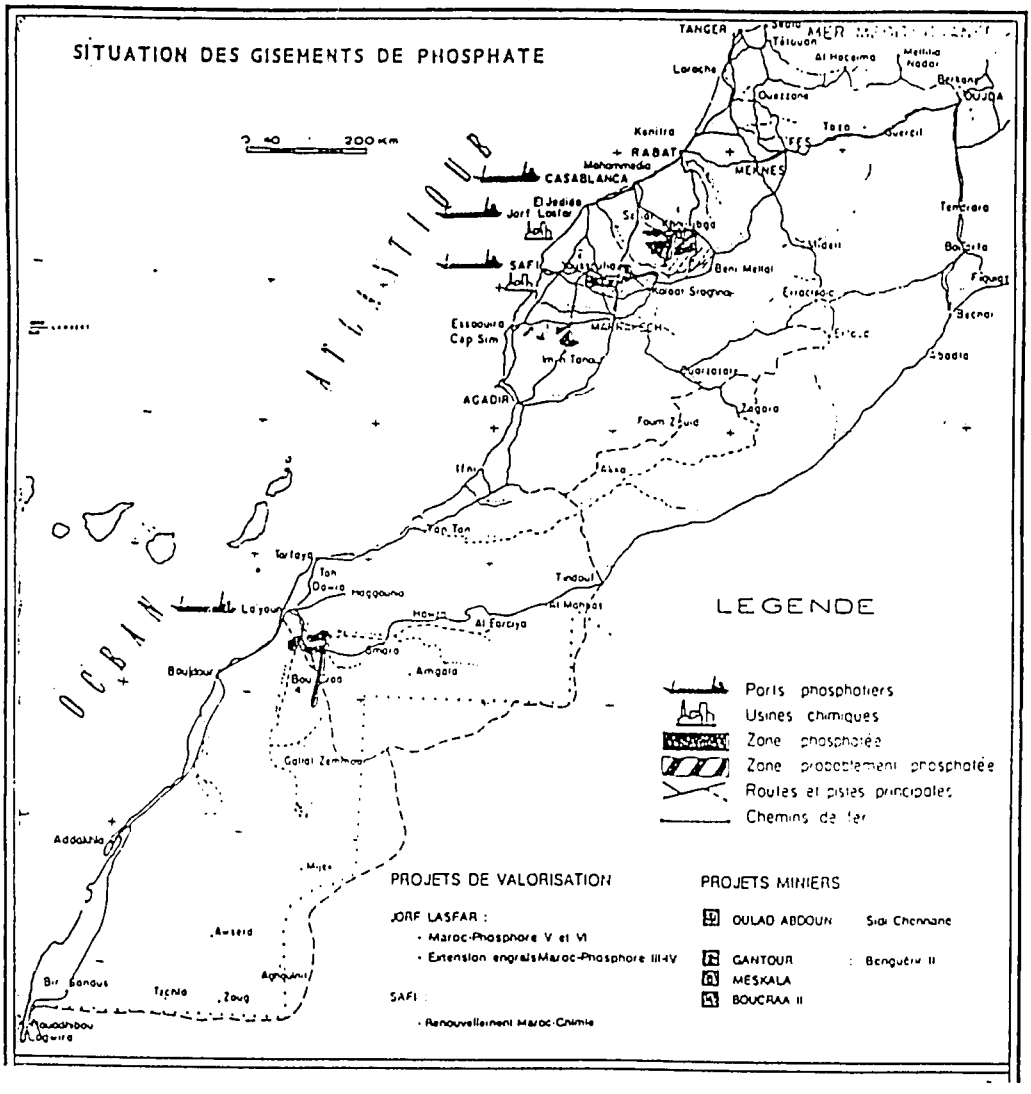
OTHER MEASURES TO LIMIT POLLUTION THROUGH COAL ARE TAKEN. THEY ACT FROM THE BEGINNIG OF THE DISCHARGING PROCESS UNTIL THE DELIVERY IS MADE TO THE CONSUMER. LIKEWISE THE CHOICE OF SITES FOR THE THERMAL POWER STATIONS OF JORF LASFAR AND MOHAMMADIA AND SITES FOR CEMENT PRODUCING UNITS (THE CASE OF CIOR IN OUJDA, CINOUCA IN CASABLANCA AND CIMAR IN SAFI) TAKES INTO COSIDERATION THE CONSTRAINTS IMPOSED BY THE CONJUNCTION COAL-ENVIRONMENT.

THE ASSESSMENT OF ENVIRONMENTAL PROBLEMS HAS PERMITTED MOROCCO TO CONCENTRATE ITS EFFORTS FIRST ON NATIONAL REGULATIONS, AND ON THE CREATION OF A GOVERNMENTAL BODY IN CHARGE OF THE ENVIRONMENT WHICH HAS BEEN GIVEN THE MEANS AND THE NECESSARY STAFF IN ORDER TO FULFILL THIS TASK IN THE BEST OF CONDITIONS.

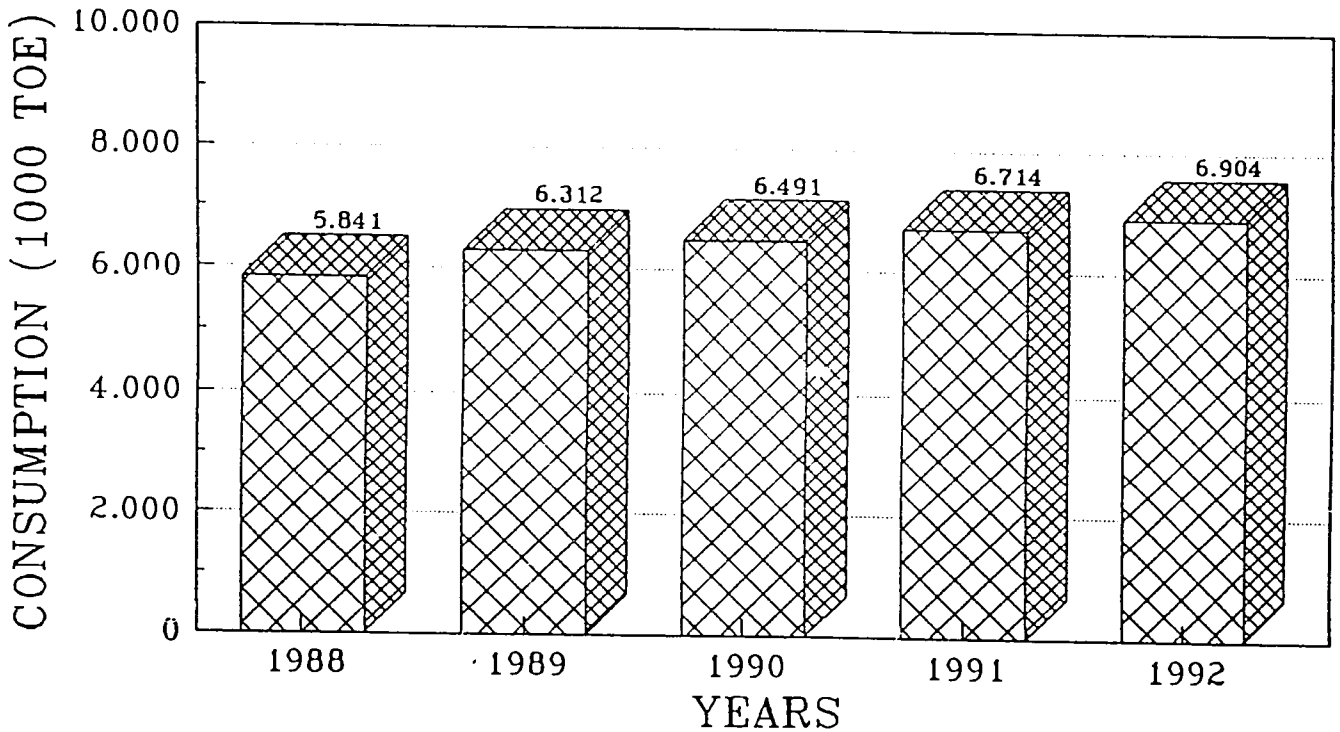
ANNEX



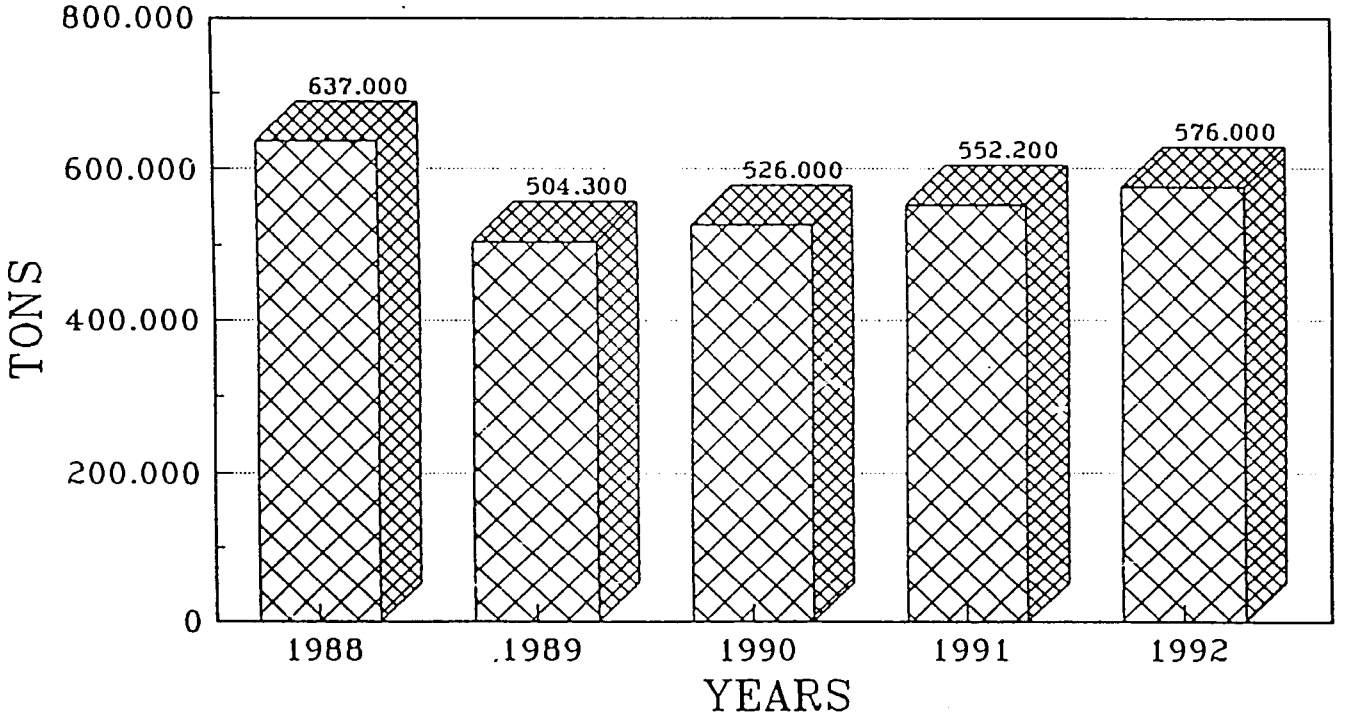
GEOLOGIC PROVINCES


SITUATION DES GISEMENTS DE PHOSPHATE
0 40 200 km
OCEAN ATLANTIQUE
MER
TANGER
Tétouan
Al Hoceima
Melilla
Nador
Larache
Berkane
OUJDA
Ouezzane
Taza
Guercif
Kenitra
RABAT
FES
MEKNES
Mohammedia
CASABLANCA
El Jadida
Jorf Lasfar
SAFI
Beni Mellal
Khouribga
Kasbat Sraghna
Essaouira
Cap Sim
MARRAKECH
Imin Tana
AGADIR
Ouarzazate
Zagora
Foum Zguid
Tiznit
Tata
Tan Tan
Tarfaya
Tan Tan
Dawra
Haggouna
Tindouf
Laayoun
Hawza
Al Farsiya
Al Marsat
Boujdour
Amgala
Galat Zemmour
Addakhla
Mijek
Awserd
Agguinit
Bir Gandous
Tichla
Zouq
Mauadhdou
Lagouira
Temsiria
Bouarfa
Figuig
Bechar
Abadla
Erfoud
Erracidia
LEGENDE
Ports phosphatiers
Usines chimiques
Zone phosphatée
Zone probablement phosphatée
Routes et pistes principales
Chemins de fer
PROJETS DE VALORISATION
JORF LASFAR :
- Maroc-Phosphore V et VI
- Extension engrais Maroc-Phosphore III-IV
SAFI :
- Renouvellement Maroc-Chimie
PROJETS MINIERS
OULAD ABDOUN
Sidi Chennane
GANTOUR
: Benguérir II
MESKALA
BOUCRAA II

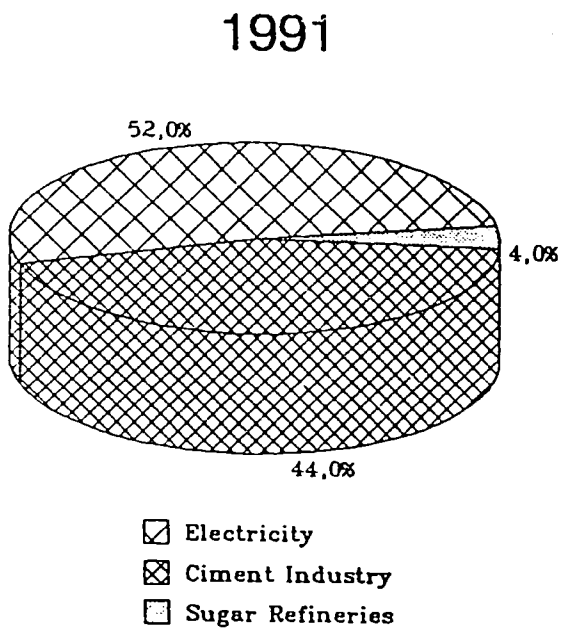
EVOLUTION OF ENERGY CONSUMPTION

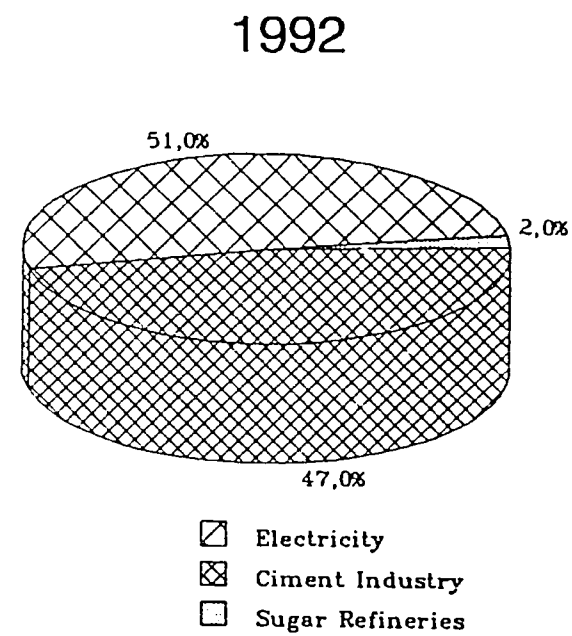


EVOLUTION OF ANTHRACITE PRODUCTION OF THE JERADA MINE

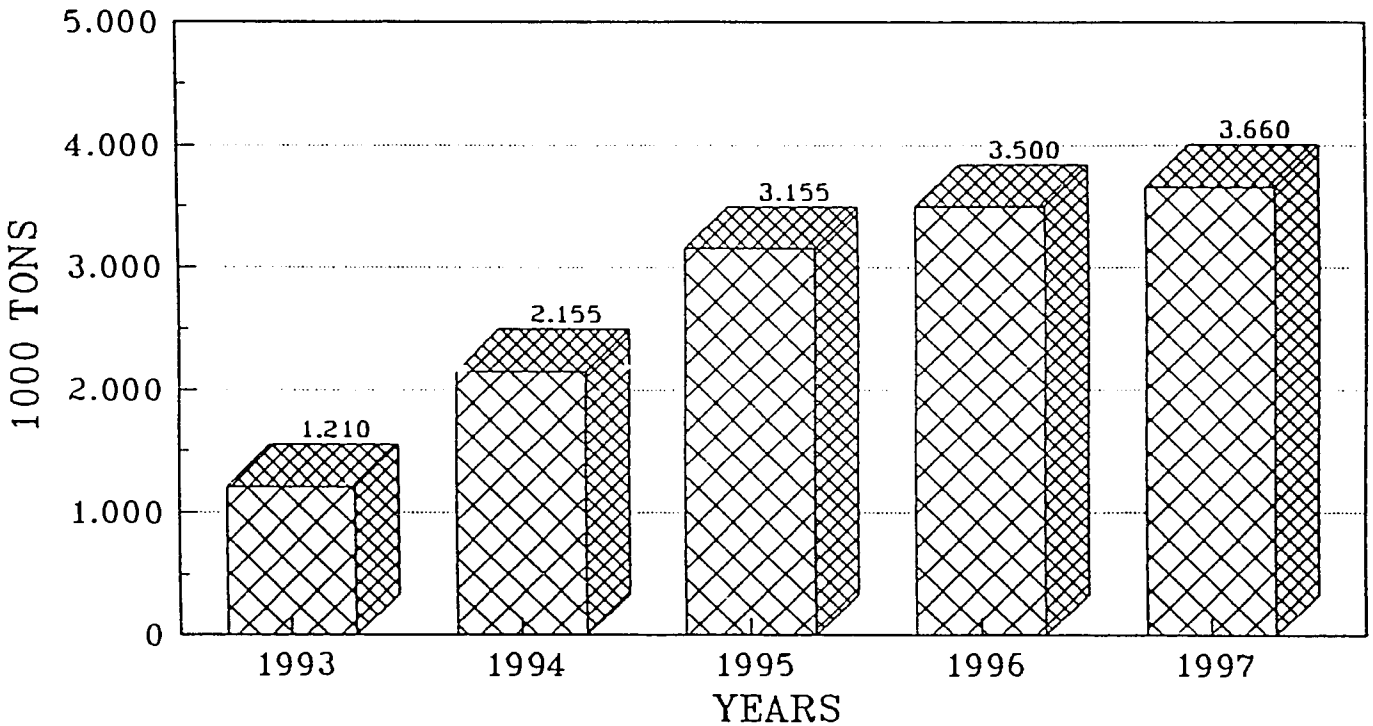


VENTILATION OF IMPORTED COAL CONSUMPTION

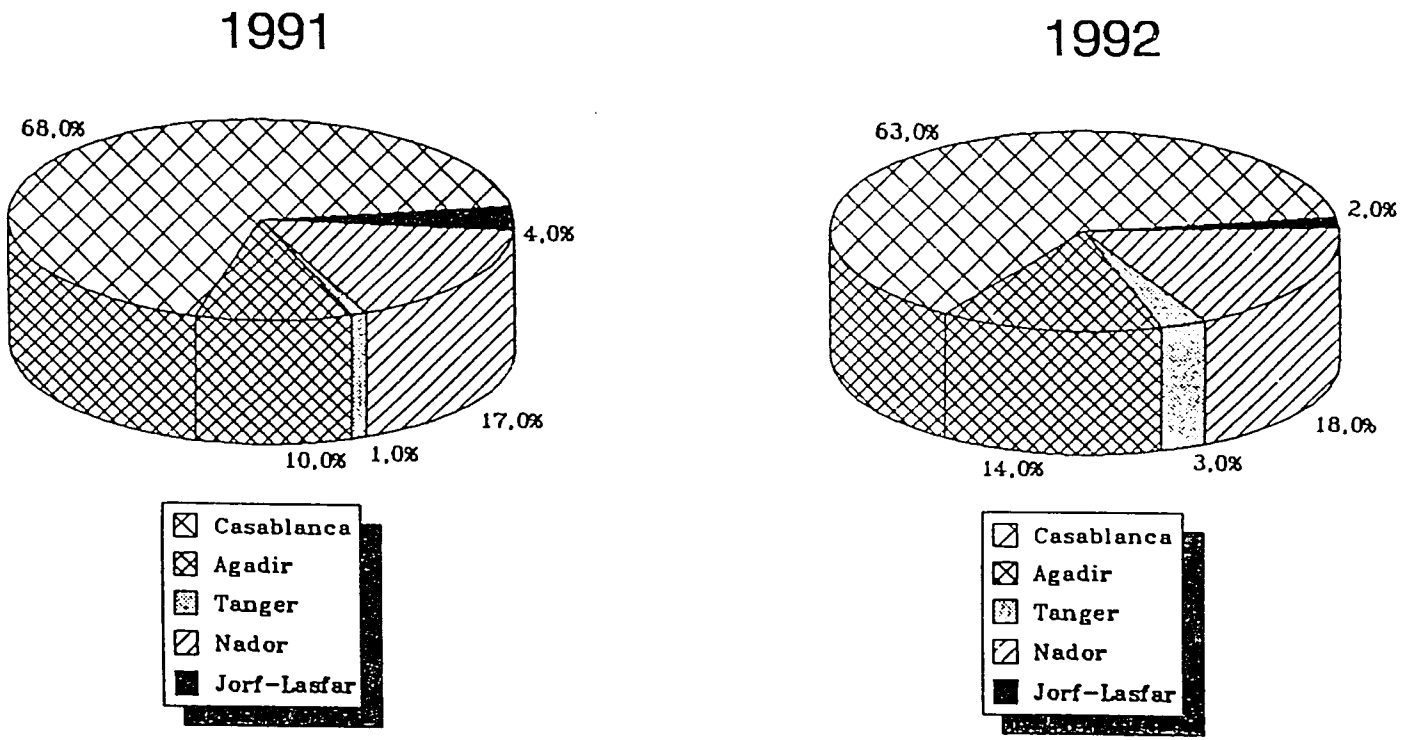




PREVISION OF IMPOTRD COAL



DISTRIBUTION OF IMPORTED COAL BY PORT



IEA Second International Conference on Clean and Efficient Use of Coal and Lignite: Its Role in Energy, Environment and Life

30 November - 3 December 1993

Workshop A (4)-Regional Needs

INDONESIAN COAL FOR ENVIRONMENTAL VALUE IN COGENERATION PLANT LJUBLJANA - SLOVENIA

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ABSTRACT

TERMOELEKTRARNA - TOPLARNA LJUBLJANA (TE-TOL) is coal fired Power Cogeneration Plant providing electricity, district heating and process steam to the city of Ljubljana with the total power and heat generation capacity of 115 MWe and 350 MWt. The TE-TOL facility was designed to burn low grade coals from local coal mines.

It has three pulverised coal fired boilers equipped with electrostatic precipitators to control particulates while other emissions are released uncontrolled to the atmosphere from 100 m high stack. The coals contain moderate to high levels of sulphur (1.1 - 3.2 %) and ash (up to 35 %) and resulting sulphur emissions and ash generation are significant because annually more than 600,000 tons of coal are required.

TE-TOL is with some 20,000 tons of SO_2 and some 200,000 m3 of ash annually ranked among the greatest SO_2 emitters and waste producers in Slovenia. In Slovenia an act has been enforced governing permissible quantities and concentrations of harmful substances that may be released into the air. According to this act it is necessary that by the end of the year 1993 emissions of great pollutants should be brought down bellow the legally foreseen limit. TE-TOL has consequently been acceleratedly looking for possibilities that would assure a decrease of excessive pollution of the environment.
Due to the act and the fact that TE-TOL generates enormous quantities of ash the most efficient sanitation measure to decrease TE-TOL harmful effects to the environment has turned out to be the use of high quality imported coal having a low sulphur and ash content.

In the period between 1991-1993 TE-TOL experienced a trial burning of high quality brown coals imported from the USA, Russia and Indonesia. The relevant results have shown that from the technological point of view all the tested coals are suitable for TE-TOL boilers, but from the ecolological one - it is the Indonesian coal that offers the best solution.

INTRODUCTION

The Republic of Slovenia, that borders to Italy, Austria and Hungary, was a northernmost republic of former Yugoslavia. It declared its independence in June 1991 and adopted its own constitution after the breakdown of what was once Yugoslavia. Its surface covers about 20 000 km2 and it has approximately 2 million inhabitants. It is a mountainous country, about 50 % covered with forests. Most of the population live in valley areas. Its capital is Ljubljana. It has 300 000 inhabitants and is located in a large basin in central Slovenia.

The thermal cogeneration plant of Ljubljana (TE-TOL) is located in the city surroundings in the part of the city called Moste. The plant is very important to city of Ljubljana, as it provides electricity, district heating and process steam to residential, commercial and industrial end users.

PLANT DESCRIPTION

The TE-TOL facility has three pulverised coal fired cogeneration units and a peak load boiler house equipped with four fuel oil fired steam and hot water boilers. Table 1 provides an insight into the facility capacity.

Table 1
TE-TOL System Capacity

Unit	Fuel	Start Year	Electric Output	Thermal Output	Steam 10 Bar 250 °C
Unit 1	Coal	1966	32 MWe	58 MWt	
Unit 2	Coal	1967	32 MWe	58 MWt	
Unit 3	Coal	1984	50 MWe	116 MWt	
Boiler 1	Fuel Oil	1979		58 MWt	
Boiler 2	Fuel Oil	1978		58 MWt	
Boiler 3	Fuel Oil	1978			5.6 kg/s
Boiler 4	Fuel Oil	1979			5.6 kg/s

The three coal fired units are the first units on line with the peak load boiler house where energy is produced as peak energy in the time of low temperatures or as a substitute source of energy during heat and power generation.
A reliable production of steam during winter months is an absolute necessity for the plant provides district heating to over 50.000 households and to other community facilities such as hospitals, schools, institutes. Electric power generation by the plant is important, but not as critical as the steam

production, because electricity can be transported into Ljubljana through connecting transmission system from neighbouring power plants.
TE-TOL is ranked among the largest electric power producers in Slovenia. It is the greatest heat producer for district heating in Slovenia.

EMISSIONS

TE-TOL was constructed to burn brown coal and lignite from local coal mines; these are mainly the brown coal from the Trbovlje mine that lies about 60 km east of the city of Ljubljana and the lignite from the Velenje mine that lies about 80 km north of Ljubljana.
On the basis of fixed-carbon content, volatile matter, moisture, sulphur content and heating value the coals are classified among those of the lowest rank. Their analyses is as follows:

Table 2
Average Domestic Coal Properties
(as received)

		TRBOVLJE		VELENJE	
Property		Content	Expected Range	Content	Expected Range
Moisture	(%)	25	20-26	39	37-40
Ash	(%)	28	24-33	18	17-20
Combustible	(%)	47	45-49	43	42-44
Sulphur	(%)	1.9	1.1-3.2	1.3	1.2-1.5
Heating Value (net)	Mj/kg	11.6	10.5-13.5	9.4	9.2-9.8

The TE-TOL air pollution control equipment consists of electrostatic precipitators (electrofilters) allotted to each boiler for control of particulates; other emissions are released uncontrolled from a 100 meter high stack. As shown in Table 2 the domestic coals contain moderate to high levels of sulphur and ash, and resulting sulphur emissions and wastes (ash) production are significant because of the large quantities of fuels required (see Table 3).
The used low grade domestic coal considerably contributes to the pollution of the Ljubljana region. The power cogeneration plant is the largest SO_2 emission source in the region and the third in the Republic of Slovenia. However, data analysis of emission and air pollution as well as weather conditions show that TE-TOL exerts a relatively small impact on the city. In spite of its high stack, air pollutants are scattered over a large area. In most cases with a lake of cold air at the bottom of the Ljubljana basin (temperature inversion), flue gases from TE-TOL will break through a stable ground air layer and will thus not worsen the air pollution in Ljubljana.

The greatest air pollution levels in Ljubljana occur during the winter heating season when concentrations of sulphur oxides frequently exceed the Slovene one hour mean limit value of 350 ug /m^3. The most important sources of air pollution resulting in high ground level concentrations within the urban area are commercial heating boilers, residential heating units and traffic.

Table 3
TE-TOL emission data for the year 1990

Coal consumption: 690,000 tons
SO2 discharge : 21,200 tons
Average SO2 emission concentration: 5990 mg/m^3
NOx discharge: 1400 tons
Average NOx emission concentration: 420 mg/m3
Solid Particles discharge: 950 tons
Solid particles emission: 200 mg/m^3
Ash generation : 250,000 m^3

In recent years, several acts regulating individual fields of air pollution in Slovenia have been enforced. The Act on the Limit Value of Concentration and Mass of Pollutants Released in to the Air (emission) was adopted in 1988 and requires a decrease of pollutant concentrations such as concentrations of SO_2, NOx, CO, solid particles and other harmful compounds bellow the permissible level. This act is to some extent, more restrictive than the German Emission Standards, which were its primary basis. For example, the German regulations require more stringent emission limits for new facilities, while allowing less stringent requirements for existing plants with a few years of the residual useful life.
The following are requirements that apply to coal fired cogeneration units in TE-TOL:

Sulphur Dioxide (as SO_2)	400 mg/m^3
Solid particles	50 mg/m^3
Nitrogen Oxides (as NO_2)	400 mg/m^3
O_2 reference value (dry, 1,013 mbar, 0 ^oC)	7 percent

The above mentioned obligations should be fulfilled until December 31, 1993.
One of the imperatives of the Act on the Limit Values of Concentration and Mass of Pollutants Released into the Air is that Thermal power plants must set up ecological information system that will ensure an on-line monitoring of air pollution. The TE-TOL ecological monitoring is already in operation and consists of equipment for continuous measurement of SO_2, NOx particulates and O_2 in the flue gases.

Due to the new atmospheric emission requirements several options for the control of emissions were examined. Apart from air pollution the most notorious problem in utilisation of low grade coals in TE-TOL is the ash disposal. TE-TOL has no ash disposal site of its own. For several years large quantities of ash have been deposited on a sanitary landfill site, partially utilised as a foundation material for road construction or dumped in abandoned pits.
Nowadays (from 1992 on), due to the lack of the space, it is only a part of the generated ash - one quarter approximately- that can be disposed on a Municipal sanitary landfill site. This deposition involves a great amount of financial means.
Due to the public opinion concerning the radioactivity of the coal ash (mainly Rn-222), its useful exploitation has so far not yet been experienced in Slovenia in spite of the fact that it has been successfully used in the world in the field of civil engineering. In the season of civil engineering works (from April to October) some 30,000 m^3 of the ash is being transported to Italy where it is used as an additive to concrete. Owing to the unsolved question regarding deposition or use of the rest of ash from TE-TOL, a conclusion has been reached that the simplest and also the least expensive sanitation measure to decrease TE-TOL harmful effects to the environment is the replacement of the domestic coal with the high quality imported coal.

In 1991, combustion tests of low sulphur coals of different origins started. Till now, testing and use of the following imported coals have been experienced:

- Coal from Cordero Mine , Wyoming, USA

- Coal from Perejaslavskij, Siberia, Russia

- Coal from PT ADARO, South Kalimantan, Indonesia
  (Paringin/Wara blend coal)

The proximate analyses of the coals is summarised in table 5.

Table 5
Proximate analyses of imported coals
(as received)

		RUSSIA	INDONESIA	USA
Moisture	(%)	32.1	28.6	31.1
Ash	(%)	5.2	2.6	6.3
Volatile Matter	(%)	29.9	34.2	31.2
C-fix	(%)	32.9	34.6	31.4
Sulphur	(%)	0.25	0.14	0.40
Heating Value (net)	Mj/kg	16.3	18.6	18.3

The test burning of the imported coals has proven that from the technological point of view all the coals are suitable for the equipment that has been designed for the coals that are of low burnability (less than 13 Mj/kg).
Considering the ecological aspect, the blend coal from Indonesia (ENVIROCOAL) has distinguished itself as being of the utmost quality (see Table 6). Measurements of emission concentrations of SO_2 have shown that emission concentrations released at the burning of the Russian and USA coals are above the permissible values, while in the case of the Indonesian coal these values are far below them . It has also been noted that the ash generation is drastically reduced. In the Indonesian case this is more than ten times. When burning the imported coals it was noted that the NOx emissions did not change considerably in comparison with domestic coals and it gets on average pretty close the legal limits.
Emissions of dust particles are essentially lower than those noted in the burning of the domestic coals, too.

Table 6

The results of emission measurements as obtained at the burning of Indonesian coal (at 7 % O_2 Vol)

Average SO2 emission concentration:	190 mg/m^3
Average NOx emission concentration:	420 mg/m3
Solid particles emission:	40 mg/m^3

CONCLUSION

Considering the favourable results- particularly from the air protection point of view-obtained at the trial burning of the Indonesian coal, TE-TOL has reached a decision to replace a great portion of domestic coal with the Indonesian one. An import of 200,000 tons of high quality coal has been foreseen for the heating season 1993/94. This coal is planned to be used especially in weather conditions in which the effect of TE-TOL on the air pollution in Ljubljana is the worst. With this respect, special forecasts of Hydrometeorological Institute of Slovenia will be followed. Simultaneously, the problem of ash in most critical periods of time when the civil engineering industry has no need of it, will be solved, too.
In TE-TOL ,it has been foreseen that the use of high quality coal will be increased provided that the economic and general situation in this part of the world will make this feasible.
According to our estimations the discussed high quality coal is to extend the life of boilers of Units 1 and 2, that have been in operation for more than 20 years, for another 5 to 10 years, which is vary much convenient in the situation when there are no financial means available for their renovation.

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LOW-RANK COAL WATER FUEL (LRCWF's) Commercial Demonstration

Oil importing nations have grave concerns regarding the security of oil supply, volatility of oil prices and safety of oil shipping, and are seeking alternatives. Of the alternatives, bituminous coal-water fuels (CWF's) appear the most promising and have spawned a new industry that already produces over 3.5 MM tpy of CWF. The magnitude of the alternative oil market can be gauged by the consumption levels of heavy oil for just the power industry in Japan, Korea and Taiwan alone, nearly 200 million barrels of oil, equivalent to about 80 million tons of CWF. Lower cost, better burning low-rank coals were excluded until the Energy & Environmental Research Center (EERC) pioneered the use of hot-water drying (HWD) to permanently reduce the inherent moisture in LRC's.

The technical feasibility of producing CWF from LRC via HWD was demonstrated in the EERC pilot plant by producing a premium fuel from the ultra low-sulfur LRC from the Beluga field on the Cook Inlet west of Anchorage, AK, USA. It proved to be a premium, non-hazardous fuel giving almost complete carbon burnout, low boiler-tube fouling, and SO_2 emissions well below even the most stringent air quality standards. Preliminary process economics indicated that LRCWF could be produced at costs below oil and competitive with bituminous CWF's in Japan. LRCWF's have superior combustion characteristics in terms of ignition rates and C-burnout which should produce lower deratings than their bituminous counterparts in oil-fired boilers. The Alaska CWF Consortium was founded to facilitate the next critical step, a commercial demonstration.

With the abundance of LRC's around the world and the need for developing nations to reduce their dependence on imported oil and lessen the hard currency drain, LRCWF offers a promising alternative to imported oil. Consequently, the EERC has initiated a number of test programs to assess converting indigenous LRC's into LRCWF's in a number of developing regions including, India, the Philippines and Eastern Europe.

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Regional Needs

REGIONAL PERSPECTIVES ON EXTERNALITIES ANALYSIS AND ELECTRIC RESOURCE PLANNING

Steven Kotz, Jody London
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ABSTRACT

Regulators concerned with power plants traditionally have met environmental concerns through control of emissions from individual power plants. However, some electric resources, such as conservation programs and generation using wind or solar energy, may have few or no emissions, while other electric resources may have significant emissions even after implementing all required controls. Also, some electric resources may offer benefits that traditional resource planning does not reflect.

Many jurisdictions now want their externalities policy to influence electric resource decisions by factoring externalities analysis into the planning process as well as the choice of emissions control technology. The purpose is for the electric resources serving a region to reflect that region's environmental and other social goals.

A qualitative approach for emissions-sensitive resource planning is to establish a preference or "set-aside" for resources with low or no emissions. A quantitative approach is to assign a cost to each emission, or a benefit to, e.g., fuel diversity, and to include those costs and benefits in the cost-effectiveness analysis of competing resource options. These approaches can be used separately or combined, but both approaches pose problems.

The qualitative approach is relatively easy to implement but relies on subjective judgment and may result in more expensive resource choices than "least-cost" planning would dictate. The quantitative approach tries to remedy the failure of the market to value "externalities," but administrative development of appropriate emissions costs is controversial and can lead to interregional conflict. Trading of emissions rights may be superior to administrative development of emissions costs.

REGIONAL PERSPECTIVES ON EXTERNALITIES ANALYSIS AND ELECTRIC RESOURCE PLANNING

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Steven Kotz, Jody London[1]

Electric resource planning traditionally has consisted of a determination of need (based on projected demand growth) followed by a cost-effectiveness analysis of different resource options. Key components of the cost-effectiveness analysis have been projected operation and maintenance, fuel, and capital costs. This traditional analysis has ignored other costs (and sometimes benefits) that may result from a given electric resource but that flow to society at large rather than to the power producer. Such costs and benefits, which economists refer to as externalities, can be large enough to affect resource choices, depending on how the planning process deals with externalities.[2]

This paper will examine the role externalities can play in resource planning, describe different policy options for analyzing externalities, and provide a critique of those options, including some of the problems that can be encountered in the implementation stage.

WHY CONSIDER EXTERNALITIES IN RESOURCE PLANNING?

There are several reasons to consider externalities in resource planning. Most electric power systems have been developed with the assumption that the primary operating fuel will be a fossil fuel. In the United States, the economy has built-in advantages for fossil fuels over other fuels in the form of industry supports, tax structure, accounting methodologies, and resource development policies. Economists, particularly environmental economists, would argue that the effects of fossil fuel production and consumption are not properly accounted for, and hence not properly priced.

In theory, the traditional resource planning process can be enhanced to consider both private and social impacts of various resource choices. One goal of such enhancement would

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[2] Some writers refer to traditional electric resource planning as based on "private costs," while planning that incorporates externalities is said to reflect both private and social costs.

be to establish a "level playing field" for competing electric generation technologies, thereby promoting a more competitive market and offsetting some of the institutional advantages of fossil fuels. For example, while fossil fuels can emit significant air pollution, other generation options such as geothermal, hydro, and wind, or demand-side management (conservation and load shifting) may have low or no emissions. Even cogeneration that uses a fossil fuel can be less damaging to the environment than conventional generation because the same heat output is used twice, once for the process load and once for power production.

Consideration of externalities frequently starts with polluting air emissions, but different generation resource choices may also have different impacts on water quality, land use, etc. Although many jurisdictions will require a project developer to mitigate adverse environmental impacts, the project may still have "residual" impacts after all emission controls and mitigation strategies are implemented. Environmental economists would argue that these residual impacts must be separately evaluated. Stated differently, they believe the failure to assign cost to externalities in the traditional planning process can be said to treat air, water, and other natural resources as if they had no value.

By assigning a (negative) economic value to residual emissions, planners can perform cost-effectiveness tests that internalize the cost to society of a given technology's residual emissions, not just the private costs developers face. For example, a coal plant that looks relatively inexpensive in a traditional cost-effectiveness test could fare differently if the test were expanded to include the costs of stack emissions, and land and water impacts from coal mining.

Properly valuing externalities can encourage fuel and technology diversity.[3] In the example discussed above, nonfossil technologies such as wind generation may be more cost-effective than coal (or other fossil-fired technologies) when externalities come into the analysis. Alternatively, the developer of the coal plant might be able to offset the consideration of externalities through design changes, such as using more stringent emission controls or modifying the combustion process. Thus, considering externalities can promote different or new technologies.

For regions that import certain fuels, considering externalities can lead to the development of domestic resources if such development is considered a positive externality, i.e., creating jobs. Another potential positive externality is in helping to solve waste disposal problems. For example, a cogeneration plant consuming biomass from farming and timber activity will eliminate the need to otherwise dispose of those wastes. The same can be true for municipal solid waste. Landfill gas can fuel a power plant, possibly with little increase in air pollution compared to abating the gas by flaring. Ignoring these positive externalities

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[3] Traditional resource planning should also assign some value to fuel and technology diversity, both because of reliability concerns and as a hedge against price volatility in fuel markets. Consideration of externalities [illegible] in addition to, not in lieu of, valuing diversity for hedging and similar purposes.

could significantly undervalue some generation resources.

POLICY OPTIONS FOR DEALING WITH EXTERNALITIES

Regulators have several options for adapting the resource planning process to address externalities. While each option may be pursued independently, some of the options can be combined, and regulators may wish to implement some such combination since the options have somewhat different objectives.

Many jurisdictions require consideration of alternatives to a given project (such as construction of new generation facilities) in the course of siting or licensing the project, if the project seems likely to have significant environmental impacts. Considering alternatives does not directly address externalities, but such consideration can identify alternatives with fewer negative externalities or more positive ones. Also, the licensing process may identify mitigation measures that reduce environmental harm or provide compensating benefits. If the project developer is required to pursue these mitigation measures, one might argue the additional costs these measures entail effectively internalize the project's negative impacts.

Another method for dealing with externalities is to set aside a portion of anticipated resource need for certain technologies. This allows planners to favor those technologies that have the most beneficial environmental characteristics. In California, state law requires that the Public Utilities Commission do this. The state law essentially requires that "renewable" generation (wind, solar, hydro, geothermal, etc.) fill some portion of the need for new electric capacity.

Implementing this renewable "set-aside" in the current resource planning cycle, the Commission has identified, for each regulated electric utility, an amount of capacity that power producers utilizing a renewable technology have an opportunity to provide. Because the utilities are conducting a competitive solicitation for this power, the eligible power producers must still bid against each other to fill the set-aside. If renewable bidders cannot provide the power at a price below that at which the utility believes it could build the renewable resource, then the utility can provide the needed capacity itself.

A renewable set-aside represents a qualitative approach to externalities, in that both the preferred technologies and the amount set aside depend on the regulator's judgment. A more quantitative approach is to assign monetary values to the externalities. Since externalities can be positive or negative, the assigned value could be an additional cost or an additional benefit associated with a particular resource choice. Promoting the use of a domestic fuel could be seen as a benefit. Conversely, jurisdictions that must import a given fuel may assign additional costs to a resource choice that would increase dependence on imported fuel.

In California, state law requires the monetizing of polluting air emissions and other

environmental externalities.[4] To implement this requirement, regulators have directed electric utilities to include air emissions "costs," along with traditional construction, fuel, and other fixed and variable costs of the various technologies, in conducting cost-effectiveness analysis for resource planning purposes, but not in dispatching existing power plants or making short-term purchases.[5]

As of this writing, controversy continues on how to perform cost-effectiveness testing that includes valuing of externalities. Controversy centers on how to set the (negative) value for the various polluting emissions.

One viewpoint is that the emissions value should reflect the marginal cost of control for the pollutant. This marginal cost is based on the most expensive emission control measure that the regulator has found to be cost-effective in a given jurisdiction.

Another viewpoint is that the emissions value should reflect the damage attributable to the pollutant; here, there is the further question whether the damage assessment should focus only on human health or should include impacts on crops, timber, fish, cattle, or indeed all biota. In either case, the emissions values are not supposed to represent out-of-pocket costs for the power producer, although they may well affect how a given electric resource scores in cost-effectiveness analysis.

Another controversy concerns whether a single value should apply to a pollutant, regardless of where the emission occurs, or whether different values should be used, depending on the point of emission. Some would argue that in an area with good air quality, the incremental cost of additional pollution is low, while the cost of additional pollution in an area with bad air quality is higher. Some have argued just the opposite, that regions with good air quality are precisely those areas (like national parks) where pollution would significantly harm those attributes that make the area valuable. Some have argued that differentiating based on the site of emission is complex and could lead to perverse results, such that uniform valuation for any given pollutant is preferable.

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[4] This cost for a particular power plant is derived by multiplying the pounds of air pollutant emitted for a given amount of generation from the plant times the cost per pound of that pollutant. Expressed algebraically, the formula is:

$$\text{lb/MWh} \times \$/\text{lb} = \$/\text{MWh}$$

for generation from the plant. The costs for each polluting emission being evaluated can then be added and factored into the cost-effectiveness calculation along with the traditional cost categories.

[5] In the future, energy regulators in California may also have to address under the statute how to value other environmental impacts besides those affecting air quality. The priority assigned to monetizing air quality impacts reflects the severity of air pollution in California's major metropolitan areas and the need to substantially increase investment in pollution abatement for California to meet state and national air quality standards.

California regulators have not finally resolved these issues. Some air quality regulators argue for the cost of control method, and some energy regulators have followed this approach, arguing that energy planning should reflect the mitigation programs established by the relevant air quality regulator. But who is the relevant air quality regulator? The California Public Utilities Commission has said the answer depends on where the emitting facility is located; on this basis, the Commission has also approved nonuniform valuation of most air pollutants, depending on air quality in the basin where the emission occurs.[6] The California Energy Commission initially also favored the cost of control method but has recently expressed a preference for damage analysis.

An alternative to setting emissions values through an administrative process is to establish a market for emissions "rights," expressed as allowable tons of emission from a given stationary source over a specified time period. Depending on applicable regulations and costs of control at a particular facility, the owner might choose to acquire additional rights, market its excess rights, or bank those rights to allow for future expansion of the facility. Over time, the market price for such rights should approach the marginal cost of controlling emissions.

The theory supporting such markets is that they will be more efficient than regulators in pricing emissions while accomplishing the goal of internalizing pollution costs. Currently, the United States has public trading of sulfur dioxide emission rights, with the intention of eventually having a nationwide market. Also, some jurisdictions are working on market programs that would apply to a single air basin for emissions of, e.g., nitrogen oxides within that basin.

CRITIQUE OF POLICY OPTIONS

Reliance solely on the licensing process for dealing with externalities has deficiencies. From the regulator's perspective, licensing statutes may not allow consideration of the full range of alternatives, and may not solve the problem of properly evaluating residual emissions. From the project developer's perspective, licensing comes late in the planning process, so the cost of delay and redesigning to meet regulatory requirements may be excessive.

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[6] Under state and national regulation in the United States, each air basin is evaluated to determine the severity of pollution from various designated pollutants. For each pollutant, an "acceptable" concentration, or standard, is established. (Typically, the standard is expressed volumetrically or in parts per million over a stated period of observation.) The regulatory intent is to set these standards at levels that protect the public health, allowing for an adequate margin of safety. An air basin that meets the standard is deemed to be an attainment area for that pollutant; conversely if observed concentrations regularly exceed the standard, the air basin is deemed to be a nonattainment area for that pollutant. An air basin can be in attainment for some pollutants and in nonattainment for others.

The developer generally wants to know well in advance of licensing the standards to which the project must be designed. This factor argues for establishing generic externalities policies, including whether and how the jurisdiction intends to value externalities, rather than developing those policies on a case-by-case basis in individual licensing proceedings.

A set-aside for favored resources, such as conservation programs or generation technology using renewables, has the advantage of simplicity and expresses, in advance of project-specific planning activity, a broad policy judgment regarding the social value of the favored resources. Given the difficulties posed by quantitative approaches to externalities, this qualitative approach has appeal. There are also disadvantages to a set-aside, however.

One reason given for analyzing externalities is to level the playing field between competing electric resources. A set-aside arguably does the opposite--it reacts to one kind of tilt by introducing a new tilt. Diminished competition is the probable result.

For example, assume that a jurisdiction has a competitive bidding process for new electric resources. If the jurisdiction creates two bidding arenas, one for fossil-fired resources and one for all other resources, higher prices are likelier to result for both types of technology, compared to a situation in which all technologies compete in a single arena. A jurisdiction contemplating the use of a set-aside should expressly consider this likely price effect.

Some regulators have proposed to compensate for this effect by setting a maximum price for the non-fossil set-aside. The maximum price could be based on the cheapest fossil-fired resources, but if non-fossil bidders can meet or beat the prices of fossil-fired resources, there's no reason for a set-aside in the first place. On the other hand, if the maximum price is to be based on some premium above the prices of fossil-fired resources, then the regulator will need some method for determining an appropriate premium. Such a determination would probably entail express valuation of externalities, but if one must expressly value externalities the apparent simplicity of the set-aside approach vanishes.

Without quantitative analysis, the relative size of the set-aside also becomes purely subjective. A generous set-aside, combined with the price effects discussed above, may have a substantial impact on electric rates. If the price differential between fossil-fired and other resources is large, this potential impact should be carefully analyzed. If the price differential is small, a set-aside may amount to an unnecessary subsidy.

Monetizing externalities might remedy the defects of the licensing process and set-asides, but there are formidable difficulties in implementation. The reason for the difficulties is the same reason that markets do not capture externalities: they are hard to value, for a variety of reasons. They tend to affect large geographic areas. They may affect the health and comfort of many people, but the causal relationship may be hard to establish. Their cumulative impact may be great, but their impact on a single individual or at a given time

may be small.

The difficulties do not justify ignoring the problem. A principal reason for regulation is to address those problems that markets do not. However, some form of interregional cooperation may be necessary if a coherent approach to externalities analysis in electric resource planning is to emerge.

Consider for example a jurisdiction consisting of a single air basin with acute smog problems. The jurisdiction desires to reduce emissions of smog precursors like nitrogen oxides, and so assigns a high cost to such emissions. Should the jurisdiction assign the same cost to such emissions if the energy would be imported from a power plant outside its air basin? If it does not assign the same cost, it is arguably adopting a policy of exporting its pollution to other areas. Moreover, the result of the nonuniformity would be to automatically consider a power plant outside its air basin cheaper than the identical plant within the basin. Such a policy could have undesirable economic effects.

But if the jurisdiction applies the same cost regardless of the emission site, other regulators may complain that the jurisdiction is trying to give extraterritorial effect to its own environmental policies. This complaint is particularly plausible where a high cost is assigned to emissions in an air basin where smog is not a problem.

Another problem concerns what air emissions should be evaluated. California regulators have assigned costs to the following power plant emissions: reactive organic gases (also called volatile orgame compounds); sulfur oxides; particulate matter; nitrogen oxides; and carbon dioxide. The latter is not a regulated pollutant under state or national clean air statutes, but it is a concern because of fears about carbon dioxide as a "greenhouse gas" contributing to global warming.

The seriousness, even the existence, of a global warming problem remains controversial. Many environmentalists argue that immediate steps to slow or reverse the growth of emissions of greenhouse gases are necessary, at least until such time as definitive studies show either there is no such problem or there is some other solution. Even given this viewpoint, the assignment of cost to carbon dioxide emissions could have perverse consequences, absent a global strategy to reduce such emissions.

Consider for example a jurisdiction that assigns a high cost to carbon dioxide emissions, such that it finds coal-fired generation not to be cost-effective and ceases building coal plants. The jurisdiction may wind up with more expensive out-of-pocket costs for electric power, while other jurisdictions continue to build new coal plants and operate existing ones. The result may be no decrease in carbon dioxide emissions overall but increased electric rates in the jurisdiction assigning a cost to such emissions.

This example suggests that how one implements externalities valuation may depend in part on whether a particular emission has a strictly local impact or has interregional or even

global impact. The same factor may also be important in creating emissions rights as a market-based solution to externalities.

Market-based solutions may ultimately supersede attempts to administratively assign externalities costs, particularly for fugitive emissions whose impacts cross state or national borders. Such solutions do not avoid all the problems of administrative solutions. For example, both approaches require monitoring of actual emissions, and timely and effective sanctions for violations. The choice between market-based and administrative solutions will also be influenced by judgments about how much government planners should influence electric resource decisions, and about how much private decision makers should influence the attainment of environmental goals.

WORKSHOP A5

ENVIRONMENTAL STRATEGIES: ENVIRONMENTAL CONSEQUENCES AND RESPONSE

Environmental Strategies

OVERVIEW OF COAL USE AND EFFICIENT FUTURE TECHNOLOGY

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INTRODUCTION

Coal utilization is an important part of the national economy in China. Because of the abundant coal resources, that the proven reserve of coal accounts for 95% on total fossil fuel. Therefore, coal has been dominated on energy production and consumption for a long time. In 1990, the run-of mine coal reached 1.09 billion tons accounting for 76.19% in the primary energy consumption structure and furthermore, this pattern will not be fundamentally changed in next two or three decade. The environmental problems in China are mainly caused by burning a large amount of coal. The national particles emission in 1991 was 13.14 Mts and SO2 emission 16.22 Mts, among which 70% and 90% were emitted by burning coal respectively. It is expected that, the run-of-mine coal production will be 1.46 billion tons by the year 2000. As a result of the extensive production and utilization of coal, a series of environmental problems should be paid more attention.

CHARACTERISTICS OF CHINA'S ENERGY CONSUMPTION

Characteristics of China's energy consumption are quite different from those of developed and developing countries. Its main characteristics are as follows;

* China is one of the few countries in the world which use coal as its principle energy source;
* Half of the energy consumed in the countryside of China is non commercial energy. Excessive consumption of biomass energy caused serious damage to ecological environment;
* With a lower per capita energy consumption and higher energy consumption for unit output value. The China's per capita commercial energy consumption in 1990 was 864 Kgce, only 40% of the world's average.(1)

The coal consumption and mix on different sectors in 1990 are listed in Table 1(2). Coal expended in industry sectors reached 810.91 Mts, accounting for 76.85% on the total. Second bigger user was household, accounting for 16%. As compared with the developed and a part of developing countries,however, coal was not only to use for power generation, steel and iron making, but also for chemical, construction materials industries and even household use.

EFFICIENCY OF COAL USE

Industrial Sectors

Although the technologies of coal use have made some improvement in past two decade, such as to import advanced technology for steel and iron making, synthetic ammonia, power generation and building material from developed countries, however, the level of energy expense per GNP is still higher than developed countries. The unit energy consumption in various industry products are listed in Table 2. The extreme energy use in small plants can be as much as twice that of modern plants. Many small plants are not only found in the light manufacturing sectors but they also represent an important share of heavy industrial and building materials. The backward technology of many small plants leads to the high average energy expense in nationwide.

Residential sectors

Urbanization has been increasing rapidly in China during the past decade. The number of cities have been increased to 467 in 1990. The ratio of population in cities and towns from 19.4% in 1980 increased to 26.4% in 1990. Urban household energy consumption for cooking was 41.62 Mtce, which was 4.2% of the total energy consumption in nationwide. The urban domestic cooking energy consumption structure and mix are listed in Table 3.(1990) The various gas fuel for domestic cooking share of 14.63% only on total. In 1990, approximately 63 million people were supplied with gas for cooking in urban.

Honeycomb briquette was supplied in rest part, that is about 33 Mts/yr. Based on the statistics in 1990, the utilization efficiency of various fuel for domestic cooking are 60% of gas, 25-35% of honeycomb briquette and 15% of bulk burning of coal.[3]

Industrial Boilers

More than 400,000 industrial boilers with 80,000 stph (ton of steam per hour) operated in China, among which 45% boiler were used in industrial sectors and 55% boiler for house heating. About 95% are coal fired. Coal consumption in industrial boilers reached 300 Mts/yr. The capacities of industrial boilers range from 0.25-35 stph. The capacities distribution, share and estimate thermal efficiency are listed in Table 4[4]. The majority of industrial boilers (82 percent) are small units and average thermal efficiency is estimated at 55-65%. It is lower, as compared to 80% efficiency typical in OECD countries.

Power Generation

China's electricity has been growing with great speed.The average annual growth rate of generated power between 1949 and 1991 was 12.8%. In 1991, the total installed capacity reached 151.47 GW, among which thermal power accounted for 113.59 GW and hydropower 37.88 GW; electricity generation reached 677.55 TWh, among which hydropower accounted for 125.09 TWh.[3]

Fuel consumption of thermal power station was 236.9 Mtce, among which coal accounted for 90.8%.The gross coal consumption rate was 390 gce/KWh and net coal consumption rate 420 gce/KWh in average. The majority of power boiler

in operation are 125-200 MW range, but about 46% are under 100 MW. Among the small plant, about 10-20% of electric power capacity are comprised of very small power plants (<25 MW); unit coal consumption rate in such plants is as much as 600 gce/KWh.

China is a developing country and its modernization construction is under way. Advanced and backward technologies exist simultaneously in coal use. Much more small plants with backward technologies and equipments are operating in various industrial sectors that is leaded to decrease average efficiency of coal utilization.

EFFICIENT FUTURE TECHNOLOGY

About 80% of coal production is expended by combustion at various sectors. How to use the coal in rational and to raise using efficiency are urgent task at now and near future. Some of the efficient future technologies as follows;

Developing Circulating Fluidized Bed Combustion (CFBC)

At present, about 3,000 bubbling fluidized bed boilers were operated with output of 2,0000 stph, which represents 2.5% of total steam production. The capacity range are from 2-120 stph. Washery waste and low grade coal were used as fuel, due to its fuel flexibility. An important research is being conducted on CFBC at various institutions. High combustion efficiency and low emission of SO_2/NO_x are regarded as two most distinguished characters The first 6t/h packed CFBC boiler was put into operation in 1988. Plant test showed that its thermal efficiency had reached 83.8% when burning low grade bituminous coal with heating value of 12,5 MJ/Kg. A 20 t/h coal fired stoke chain boiler was retrofitted into a 30 t/h CFBC boiler by JiangXi Boiler Work and it was put into operation in 1989. As compared with original thermal efficiency of 54%, the retrofitted one reached 86. 6% when burnt low grade coal with heating value of 15,0 MJ/Kg. In addition to, the capacity of 20, 35, 75 and 130 t/h were also developed. Among them, five 35 t/h units were also put into operation. A 220 t/h CFBC boiler has been designed and constructed, it is expected that will put into operation. The main parameters of CFBC boiler in China are listed in Table 5.[4]

The feature of CFBC boiler as follows;

* Fuel flexibility (high ash, high moisture and low volatile matter coal).
* Higher turn-down ratio from 25% to 110% of full load.
* Thermal efficiency >80% or more.
* Higher sulfur capture efficiency (80%), when 2-3% sulfur content in coal. and desulfurized agent used.
* Low NOx emission (<300 ppm).

It is expected that the CFBC will further promoted into application to replace stock chain boiler in small power plant in China.

Developing District Heating (DH)

There are large climatic differences among regions in China. Heating facilities are officially allowed in only the northern part of China. It can be divided into heating zone, transition zone and nonheating zone. In the heating zone, 50-65% of heating is by dispersed single building boiler, 30-45% is by stones burning coal or briquette and 5% by DH. The DH are found in 70 cities in China, they supply heat to both residential and institutional buildings; an estimate of the distribution is 60% residential and 40% institutional. More 200 million m^2 of floor area were heated by DH in 1991. Of which, about 123 million m^2 represented residential floor area. The DH/CHP represents 60-70% of current district heating compared with 30-40% for DH from large heat only coal-fired boilers (block heating). Over the next decade, the objective is to increase DH coverage to 25-30% of all cities in the heating region. The increase in DH is expected to be met 50% by DH/CHP and 50% by block heating. At present, large amount small capacity(<4stph) of boiler were used in block heating, its thermal efficiency is low that is mentioned at above, therefore, it should be replaced by large capacity boiler, such as >10stph, for rasing the thermal efficiency and decreasing coal expense.

To Develop Large-Size Coal Fired Power Station

As listed in Table 2, the electricity generating by small power plant take about 46% of total. Obviously, those small power plants should be retrofit with advanced coal fired technology. On the other hand, 300 MW and 600 MW units will mainly be installed in new power station. Moreover, the development of Co-generation thermal power is promoted at places with concentrated thermal loads. It is expected that, electricity generation should reach 1,200 TWh and the installed capacity 240 GW by the year 2000, among the newly installed capacity, thermal power will account for 2/3 and above. Hereafter, the fuel for thermal power stations will still be based on coal, while the existing oil-burning units will be converted to coal-fired ones wherever possible.

To Develop Town Gas with Complete Coal Gasification

Since China has insufficient reserves of natural gas and the prospect of coke oven gas production is limited, therefore, the complete coal gasification process should be developed in next decade for domestic cooking to replace the honeycomb briquette and bulk coal burning in cities and towns. In medium cities and towns can be adopted the cyclic two stage gasification technology. The key advantage of this technology are lower capital and avoidance of many operating and equipment. The product gas, however, has a heating value of 10.5-12.5 MJ/NM^3(2500-3000 Kcal/NM^3) and 35-45% of CO content in gas. This gas does not meet minimum town gas standard of greater than 14.6 MJ/NM^3 and less than 10% CO in China. Actual, the top gas from a two stage gasifier is already methane rich, while the bottom gas is mainly H_2 and CO by combining them, the rich gas is diluted. A better way, therefore, would be to convert the bottom gas to use as fuel gas, the high heating value top gas could be used for town gas. Another way is methanation to convert H_2 and CO to methane increasing heating value. In large cities, the modern complete coal gasification technology should be developed in future. The Lurgi pressurized gasification process has been adopted in LanZhou and HarBin city to produce medium heating

value of 16.7 MJ/NM^3 for domestic cooking. It is well commercialized moving bed gasification process. Although the oxygen is needed for this process, a reasonable plant size to achieve economic of scale, the unit cost of the gas may be lower, because of high heating value of gas produced. Since gas distribution investment remain the same, irrespective of the quality of gas, the heating value of gas should be as high as possible to optimize the distribution network. In addition to, modern coal gasification offers saving in operating and environmental control costs as compared with alternative atmospheric type gasification. Of course, the initial capital of it are very large.

To Develop Coal Briquette

Lump coal is used at some households and industrial boilers to ensure efficient combustion with minimum particulate emission. Up to now, its throughput was decreased gradually along with wide applied of mechanize mining in past two decade. A great quantities lump coal, however, should be supplied to boilers, kilns and domestic stoves. For this reason, a artificial lump coal, that is namely coal briquette was developed in China. In 1990, the coal briquette output reached 23 Mts for ammonia production to replace coke and lump anthracite in small and part of medium fertilizer plants. However, coal briquette used in stocker boiler is just beginning although research and development on it for a long time. The test result of burning coal briquette in stocker boiler has shown that the thermal efficiency rasing 10-17% and coal consumption reducing 10-20%. A comparison between coal briquette and run-of-mine coal burning test in same type boiler as listed in Table 6. Also, the dust, SO_2 and BaP emission can be reduced 71- 89%, 60% and 60% respectively, when burning briquette at stocker boiler. All of the coal briquette was made by low pressure moulding process, so the binder is needed. About 10 kinds binders have been used that are including activity clay, lime, humite waste liquid paper making and so on.(7)

Limited supplies of fuel gas are used for cooking in various cities, honeycomb briquette (usually anthracite-based) are promoted in major cities as a measure to replace direct raw coal burning. The honeycomb briquette is a low cost way to use medium ash anthracite, the ash and binders acts as a structure in which the carbon burns. If lime is used as a desulfurization agent, SO_2 emission will be reduced at 60-70%. A kind of bituminous briquette has been developed for use in cooking stoves; called top-lit honeycomb briquette. The smokeless nature of this briquette depends on them being lit at top and burning downward, countercurrent to the upward flow of air. It can be used one piece for one time cooking. According to the survey and statistics, the thermal efficiency of honeycomb briquette is about 25-30% compared with 15% for raw coal at bulk burning. The dust and SO_2 emission can be reduced 68% and 50% respectively, when lime is used. It is expected that, the honeycomb briquette will be popularized in the towns which without supply of town gas, as well as part of rural.

To Develop Coalbed Methane

According to a calculated, the reserve of coalbed methane in coal mine areas

reached 30-50 TM^3 in 1990. About 300 pair of high gassy and coal gas outburst mines are accounted for 47% of total underground mining. Among which about 110 pairs of mines had installed gas suction system. The output of coalbed methane reached 430 million M^3/yr and used for domestic cooking. However, quantity of methane from mine ventilation system reached 5.5 Bm^3/yr, which is discharged into atmospheric. Methane is one kind of greenhouse gas, it can be cause greenhouse effect and lead to global warming. On the other hand, coalbed methane will threaten safety in production of underground mining. As one of the objects of Ministry of Coal Industry in China, the suction ratio and utilization of coalbed methane will be increased in next decade. It is expected that, the output will be reached 1.5 billion m^3/yr by 1995 and 5-6 billion m^3 by 2000. At the same time, emission of coalbed methane will decreased 30-50% into atmospheric.

SUMMARY

The coal has been a dominant energy resources in China for a long time, accounting for over 70% on the primary energy production and consumption structure, and this patterns will not be fundamentally changed in next two or three decade.

Along with economic development and increase of people's living standard, the energy consumption will grow rapidly in future. The optimum strategy is to improve efficiency of energy use for energy conservation and environmental control.

About 80% coal production has been used in direct burning, and the bigger coal consumers are power station, industrial boilers, and domestic cooking. The thermal efficiency is low due to the backward technologies and facilities in these sectors.

Some advanced technologies should be adopted, such as the CFBC, DH/CHP, large power plant, small capacity of boiler for black heating replaced by large size boiler, advanced complete coal gasification and coalbed methane for town gas supply, to develop the briquette for domestic and boiler use. All of the measures, as mentioned above, will improve the efficiency of energy in next decade in China.

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Table I Coal Consumption and Mix on Different Sectors (1990)

Sectors	Coal Consumption Mt	Mix %
Total	1055.23	100.00
1, Agriculture	20.95	1.99
2, Industry	810.91	76.85
3, Construction	4.38	0.41
4, Transportation	21.61	2.05
5, Commercial	10.58	1.00
6, Non-Energy Production Sectors	19.80	1.88
7, Residential	167.00	15.82

Source: China Energy Statistic Yearbook 1991.

Table II Unit Energy Consumption in Various Industries

Product	Small plant Share of Production	Energy Measures	Aver. Consum.	Small Plant	Modern Plant
Power	46.0	gce/KWh	420	500-600	380
Coke	<30.0	t coal/t coke	NA	2-3	1.4
Crude steel	40.0	coke rate	550	600-700	NA
Ammonia	52.0	M Kcal/ton	15	17.5	8-10
Cement	82.0	tce/ton	0.19	0.17-0.20	0.1-0.18
Brick	90.0	tce/M pieces	123	120-200	105

Source: World Bank: Efficiency and Environment Impact of Coal Use in China 1991.

Table III Cooking Energy Consumption Structure and Mix in Urban (1990)

Fuel	Consumption Mtce	Mix %
Total	41.62	100.00
Coal	35.53	85.37
LPG	2.45	5.90
N. Gas	1.54	3.7
Coal Gases	1.57	3.8
Coalbed Gas	0.53	1.23

Table IV Capacity Distribution, Share and Thermal Efficiency of Industrial Boilers

Capacity stph	<1	2-4	6-20	>35
Share %	17	65	16	2
Thermal Efficiency %	50-55	63-65	65-70	>70

Sources: MMEI

Table V Main Technical Parameters of CFBC Boiler in China

Capacity	stph	6	10	20	35
Steam Pressure	Mpa	-	1.27	2.45	3.82
Steam Temp.	°C	-	194	390	450
Fuel		L. H. V. Coal, Slimes	Brown Coal, Slimes	Bitu. Coal	Bitu. Coal
Combustion Efficiency	%	>95	97	>95	98
Boiler Therm. Efficiency	%	83.36	87.75	>85	86-88
Desulfurization Efficiency	%	>90	-	>90	>80
Load Turn-down	%	100-25	110-25	100-25	100-50

Table VI A Comparison of Result Between Raw Coal and Briquette

	Briquette	Raw Coal
Proximate analysis wt% Air Dry Basis: Moisture Ash Volatile Matter Total Sulfur Calorific Value MJ/Kg	 3.4 29.04 28.92 3.70 217.44	 7.10 23.02 23.51 3.60 213.26
Feed Water Temp. °C	50.00	44.50
Steam Pressure Kg/cm^3	6.30	6.40
Steam Output Kg/h	3600	3300
Boiler Thermal Efficiency %	76.45	59.16
Coal Saving Rate %	22.6	-

Reducing Environmental Impact From Using Coal and Lignite in Thailand

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I. Introduction

In 1991 which is the end of the Sixth Economic and Social Development Plan, the total primary energy consumption of Thailand was 672.2 bpd COE, doubled the amount that consumed, 335.2 bpd COE, in 1986 which is the end of the Fifth (five year) Plan. It is projected that at the end of the Seventh Plan in 1996 and the Eight Plan in 2001, the total primary energy consumption will increase to 1,122.5 and 1,582.5 bpd COE respectively[1]. Crude oil and petroleum products, natural gas, and lignite and coal accounted the largest shares of the total primary energy consumption. In 1991, their shares were 63.2 %, 20.3 % and 13.9 % respectively.

With regard to lignite, consumption at the end of the Fourth Plan in 1981 was 1,696 thousand tons accounted for only 0.4 % of the total final energy consumption. The major consumers are power plants at Krabi and Mae Moh and the tobacco curing industry. However, since the government introduced the policy to diversify energy dependent from crude oil and petroleum products to other type of fuels in the Fifth Plan during 1982 - 1986, the total lignite consumption increased drastically from 1,696 thousand tons in 1981 to 14,542 thousand tons in 1991. As a result the pollution emitted from burning lignite increase accordingly. The flue gas emissions from a 150 MW lignite-fired power station is estimated at 240.5 kilogramme per second. Therefor, if there has no sufficient and effective regulatory measures and supervision, the emissions could cause considerable environmental impact to life in the future. The government aware of the seriousness of this problem. In its Seventh Plan during 1992-1996, a number of measures and guidelines to limit air pollution are thus introduced. With regard to environmental management, some relevant laws and regulations have been amended. This includes the National Environmental Quality Act, the strengthening of agencies responsible for environmental issues., etc.

II. Current Status and Future Lignite Requirements

Domestic coal and lignite in Thailand are mostly deposited in the northern and southern parts of the country. It is estimated that the total measured reserves is approximately

[1] National Energy Policy Office, Thailand Energy Situation 1991 - 2001.

1,767 million tons. Most of these reserves are low ranked lignite, or lignite-sub bituminous. Some sub-bituminous are also found.

Mine	Heating Value : kcal/kg[1)]
Li	4,400
Krabi	2,600
Mae Moh	2,500
Chae Khon	3,610

During the period 1982-1991 lignite production increased at least 7 fold from 2,042 thousand tons in 1982 to 14,689 thousand tons in 1991. The major consumers are thermal power plants recorded at 1,687 thousand tons in 1982 and 11,725 thousand tons in 1991 meeting the total installed capacity of 2,025 MW or 18.4 % of the total generating capacity of the Electricity Generating Authority of Thailand (EGAT).

As for industry total consumption in 1981 was only 162 thousand tons. The major consumers are tobacco curing industry. After 1986, about 4,000 industrial boilers in cement, pulp and paper, food processing, textile and chemical have converted to use lignite as fuel. It's consumption in 1982 and 1991 are 355 and 2,817 thousand tons respectively. It is projected that future coal and lignite consumption in 1996 and 2001 will increase to 19,679 and 44,213 thousand tons.

	Year 1996	Year 2001
Lignite (1,000 ton)	17,956	37,023
- Power Generation	13,754	30,854
- Industry	4,202	6,169
Coal[2)] (1,000 ton)	1,724	7,191
- Power Generation	286	5,146
- Industry	1,438	2,045
Total	19,679	44,213

III. Environmental Impact From Burning Lignite

1. Pollution Impact to Life

Lignite is comprised of carbon, hydrogen, oxygen, nitrogen and particulates., etc. From the burning process, lignite emits several pollutants such as SO_2, SO_3, NO_X, HC, CO and particulates. The amount of these pollutants emitted depends on the quality of lignite and the burning devices used. When inhaling for a certain amount and time, these pollutants can be harmful to life, livestock and crops, in addition to other non-life. Although there are several pollutants, here will mention only the major ones i.e SO_2, NO_2 and particulates of which their impacts can be summarized as follows.

1) Department of Energy Development and Promotion, Thailand Energy Situation 1992, Bangkok 1993.
2) Imported coal

SO_2 is a colourless gas with a pungen order ; it can oxidize to form sulfur trioxide, which forms sulfuric acid with water. To human health, SO_2 causes a number of respiratory diseases such as asthma, chronic bronchitis, emphysema. It reduced lung function and irritate eyes. To others, it corrode metals and deteriorate other materials. It forms acid rain ; leaf damage and reduce growth in plants.

NO_2 is a brownish-red gas with a pungent odor, often formed from oxidation of nitric oxide. To life, in causes respiratory illness, fading of paints and dyes. It reduced growth, premature leaf drop in plants and form acid rain.

Particulate in the from of ash, to life, causes asthma or other respiratory or cardiorespiratory symptoms ; coughing, chest discomfort. To other, it causes soiling and interfere plant photosynthesis, deteriorate building materials., etc.

2. Environmental Standards Related to Air Quality

There are two types of air quality standards set to control air pollution in Thailand. The Ambient Air Quality standards is set to limit the maximum allowable toxic concentrations in the air for a period of time. In general the acceptable level of concentration should not exceed the level that can be threaten health. Currently, the concentrations of SO_2 and suspended particulates for 24 hours have been limit at 0.30 and 0.33 mg/Nm^3 respectively, and for one year at 0.10 mg/Nm^3 for both pollutants, Table 1 shows the Ambient Air Quality Standards presently applicable in Thailand. However, Ambient Air Quality Standards alone may not sufficient to create efficiency of air pollution control, most countries therefore also set the Industrial Emission Standards in complementary. Currently, particulates and NO_x emission from boiler using coal and lignite are set at 400 mg/Nm^3 and 940 mg/Nm^3 respectively.

3. Abating Impact From Burning Lignit in the Past

As a matter of fact, environmental impacts to human life, livestock and crops from burning lignite is not new to Thailand. In the industrial sector, particularly the tobacco curing, after working for some years, workers suffered the problem of sulfur related health, in addition to a corrosion in metals parts of relevant facilities. The tobacco planters solved the problem by turning to other fules such as fire wood, fuel oil and diesel, and LPG. However, each of these fuel has its limitations and lignite is still being chosen due to its comparative cost advantage. Sulfur health related problem in the tobacco curing industry is therefore remain unsolved.

In the power sector, there was an incident due to the malfunction of the filtering devices in the Mae Moh power plant, co-incidental with the climatic inversion during 1-2 October 1992. About 700 villagers were reported to suffer from inhaling toxic fumes containing SO_2. The incident damaged also some livestocks and crops. Since this is the most severe incident has ever happended in using lignite as fuel. In order to prevent the recurrence of the incident, the government took several immediate actions in abating the impact. The following are the short-term control measures adopted.

i) If the emission of SO_2 reach 250 $\mu g/Nm^3$ and the height of inversion is between 120-450 metres, reduce the generation of unit Nos. 1-3 for 90 MW.

ii) If the emission of SO_2 reach 280 $\mu g/Nm^3$, reduce the generation of unit Nos.4-7 for 120 MW, together with another 200 MW of unit Nos. 8-11, total to 410 MW or about 20 % of the installed capacity of the existing 11 units in operation.

iii) If the emission of SO_2 reach 300 $\mu g/Nm^3$, reduce the generation of unit Nos.8-11 for another 200 MW, total to 610 MW or 30 % of the total lignite generating capacity.

iv) If the emission of SO_2 exceed 300 $\mu g/Nm^3$, cease one unit each of the unit Nos.1-3, 4-7 and 8-11, total to 975 MW or 48 % of the total lignite generating capacity.

Table 1[1)]

Ambient Air Quality Standards

Pollutants	1-hr average value mg/Nm3	8-hr average value mg/Nm3	24-hr average value mg/Nm3	1-yr average value mg/Nm3	Methods of Measurement
Carbon Monoxide (CO)	50	20	-	-	Non-Dispersive Infrared Detection
Nitrogen Dioxide (NO_2)	0.32	-	-	-	Gas Phase Chemiluminescence
Sulfur Dioxide (SO_2)	-	-	0.30	0.10*	Pararosaniline
Suspended Particulate Matter (SPM)	-	-	0.33	0.10*	Gravimetric-High Volume
Photochemical Oxidant (O_3)	0.20	-	-	-	Chemiluminescence
Lead (Pb)	-	-	0.01	-	Wet Ashing

Note : * Geometric mean value.

1) Office of the National Environment Board, Laws and Standards on Pollution Control in Thailand, 2nd ed, Thailand, July 1987.

Table 2[1)]

Industrial Emission Standard

No.	substance	Sources	Values Standard
1.	Particulate	Boiler & Furnance	
		- Heavy oil as fuel	300 mg/Nm^3
		- Coal as fuel	400 mg/Nm^3
		- Other fuel	400 mg/Nm^3
		Stell manufacturing	300 mg/Nm^3
		Other Source	400 mg/Nm^3
2.	CO	any source	1000 mg/Nm^3 or 870 ppm
3.	Sulfuric acid	any source	100 mg/Nm^3 or 25 ppm
4.	SO_2	H_2SO_4 Production	1300 mg/Nm^3 or 500 ppm
5.	NO_x	Boiler	
		- Coal as fuel	940 mg/Nm^3 or 500 ppm
		- Other fuel	470 mg/Nm^3 or 250 ppm

1) Department of Industrial Works, Ministry of Industry, Factories Act 1992, Bangkok 1992.

Table 3 shows the existing installed capacity, lignite consumption and electricity generation by various plants at Mae Moh.

Table 3

Installed Capacity, Lignite Consumption and Electricity Generation of Lignite Fired Power Plants at Mae Moh

Unit	Installed Capacity (MW)	Electricity Generation (10^3kWh/day)	Lignite Consumption tons/day
1	75	493	1,467
2	75	493	1,467
3	75	493	1,467
4	150	985	3,300
5	150	985	3,300
6	150	985	3,300
7	150	985	3,300
8	300	1,970	6,300
9	300	1,970	6,300
10	300	1,970	6,300
11	300	1,970	6,300
12*	300	1,970	6,300
13*	300	1,970	6,300

IV Strategies in Reducing Environmental Impact From Using Lignite

The effectiveness of the environmental standards set to protect and improve the environmental quality depends on several factors, namely, sound policies and guidelines, good management and efficiency use of the fuel. As these factors are considered to cover overall air quality control including air quality affected from burning lignite, the following discussion will be based on this ground in presenting strategies in reducing environmental impact from using lignite.

1. National Policies and Guidelines

The National Economic and Social Development Plan incorporated environmental issues for the first time in its Sixth Plan. However, the guidelines contained are still very broad and did not touch on conserving air quality by source. In the Seventh Plan, a chapter on Environmental Development for Better Quality of Life is incorporated aiming to improve the deteriorated natural resoruces. Policies, targets and measures to control pollution by sources of origin have spelled out. More importantly, guidelines for environmental development to improve better quality of life are given. As far as air pollution created from burning lignite is concerned, required standards to control maximum allowable level of SO_2 and dust particles to be emitted from chimneys and generators are addressed. In order to

* To be commissioned in 1995.

meet the required standards, industrial and power plants are required to install SO_2 treatment unit. The guidelines also recommended the introduction of fiscal incentive and measures to ensure the effectiveness in implementing the standards. In addition, the Chapter on Energy Development has set targets to limit the amount of SO_2 generated from burning lignite in the power and industrial sectors.

Unit : '000 tons

	Year 1990	Year 1996
Lignite for industry	205	190
Lignite for electricity generation	535	620

2. Management

Good management is necessary for the success of protecting environmental quality. In principle there are several levels of management, from the broadest to the narrowest levels. As for the broadest, laws and regulations are referred to whereas the narrowest level refer to institutional arrangments assinged to undertake environmental tasks. In addition, this heading will also touch on the supplementary of the energy conservation programme initiated in Thailand.

2.1 Legal Frameworks

There are a number of laws and regulations related to pollution control enacted by different ministries. The Factories Act governing by the Department of Industrial Works (DIW), Ministry of Industry is responsible for issuance of factory establishment license. Applicants are required to submit details on effluent treatment system. For certain projects, file on Environmental Impact Assessment (EIA) is also required to be approved by the Department of Pollution Control prior to the factory start-up. The DIW is also responsible for the enforcement of Poisonous Substance Act which include pollution control from industries.

The National Environmental Quality Act 1992 created the National Environmental Board (NEB) and three departmental agencies to responsible for policies and planning, control and extension tasks, under the Ministry of Science, Technology and Environment. Besideds, this Act has also initiated the " Environmental Fund" to provide loan supporting to the public and private sectors in purchasing air and water pollution control devices. The Fund is also a financial source in assisting and supporting the undertaking of environmental conservation activities.

2.2 Institutional Arrangements

In order to response to the revised scope of work indicated in the National Environmental Act 1992, the NEB is empowered to list development projects that are required to submit an EIA report prior to approval, approve environmental management plans, provide recommendations in amending related laws and regulations. In addition, the NEB is also empowered to provide recommendations on standards, monetary, fiscal and tax measures to be undertaken in promoting environmental quality., etc.

Another significant institutional arrangement is the re-organization of the Office of the National Environmental Board into three separated departmental agencies i.e. Office of the Environmental Policy and Planning, the Department of Pollution Control and the Department of Environmental Extensions. Functions of these departments can be highlighted as follows :

i) Office of the Environmental Policy and Planning is responsible for the formulation of national policy and planning to promote environmental quality, coordinate environmental management plans, monitor and prepare report on environmental quality sitution, conduct and analyse environmental impact arised from activities or projects which could damage the quality of environment, etc.

ii) The Department of Pollution Control is responsible for providing recommendations on environmental controls, standards , the formulation of environmental management plans and measures, monitor and prepare reports on pollution situation, develop appropriate systems, patterns and methods for the managements of pollution control by source, implement the environmental control rules and regulations., etc.

iii) The Department of Environmental Extension is responsible for promoting, promugating and public relation activities, collect, prepare and provide service on environmental technologies, etc.

3. The Energy Conservation Programme

Resulted from the increasing difficulty in balancing the electricity demand-supply of the country, the government gives priority to energy efficiency. This is due to the fact that the efficient use of energy and its conservation not only help reduce investment requirements in energy production, but also helps reduce the impact of energy consumption on environment. Thailand initiated its energy conservation programme since 1982. A number of projects have been implemented. They include promulation and technical services, the introductory of the Time of Day (TOD) Rate for large industry and mining consumers, the Demand Side Management (DSM) Programme, and the enact of the Energy Conservation Promotion Act 1992. The contribution of these programmes can be

summarized as follow :

i) The Energy Conservation Project.

This project started in 1982. Activities included are energy audit services to factories, buildings and training, research and improvement of equipment. Incentives are provided through low rate interest loan and tax reduction for energy saving appliances and equipment. Regulations made through the review of rules and regulations. At the end of 1986, the total energy saved are 132.09 GWh/year equivalent to 45.78 million litres of crude oil/year, and 243.55 million litres of crude oil, total to 289.33 million litres of crude oil/year or 74% of the potential set at 850 million litres of crude oil equivalent.

ii) Time of Day Rate

Due to differences of load characteristics in the Metropolitan Electricity Authority and the Provincial Electricity Authority sale areas, the Electricity Generating Authority of Thailand has to reserve additional investment in order to cover the system peak. Investment for this portion increase every year to maintain sufficient reserve margin and reliability of the total system, especially during the period 1989-1991. To solve this problem, the government introduced the Time of Day Rate applicable for large industrial and mining consumers with demand exceeding 2,000 KW effective from 1 January 1990 onwards. It is target that 70 MW or 10 % of the demand for power at peak time of these consumers will be saved.

iii) The Energy Conservation Promotion Act

This Act has just been effective in April 1992. With regard to regulatory functions, it defines the responsibilities of relevant agencies in implementing energy conservation tasks and programmes. It also defines the types and means in conserving energy as well as rights and responsibilities of the regulated factories and buildings. As for promotion tasks, an Energy Conservation Fund is created to provide financial assistance to both the private and public sector in undertaking energy conservation programmes. It also assist activities which help to protect and solve problems arising from saving energy. It is expected that this Act will encourage electricity saving approximately 225.56 GWh per year.

iv) The DSM Programme

This programme is formulated to support the Energy Conservation and Promotion Act with particular emphasize on efficiency aspect of electrical equipment. The programme provides technical consultation service for load management in reducing electricity load and rebate for consumers in changing to higher efficiency electrical equipment. It is expected that through out the programme 1992-1996, the DSM will reduce consumption for 1,078 GWh/year and the peak demand for 226 MW.

Besides, it will reduce investment cost in building a power plant of 6,750 million Baht and save fuel expense in generating electricity approximately 754 million Baht/year.

V. Compromising Balance between Economic Growth and Development and Quality of Life and Environment

Thailand has its First Economic and Social Development Plan in 1961. Up to now, six five-year plans have already been implemented. The average growth rates achieved are 8.0, 7.5, 6.2, 7.0, 4.4 and 10.5. In terms of Gross National Product (GNP)per capita, it increase from year to year showing a better performance from the past.

Year	GNP/Capital : Baht[1)]
1980	19,493
1982	20,085
1982	20,733
1983	21,594
1984	22,267
1985	22,731
1986	23,489
1987	25,334
1988	28,256
1989	31,353
1990	34,589
1991	36,770

However, taking into account the depletion and deteriorated natural resources devoted to the growth process, these figures may not as high as they appear. Especially when the natural resources have been deteriorated to the level that is harmful to the environment and the quality of life and the cost of improving it is too high to afford at a time. While maintaining the economic growth is required, partial improvement of the deteriorated natural resources could be the choice. The process of this choice could be explained through the decision taken in installing the SO_2 treatment unit at the Mae Moh Power Plant.

When the decision was made to introduce lignite to play more important role in the Thai energy scene, the advantage is not only to divert the sole dependent on crude oil and petroleum products of the country, but also the foreign exchange saved from importing energy. EGAT has its least-cost power expansion plan since 1989 by incorporating several new thermal plants using lignite as fuel at Mae Moh. Before then, air pollution from burning lignite was not a serious problem. Control of SO_2 has been implemented by using high stacks and reduce NO_2 concentrations by using low NO_2 burners and firing controls. However, the incident at Mae Moh power plant in October 1992 has proved that these controls are not sufficient.

1) At 1988 price (US$ 1 = Baht 26)

At the same time to install SO_2 treatment units for all lignite-fired power plants are not possible due to its high cost. The government therefore decided to incorporated the plan to install SO_2 treatment unit starting first with power plant unit Nos.12-13 which are scheduled to be commissioned in 1995. The cost of installation is estimated at 1,900 million Baht. The operating cost will increase 640 million Baht per year or 0.88 Baht per KWh. With regard to the other eleven power plants which have already in operation, the government has decided to install SO_2 treatment units for power plant unit Nos.8-11. The cost of installation is estimated at 7,020 million Baht with an increase of annual operating cost of 1,140 million Baht or 1.80 Baht/kWh for the whole system.

The decision whether to install further to cover the rest or not depend on the comparative cost advantage of lignite over other fuels. If the least-cost option is still be held, the rest might be worth installing. In other words,if the unit cost of electricity generated from lignite is greater than the unit cost of electricity generated from other fuels, then lignite is no more least-cost option in the EGAT's power expansion development plan. It is then viable to use other fuel which is more cost advantage and less harmful to the environment.

It should also be noted that for the same reason the set of standards for industrial boilers has to take into account the viability of the industry while environmental quality is also required to protect.

VI. Conclusion

The need to balance the supply to meet the rapid growth in the demand for energy has been facing more and more environmental concern. The concern is not limited only on the supply side, but also on the process of using energy. As for the case of lignite the more it is consumed, the greater impact to life and non-life will be. Therefore efficient control of SO_2 emission is required. However, the installation of SO_2 treatment units for all lignite-fired power plant is too costly and not viable. The decision whether and how many additional units of SO_2 treatment units are required, is determined from the level that the pollution emitted will not reach the level which is harmful to life, while the least-cost option using lignite is still feasible. In other words, contribution from least-cost electricity is required in advancing the country's economic growth and development. However, the growth and development reflecting in terms of higher or better standards of living should also be interpreted under the condition of healthy environment too.

Recently, Thailand has developed and laid down a number of necessary ground works which help to protect and improve the quality of environment in terms of formulating policies and guidelines, setting of standards, improving of management., etc. Most significantly are the issuing and amendment of related laws and regulations. In order to make these laws and regulations effective, more government inspectors should be allocated and closer coordination between relevant agencies are recommended.

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IEA SECOND INTERNATIONAL CONFERENCE ON THE CLEAN AND EFFICIENT USE OF COAL AND LIGNITE: ITS ROLE IN ENERGY, ENVIRONMENT AND LIFE

30 November - 3 December 1993

Paper Topic: Air Toxic Emissions

"Air Toxic Emissions from Coal-Fired Power Plants: Opportunities and Challenges"

Katherine K. Connor, Senior Associate

Decision Focus Incorporated

This paper presents the results of recent research conducted by the Electric Power Research Institute (EPRI) and individual utilities on the emissions of air toxics from coal-fired power plants in the U.S. The paper discusses expected air toxic emissions and risk levels for different fuels and power plant configurations, including a comparison of the relative risk levels of coal plants with controlled and uncontrolled oil-fired plants. Key issues with respect to recent air toxics regulation in the U.S. are highlighted, as are the key uncertainties and important challenges for future research. Potential benefits and opportunities from burning coal, including the potential advantages derived from coal cleaning and opportunities for co-firing wastes (such as tires) with coal also are presented.

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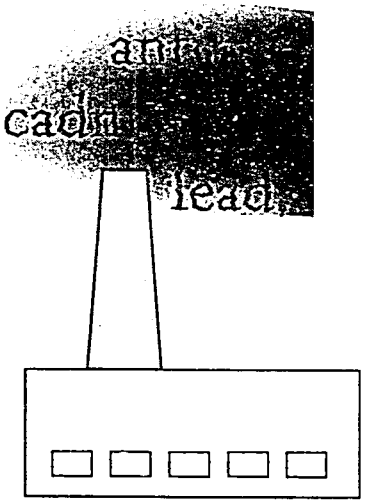
8360004. 2

- Introduction
- Overview of Current Research
- Summary of Results
- Opportunities and Challenges

8360004. 3



"... an air pollutant that causes, or contributes to, air pollution which may result in an increase in mortality or an increase in serious irreversible, or incapacitating reversible illness."

U.S. EPA

8360004. 4

[redacted] TO UTILITIES?

- Increasing public concern and activism
- Existing Federal and State regulations requiring toxics inventories, reporting, and control
- New provisions in the 1990 Amendments to the Clean Air Act
- Potential industry compliance costs of US$1 billion per year

8360004. 5

[redacted]DMENTS OF 1990

- Lists 189 hazardous air pollutants
- For regulated sources, requires "Maximum Achievable Control Technology" and no "significant" residual risk
- Studies related to the Utility Industry
  - Electric Utility Study (11/95)
  - Mercury Study (11/94)
  - Great Waters Study (11/93, 11/95)
  - Review of Risk Assessment Methods and Application

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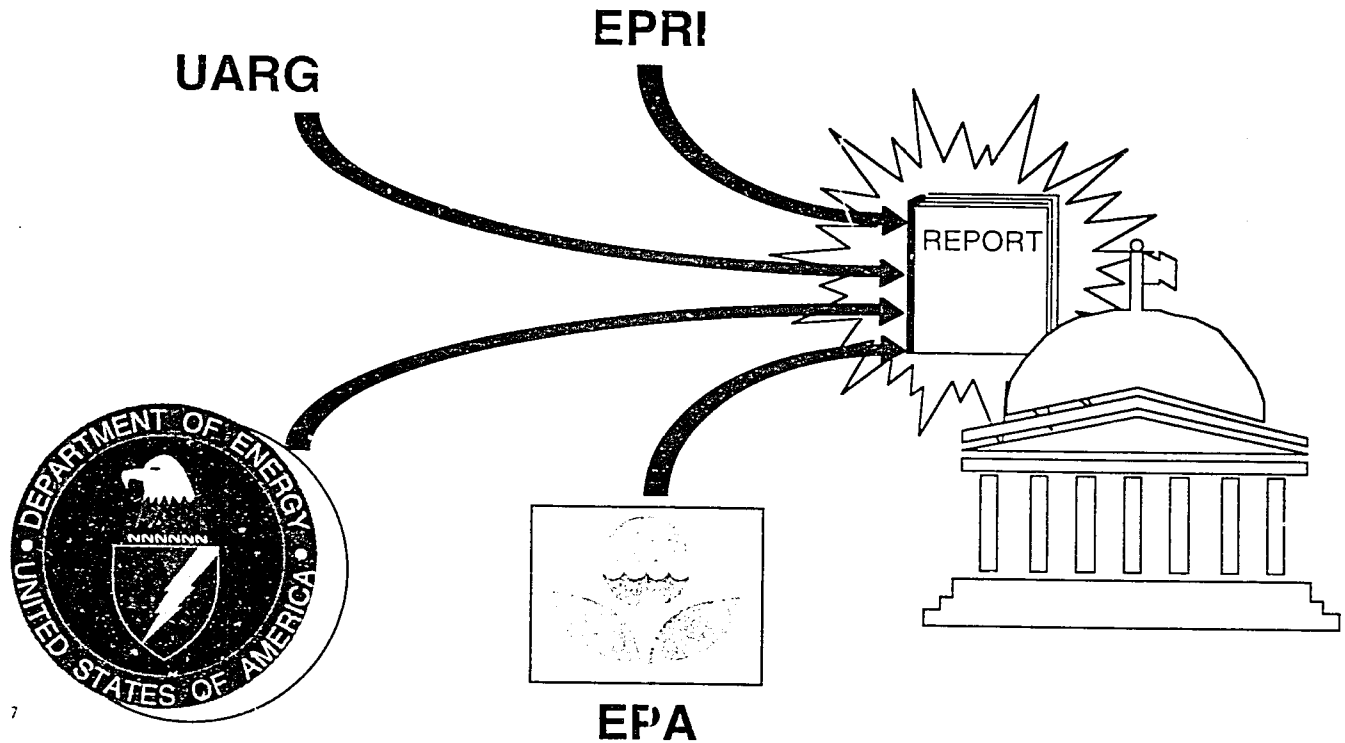
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DEPARTMENT OF ENERGY
UNITED STATES OF AMERICA
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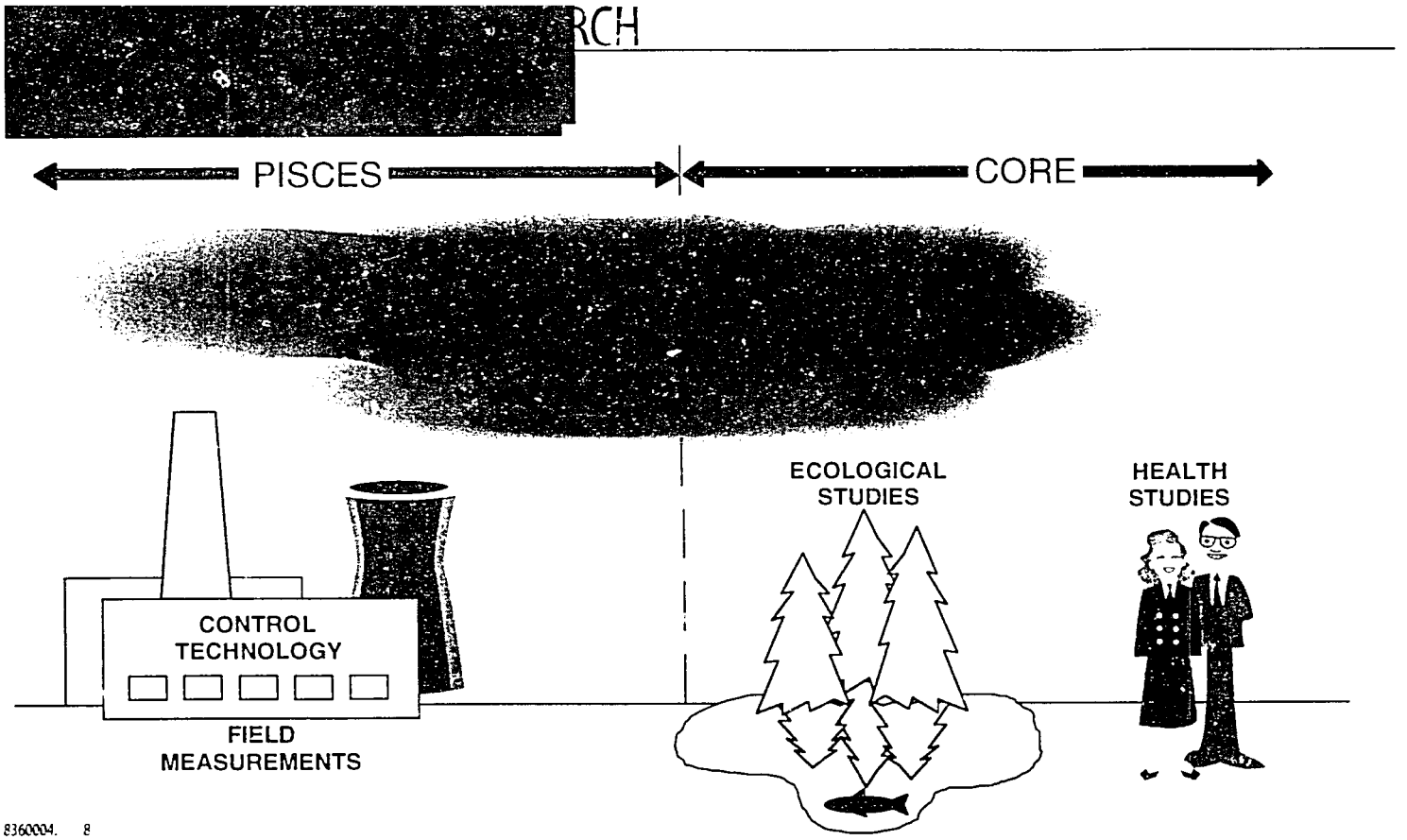
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HEALTH
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8360004. 8

[redacted]LYSIS

- Grouped 1,749 units into 14 configuration categories
- Focused on 7 inhalation carcinogens
- Computed health risk for the "Maximally Exposed Individual"

GOALS

- Prioritize groups of plants according to risks
- Identify key determinants of risk
- Identify research needs
- Provide direction for detailed risk analyses

8360004. 11

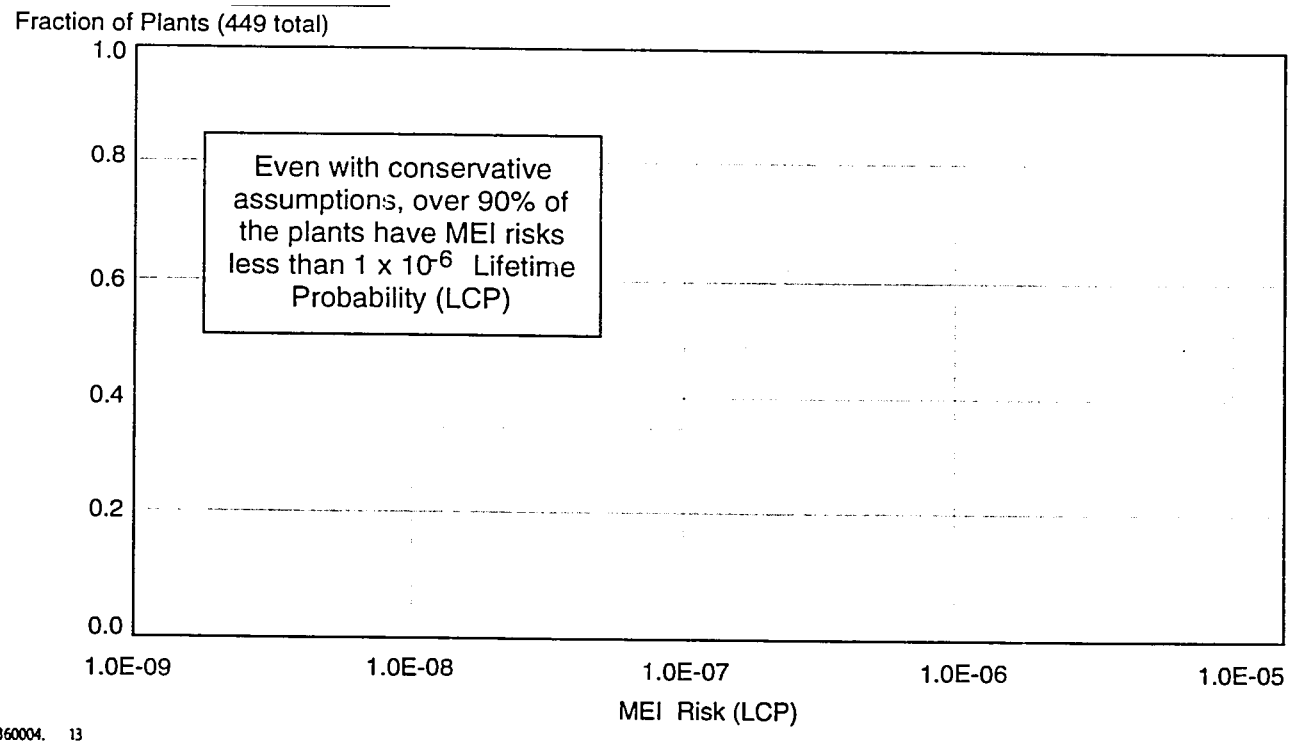
[redacted]ELD MEASUREMENTS

POWER PLANT CONFIGURATIONS

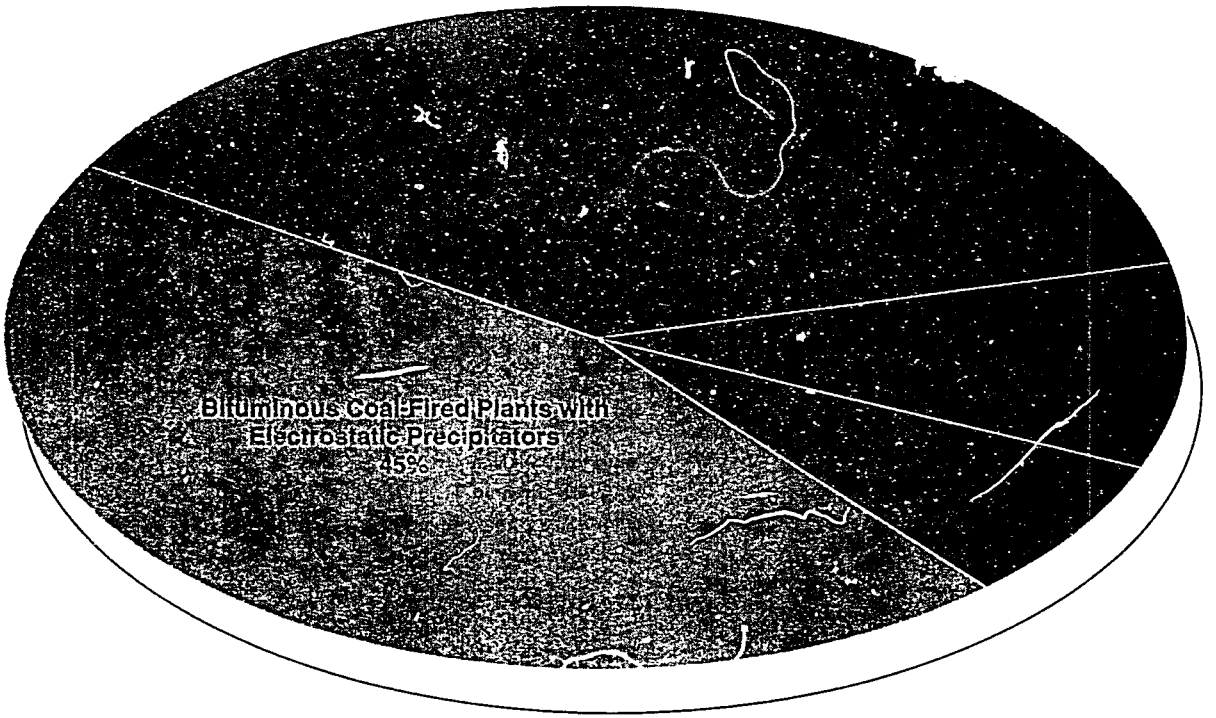
Fuel Type	Part. Control	SO2 Control	% of MW	FCEM*
Bit. Coal	ESP	None	38	√
Gas	All	All	20	√
Sub. Coal	ESP	None	11	√
Bit. Coal	ESP	Scrubber	7	√
Oil	None	All	5	√
Oil	Any	All	5	√
Other Coal	ESP	Scrubber	3	
Sub. Coal	ESP	Scrubber	3	√
Sub. Coal	Baghouse	Scrubber	2	
Bit. Coal	Baghouse	Scrubber	1	√
Sub. Coal	Scrubber	Scrubber	1	
Other Coal	ESP	None	1	
Sub. Coal	Baghouse	None	1	
Bit. Coal	Baghouse	None	1	

8360004. 12

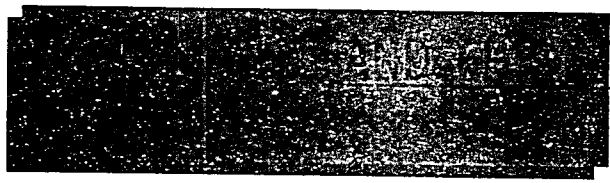
*Data from EPRI's Field Chemical Emissions Monitoring Project


Fraction of Plants (449 total)
1.0
0.8
0.6
0.4
0.2
0.0
Even with conservative assumptions, over 90% of the plants have MEI risks less than 1 x 10-6 Lifetime Probability (LCP)
1.0E-09
1.0E-08
1.0E-07
1.0E-06
1.0E-05
MEI Risk (LCP)

8360004. 13


Bituminous Coal-Fired Plants with
Electrostatic Precipitators
45%

8360004. 14



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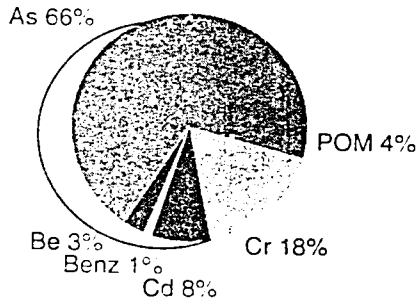
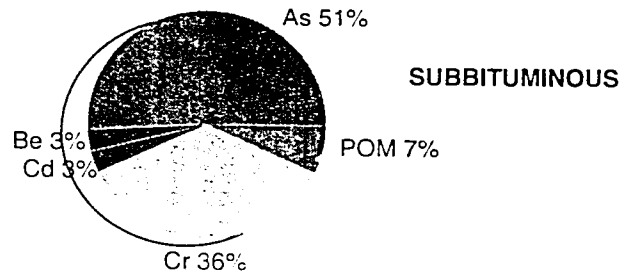
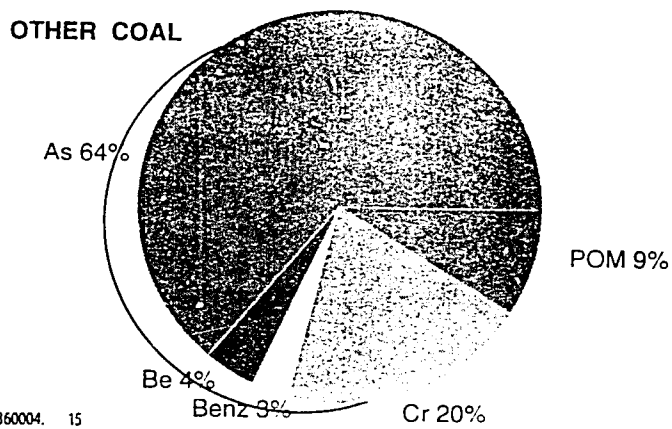
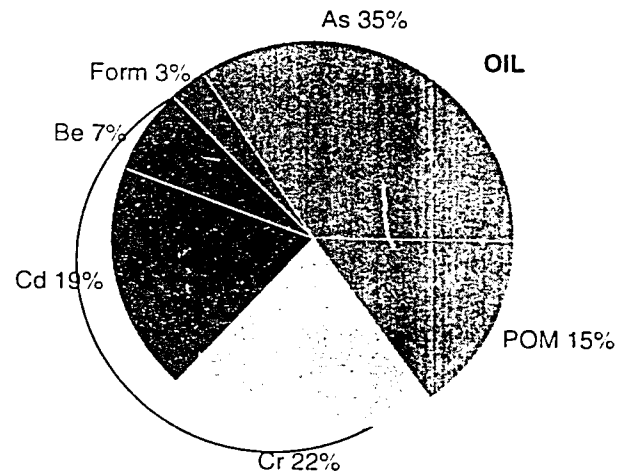


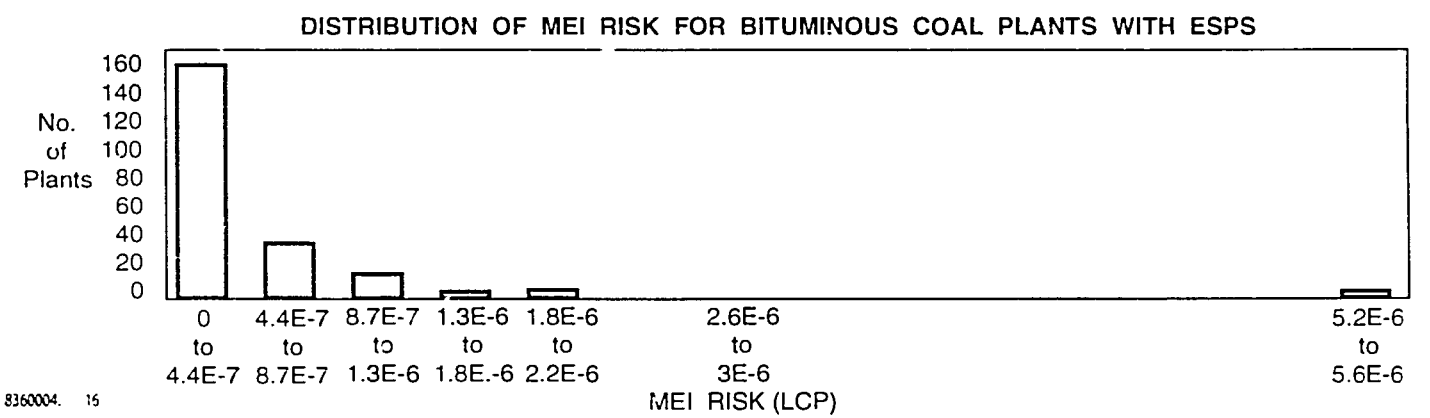




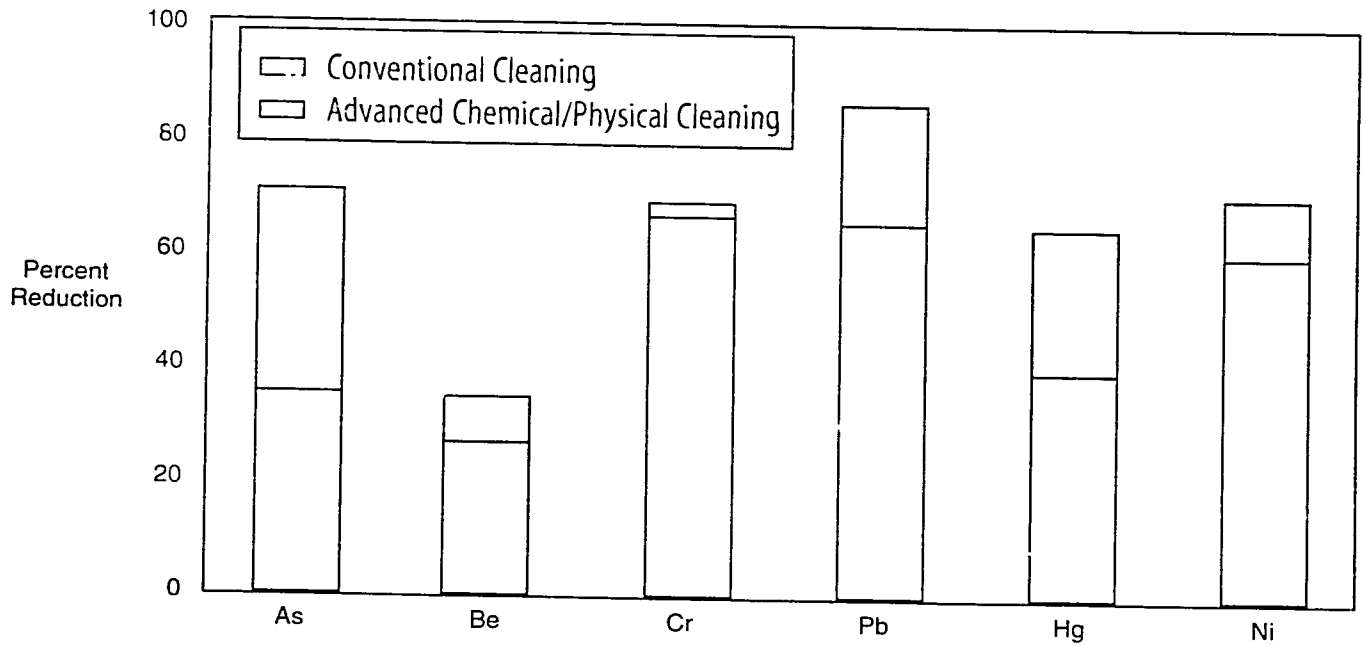


8360004. 15

- On *average* MEI risks are below potential regulatory thresholds and coal plant risks are a factor 3 less than oil plant risks
- A few outliers within the high priority plant categories will be targeted for more detailed analysis



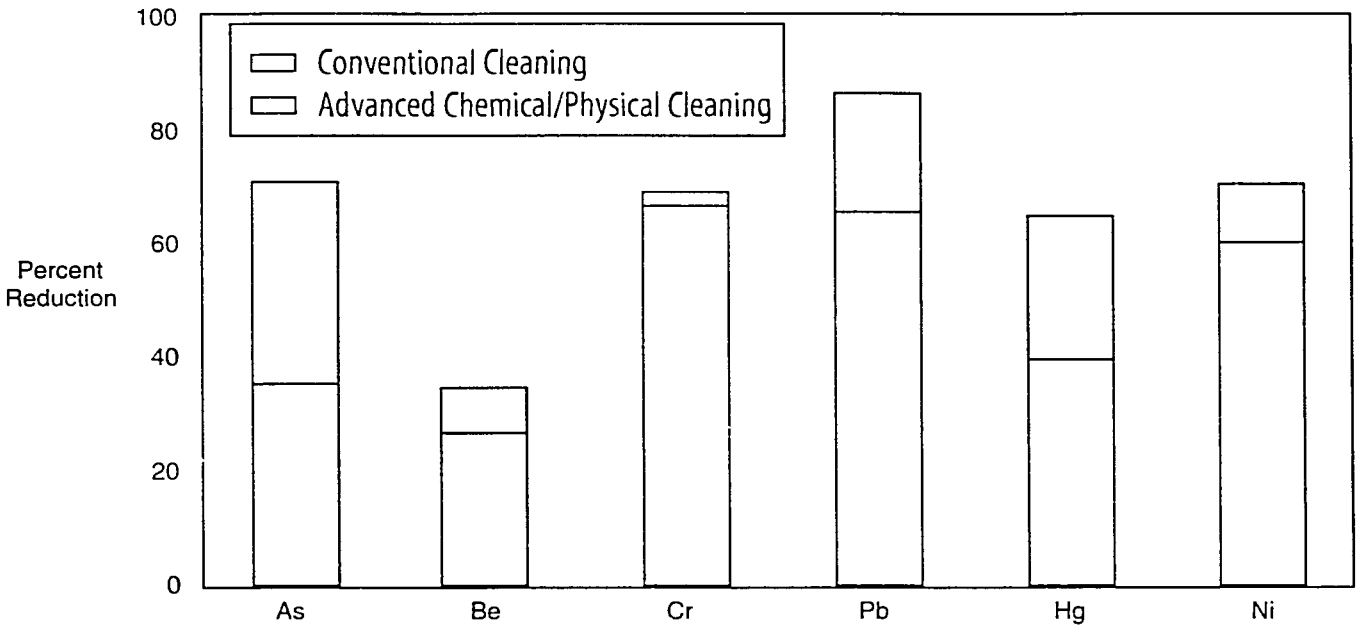
TRACE EMISSIONS



SOURCE: "Pre-Combustion Control of Air Toxics", Akers et al, CQ Inc., 1992

8360004. 17

TRACE EMISSIONS



SOURCE: "Pre-Combustion Control of Air Toxics", Akers et al, CQ Inc., 1992

8360004. 17

[redacted]S WASTE DISPOSAL PROBLEMS

For 10% Tire-Derived Fuel:

- Emissions of As, Be and Cd decreased by 8 to 10%
- Emissions of Cr increased substantially
- Even under worst-case scenarios, emission controls were not required for air toxics
- Savings of US$13.5 million (present value) in fuel and control costs

TRACE ELEMENT CONCENTRATIONS IN FUELS

Trace Metal	BB Coal (ppm)	Subbituminous Coal (ppm)	Tires (ppm)
Arsenic	3.6	6.2	0.800
Beryllium	10.0	1.3	0.001
Cadmium	0.5	0.4	0.020
Chromium	4.8	14.9	110.000

8360004. 18

[redacted]URE

- Improved sampling and analysis methods for emissions of key compounds and species (e.g. Cr, Hg, As, and Ni)
- Better data on trace element concentrations and modes of occurrence in coals
- Measurements for plants with NOx controls and for plants with new or improved particulate and SO_2 control technologies
- Information on the respirable fraction of emissions from oil-fired plants
- Better understanding of the impacts of bioavailability and metabolical processes on the actual received dose of chemicals
- Improved models of the relationship between dose and adverse health effects
- Prediction of future (2010) plant configurations, operations, and fuel supplies

8360004. 19

IEA Second International Conference
on the Clean and Efficient Use of Coal and Lignite:
Its Role in Energy, Environment and Life

30 November - 3 December 1993

ANALYSIS AND DEVELOPMENT OF LOW-EMISSION BOILER SYSTEMS FOR DOE PETC COMBUSTION 2000 PROGRAM

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ABB POWER PLANT LABORATORIES
COMBUSTION ENGINEERING, INC.

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ABB ENVIRONMENTAL SYSTEMS

The Pittsburgh Energy Technology Center is leading DOE's Combustion 2000 initiative. The objectives of this program are to continue and expand coal's use in electric power generation by developing technology to make coal burn cleaner, and make coal-fired power plants more efficient. The authors' companies form one of three teams engaged in Phase I of the project for "Engineering Development of Advanced Coal-Fired Low Emissions Boiler Systems" (LEBS) as part of the Combustion 2000 Program.

The overall objective of the LEBS Project is the expedited commercialization of advanced coal-fired low-emission boiler systems. The specified primary objectives are emissions of NO_x and SO_x less than one-third NSPS, particulates less than one-half NSPS, and air toxics in compliance. Secondary objectives are improved ash disposability, reduced waste generation, and increased generating efficiency. All primary, and all or some secondary, objectives must be met without increasing the cost of electricity from a current "NSPS plant."

This paper reports on the Concept Development and Evaluation work completed as part of the Phase I effort. During this effort many near term emissions controls technologies were screened to produce a short list of five SO_x/particulate and five NO_x candidates which were subjected to comprehensive analyses on a subsystem level. Based on this analysis, six combinations of seven technologies from the short list were evaluated for technical, economic and commercial feasibility as integral parts of an advanced supercritical steam plant design.

The paper summarizes this effort and the results of the comparative analysis based on the six plant designs.

ANALYSIS AND DEVELOPMENT OF LOW-EMISSION BOILER SYSTEMS FOR DOE PETC COMBUSTION 2000 PROGRAM

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JAMES D. WESNOR, ABB ENVIRONMENTAL SYSTEMS

BACKGROUND

The Pittsburgh Energy Technology Center is leading DOE's Combustion 2000 initiative. The objectives of this program are to continue and expand coal's use in electric power generation by developing technology to make coal burn cleaner, and make coal-fired power plants more efficient. The author's companies are one of three teams engaged in Phase I of the project for "Engineering Development of Advanced Coal-Fired Low Emissions Boiler Systems" (LEBS) as part of the Combustion 2000 Program.

The overall objective of the LEBS Project is the expedited commercialization of advanced coal-fired low-emission boiler systems. The Project is a multi-year, multi-phased effort that will conclude with the construction and operation of a proof of concept facility. Competition is restricted to the three teams selected in 1992. The Project consists of four phases with multiple awards and down selection from among the three original participants as the Project progresses. Phase I ends in late 1994.

This paper reports on the efforts of the ABB/RE&C Team to screen various candidate SO_x/ Particulate and NO_x technologies and select a single combination for incorporation in the preconceptual design of a Commercial Generating Unit (CGU).

OBJECTIVES

The overall objective of the Project is the expedited commercialization of advanced coal-fired low-emission boiler systems. The specified primary objectives are emissions of NO_x and SO_x less than one-third NSPS, particulates less than one-half NSPS, and air toxics in compliance. Secondary objectives are improved ash disposability, reduced waste generation, and increased generating efficiency. All primary, and all or some secondary, objectives must be met without increasing the cost of electricity from a current "NSPS plant". Because emission requirements vary from site to site, ABB elected to have two NO_x targets (the contract target of 0.2 lb/million Btu and approximately 0.05 lb/million Btu) and to favor SO_x and particulate control technologies which can be designed for emission levels lower than the contract targets with minimum impact on costs.

The final deliverables are a design data base that will allow future coal-fired power plants to meet the stated objectives and a preliminary design of a commercial generating unit. The deliverables for Phase I are a Project Work Plan covering all four phases, concept and component evaluation and selection, an R&D and Test Plan, a preliminary Commercial Generating Unit design, and a Phase I report.

APPROACH

The work in Phase I, which will cover a 24-month period, is organized in the following six tasks:

Task 1-Project Planning and Management
Task 2-Concept Development
Task 3-Research, Development, and Test Planning
Task 4-Component Definitions
Task 5-Commercial Generating Unit Design
Task 6-Phase I Final Report

The project will be managed by ABB Power Plant Laboratories Division of Combustion Engineering, Inc. (ABB CE) as the contractor and the work will be accomplished and/or guided by this contractor and the following team members:

- Raytheon Engineers and Constructors (Plant-wide evaluations, BOP engineering, POC & CGU A/E)
- ABB Environmental Systems (SO_x, particulates, waste reduction)
- Energy and Environmental Research Corporation (Air toxics, NO_x)
- Dr. János Beér, MIT and Dr. John McGowan, Univ. of Mass. (Consultants)
- Electric Power Research Institute (Advisor)
- Association of Edison Illuminating Companies - Power Generation Committee (Advisor)
- Advanced Energy Systems Corporation (Advisor)
- ABB CE (NO_x, efficiency, diagnostics, waste disposability, cost of electricity)

This report documents work done in Task 2 - Concept Development. The work was divided into the following subtasks:

Subtask 2.1 Coal Selection
Subtask 2.2 Subsystem Technical Assessment
Subtask 2.3 Concept Development and Evaluation
Subtask 2.4 Concept Selection Report
Subtask 2.5 Subsystem Preliminary Engineering Design

The process commenced with the identification of candidate technologies through literature search and in-house sources. The team selected and presented to the DOE those candidates

judged to have the potential of meeting the Project's primary objectives and one or more of the secondary objectives and to become commercially feasible within the Project's time frame. Commercial feasibility in this sense encompasses not only technical and economic feasibility but also acceptance by the utility industry. The utility industry, in general, is extremely conservative with respect to new air pollution control technologies. Demonstrating an economic advantage with new technology over present-day technology is not always a guarantee of acceptance. The utility marketplace is primarily interested in technologies that will not only reduce capital costs but will demonstrate high reliability, lower maintenance requirements, and simplified process operations.

The following traditional evaluation criteria were also applied: Capital Cost. O&M Cost, Equivalent Forced Outage Rate and Availability, Efficiency, Auxiliary Power, Modularization Potential.

Near-term technologies were screened to determine those that best fit the criteria described above. From the remaining candidates, rough economic comparisons were made to compare system installation costs and annualized operation and maintenance costs. Five SO_x/particulate and five NO_x candidates were selected and subjected to comprehensive technical assessment and systems analysis. They were presented to the DOE and a "short list" was developed. Finally, six combinations of the short-listed subsystems were evaluated for technical, economic, and commercial feasibility as integral parts of an advanced supercritical generation system.

In parallel with this basic activity, the team carried out the following: evaluate and select the optimum steam cycle for a 350 MWe plant, evaluate low-level heat recovery systems.

RESULTS

Coal Selection

The objective of this activity was to identify three "test coals". All future R&D and testing will be based on the test coals. One of the test coals was selected as the "design coal" to serve as the baseline test coal. The remaining test coals will be used in R&D and testing to determine process sensitivities to variations in coal characteristics.

The test coals may be either run-of-the-mine or beneficiated via standard commercial coal preparation methods. The test coals were selected so that the results of the engineering development work are broadly representative of large classes of US coals. Specifically, the test coals meet the following requirements: Current production is extensive, and remaining minable and uncommitted reserves are significant. The sulfur content of the design coal, on entering the boiler, is at least three pounds of sulfur per million Btu, if the test coals include Eastern or Midwestern Bituminous coals. The ash content and characteristics are broadly representative of major reserves of US coals. Adequate quantities of relatively uniform grade can be obtained by the contractor in support of Engineering Development and long-term testing in the proof-of-concept facility.

Based on studies funded by DOE in the early 1980's, twenty coals were reviewed. Three of these coals were selected by DOE for their coal preparation and beneficiation program: Illinois No. 6, Pittsburgh No. 8, and Upper Freeport. ABB Power Plant Laboratories has run bench-scale and pilot-scale tests of these three coals under comparable conditions, resulting in data that will be useful to the LEBS project. Therefore, these three coals were selected to be the project "test coals".

The Electric Power Research Institute (EPRI) funded a series of advanced boiler design development studies from the mid-1970's until 1991. They selected Illinois No. 6 as the design coal that would result in the most representative steam generator and plant designs for the US market. ABB participated in the EPRI studies and designed advanced steam generators for 350 MWe and 700 MWe. Since the LEBS plant will use this 350 MW advanced boiler (designed for Illinois No. 6 coal) as the Base Case, Illinois No. 6 coal was selected to be the "design coal". This coal also satisfies all selection criteria better than any of the other coals studied.

Plant Steam Cycle

A comprehensive evaluation was carried out which compared a conventional subcritical (2400 psig/1000°F/1000°F) plant to an advanced supercritical (4500 psig/1100°F/ 1100°/1100°F) plant. The supercritical cycle was selected because of its higher plant efficiency. This not only facilitates performance improvements but it will reduce the amount of pollutant produced per kilowatt of electricity generated, regardless of the emissions technologies involved. The steam generator and turbine generator performance and cost values reflect this selection.

The rest of the equipment is also consistent with this selection. Although supercritical technology has been successfully used in the U.S. and elsewhere, for non-technical reasons its commercial development in the 70's and 80's was limited. However, supercritical technology is generally viewed by the utility industry as technically acceptable and commercially feasible.

Low-level Heat Recovery

In four of the alternatives there is a significant amount of unused heat in the flue gas between the entrance to the scrubber (270°F) and the stack (130°F). A review of the literature and the limited experience with low level heat recovery systems indicates that there are heat exchanger designs, i.e., materials, which can operate safely at temperatures below the flue gas acid dew point. The only logical stream to transfer this heat to is the condensate/feedwater stream. A heat exchanger was designed which lowered the flue gas temperature from 270 to 177°F and raised the temperature of the condensate from 154 to 190°F, allowing elimination of a low-pressure feedwater heater. The capital costs and the increase in auxiliary power and turbine/generator output were evaluated. The addition of this low level heat recovery system could not be justified, primarily because of the high capital cost of the heat exchanger. (A lower cost design may be pursued in the future but only as a low-priority issue.)

Subsystem Technologies

Using the approach described above, the team developed, with DOE approval, the following short list of subsystem technologies:

NO_x Control-	SO_x/Particulate Control-
*1. Advanced Tangential Firing	*6. Advanced Wet Limestone Scrubber with EP
*2. Coal Reburn	*7. Thioclear Scrubber Process with EP
*3. High-temperature SNCR	*8. SNOX Process with Baghouse
*4. Catalytic Filter (fabric or ceramic)	9. Catalytic Baghouse with WSA Tower
5. SCR for cost comparison	10. Catalytic Baghouse with Wet Scrubber

*Selected for systems analysis.

Brief descriptions of each subsystem follow. A fuller understanding of these subsystems and their integration into systems can be obtained from the system diagrams in Figures 1-6.

1. *Advanced Tangential Firing* - This combustion system is the basis of ABB CE's low NO_x approach for the continuing evolution of tangential firing. The classic advantage of tangential firing over wall firing has been the ability to accurately control the stoichiometric and mixing history of the fuel and air. Recently developed "flame attachment" burners enable the system to rapidly devolatilize nitrogen containing compounds in the coal into a hot substoichiometric environment to force much of this material to be reduced to molecular nitrogen, rather than oxidized to NO. Following this fuel-rich stage, the remainder of the combustion air is gradually mixed in several stages to complete the combustion process while minimizing char nitrogen conversion to NO. Pilot-scale tests in ABB CE's Boiler Simulation Facility have recently demonstrated NO_x emissions below 0.20 lb/million Btu with reasonable carbon loss. This technology will continue to be developed under ABB internal funding and advances will be applied to LEBS as they evolve.

2. *Coal Reburn* - Fuel staging, commonly known as 'reburning', involves the reduction of NO formed in the initial fuel burning stage by active chemical species (radicals) produced by the fuel introduced into the second stage under substiochiometric conditions. This effect has been measured for natural gas, oil and coal. Reduction levels are less with coal as the reburn fuel because of its nitrogen content. Reburn with natural gas has been shown independently by ABB CE and EER to provide significant reductions when applied to high baseline NO_x systems. ENEL, the Italian national utility, is currently applying oil as a reburning fuel to some of their units. Coal reburn was used with good results by B&W on a cyclone boiler at Nelson Dewey Station and will be tested shortly on a 175 MW boiler by TVA at Shawnee Station. At this time, ABB CE believes that meaningful NO_x reductions can be obtained by adding micronized coal reburning to the advanced burners.

3. *High-temperature SNCR* - Technologies in this area have produced mixed results. Through recent pilot-scale tests, ABB CE has demonstrated the drawbacks of the classic SNCR process (injection at 1800-1500°F). Significant ammonia slips were measured, as well as unacceptable sensitivity to temperature variations that exist with utility-scale boilers. A recent paper by Black & Veatch (Cochran, et al. 1993) also cited these drawbacks of the SNCR process applied to large coal-fired boilers. However, work by EER and others, has shown that the high temperature injection of urea (or ammonia) may have merit. Specifically, NO_x reductions of up to 80% were obtained by EER in a small-scale reactor. It is recommended that some bench-scale tests be conducted under Task 4 to answer some questions in this area.

4. *Catalytic Filter* - Evaluation of a post-combustion NO_x reduction subsystem was included to evaluate its costs relative to in-furnace subsystems, such as low NO_x burners, SNCR, etc. The SNOX systems were chosen to be studied because the catalytic NO_x reduction process was included in the process schemes and because the complete subsystem could be integrated into the plant heat cycle to improve thermal efficiency. Post combustion NO_x reduction was also included to facilitate an alternate lower NO_x emission goal. Breakout costs for NO_x reduction will be developed through the course of Phase I, which will allow direct comparison of NO_x reduction costs by subsystem and degree of NO_x reduction.

5. *SCR* - Over the last few years, SCRs have dropped in price by a factor of two to three. SCRs have an advantage over most other post-combustion NO_x control methods because they operate in a simple manner, and, being well downstream of the boiler's furnace, they are in a reasonably constant temperature region. ABB CE is confident that the current LEBS goal is achievable by combustion control alone. However, should the marketplace demand NO_x emissions below 0.10 lb/million Btu, SCR becomes a highly attractive option. Since the ultimate goal of LEBS is to produce a commercial product, we intend to keep abreast of SCR technology and keep it as a point of comparison to other technologies.

6. *Advanced Wet Limestone Scrubber with EP* - Evolutionary improvements to these established technologies continue. For the Advanced Wet Limestone Scrubber these include: organic buffer additives, low pressure spray nozzles, improved limestone stoichiometry and SO_2 removal capability, improved gypsum crystal size and dewatering system, and lower auxiliary power consumption. For the Electrostatic Precipitator these include: wide plate spacing, gas conditioning, pulsed energization, and improved energy management systems.

7. *ThioClear Scrubber Process with EP* - The ThioClear process is in principle very similar to the Wet Limestone process. It uses an open spray tower absorber to remove SO_2 from flue gas. The gas is treated by contact with a magnesium sulfite solution with a high dissolved sulfite alkalinity. Liquid-gas contact is achieved through the use of spray nozzles, trays, or venturis. The primary difference from the wet limestone system is that magnesium sulfite, not calcium hydroxide, provides the required alkalinity to absorb the acid gas. The magnesium sulfite is regenerated from magnesium bisulfite by the addition of recovered magnesium to the absorber loop for pH control. The absorber and spray system are similar to the limestone system, with the main mechanical differences being the oxidation and regeneration system. The collection

tank is located below the absorber and is a mechanically integral vessel. Liquid in the tank is recycled back to the spray levels and also sent to the oxidation tank, maintaining constant level and a low solids concentration (2%) in the collection tank. In the oxidation tank, the magnesium sulfite solution is exposed to excess oxygen and forms magnesium sulfate. The magnesium sulfate solution is in turn transferred to the regeneration tank where, upon introduction of slaked lime containing 6% magnesium oxide, calcium sulfate is formed and magnesium hydroxide is regenerated. The calcium sulfate/magnesium hydroxide slurry is then separated in a hydrocyclone. The magnesium hydroxide solids report to the overflow and are returned to the absorber loop and the calcium sulfate crystal underflow is sent on to the dewatering system. The process has proven at the demonstration scale that it can meet the project's required SO_2 emissions limits. SO_2 removal efficiencies are expected to approach 98-99% efficiency, at lime stoichiometries of less than 1.03 and very low liquid-to-gas ratios (typically 30 gpm/kacfm or lower).

8, 9, 10. *SNOX Process and Catalytic Filters (See 4. above.)* - The SNOX (Sulfur and Nitrogen Oxide Reduction) technology utilizes two catalytic reactors to control NO_x and SO_2 in the flue gas stream and produce a saleable commercial grade sulfuric acid. No sorbents are added and no wastes are formed. Pilot scale applications of this technology have yielded greater than 95% removal of both SO_2 and NO_x. Particulate emissions of 0.0004 grains/scf are inherent to the process. The technology consists of five key processes: particulate collection, NO_x reduction, SO_2 oxidation, sulfuric acid (H_2SO_4) condensation, and acid conditioning. Flue gas leaving the boiler is first cooled in an air preheater and then further cooled in a trim cooler. The trim cooler stabilizes the temperatures in the dust filter independently of the boiler outlet temperature, which varies with load. The heat recovered may be used either for production of low pressure steam or for heating condensate or boiler feed water. A small amount of ammonia is added for NO_x conversion and a heat exchanger is used to heat the gas to the 780°F reduction temperature. The flue gas enters a trim heater to ensure the flue gas is at the optimum temperature and then enters a catalytic reactor in which the NO_x and NH_3 are converted into free nitrogen and water vapor. The flue gas is then sent to another catalytic reactor where approximately 96-98% of the SO_2 is oxidized to SO_3. Excess NH_3, CO and carbonaceous combustibles in the flue gas are expected to oxidize completely. At the same time, practically all the remaining dust is retained in the catalyst bed which therefore must be cleaned at regular intervals. The cleaning is done section-wise by a semi-automatic system with no interruption of the SO_2 reactor operation. After oxidation, the SO_3 gas is cooled in the gas-gas heat exchanger. The gas is further cooled in a falling film condenser, a special type of heat exchanger in which SO_3 is first completely hydrated into H_2SO_4 vapor in the gas phase and then condensed and separated from the gas as a condensing film. At the same time, the condensed sulfuric acid is concentrated to a strength of about 96% H_2SO_4. The process is capable of greater than 95% SO_2 removal, 95% NO_x removal and essentially complete particulate removal while producing commercial grade sulfuric acid and heat. The process was developed in the early 1980's and has been successfully tested in Europe and Asia in pilot scale units. Since April 1985, a 62 scfm pilot unit simulating the process without NO_x reduction has been successfully demonstrated in Sicily using oil coke with up to 6% sulfur as fuel, and at a power plant in Taiwan using 'black liquor' as fuel. Another pilot unit, with NO_x reduction, has been demonstrated for over 12,000 hours at a Danish power plant

using coals with about 1% sulfur. Greater than 95% SO_2 conversion and greater than 90% NO_x removal has been obtained.

The SNOX Hot Scheme is an adaptation of the SNOX process that, by taking advantage of a hot particulate collection system with integral NO_x SCR catalyst, allows reduction in capital equipment as well as an improvement in the thermal efficiency of the steam cycle. It is a simpler process and eliminates the need for natural gas. It utilizes the catalytic reactor to control SO_2 emissions and produce a saleable commercial grade sulfuric acid. The process is expected to achieve greater than 95% SO_2 removal and 80% NO_x removal. Technical concerns with the Hot Scheme process include catalyst and filter life. Present experience with NO_x reduction catalysts indicate that residual catalyst activity is about 60% of fresh catalyst and catalyst life may exceed 6-7 years. Since the flue gas will be coming straight from the boiler system, the flue gas temperature will be approximately 700°F. This elevated temperature will require a more heat-resistant fabric than normal baghouse applications or use of a ceramic filter. Bench-scale fabric filter testing has been carried out by the University of North Dakota - Energy and Environmental Research Center (UND-EERC), supported by DOE. Numerous 100-hour tests, as well as two 500-hour tests, have been completed using a pulse-jet fabric filter setup on a 0.5 mBtu/hr coal-fired unit. Operating parameters studied included air-to-cloth, particulate and NO_x removal, SO_2 oxidation to SO_3, and ammonia slippage as well as bag durability. A long-term fabric evaluation test, also in progress at UND-EERC, is expected to be completed in late 1993. Pilot scale testing of the Catalytic Baghouse will be completed by the end of 1993. Another candidate is the CeraMem catalytic filter. In testing a 60 lb/hr combustor at Exxon Research and Engineering NO_x removal efficiencies of 90% or greater were achieved with less than 25 ppm ammonia slip and no detectable SO_2 oxidation at space velocities about three times that of conventional SCR reactors. Also demonstrated were substantially complete particulate removal (greater than 99.9%), including respirable PM_{10} particles, and the ability to maintain clean filter pressure over repetitive filtration/regeneration cycles.

Systems Analysis and Selection

The subsystem technologies described above were evaluated as integral parts of six advanced supercritical power generation systems. Since all the primary and secondary objectives can be met by each of the six systems, the main evaluation criteria came down to the potential for commercial success and the cost of electricity. The six alternative systems and their assessments are as follows:

	System	NO_x lb/ Million Btu	Potential for Commercialization	Net Plant** Efficiency Increase, %	Relative C.O.E*
1	Advanced Burners Advanced Wet Limestone FGD Advanced Electrostatic Precipitator	0.2	Very high	3.46	97.6 (0)
2	Advanced Burners with Coal Reburn Advanced Wet Limestone FGD Advanced Electrostatic Precipitator	<0.2	Moderate to High	3.43	99.0 (0)
3	Adv. Burners + High-Temp SNCR Advanced Wet Limestone FGD Advanced Electrostatic Precipitator	≈0.1	Very High if the SNCR technology works	3.46	98.6 (0)
4	Advanced Burners ThioClear FGD Advanced Electrostatic Precipitator	0.2	High	3.68	97.2 (0.6)
5	Advanced Burners SNOX	≤0.05	High	3.89	96.4 (3.2)
6	Advanced Burners SNOX Hot Scheme	≤0.05	High	4.60	95.4 (3.2)

*Compared to current "NSPS" plant. The values assigned to by-products are given in parenthesis. No value was given to gypsum (Systems 1-4), full value was given to magnesium hydroxide (System 4), and 3/4 of the expected value was given to sulfuric acid (Systems 5 and 6). The value of emission allowances was not considered quantitatively.

**Net plant efficiency increase, in percentage points, over a current "NSPS" plant. The plant heat rate and efficiency, and thus the cost of electricity, can and will be optimized in Task 5 for the selected system(s).

Based on evaluation of these concepts, the Team selected a wet FGD system (System 1 or System 4) and a catalytic system (System 6) for further development in later Phases of the Project. Commercialization of one or more of the Systems is programmed for the year 2000

or sooner. Due to the fact that System 4 is in early stages of development and has not demonstrated closed loop performance, ABB Environmental Systems believes that the present estimates may not accurately reflect full-scale economics. In fact, given the degree of uncertainty, it is felt that the difference in the cost of electricity between Systems 1 and 4 is not significant. Therefore, Systems 1 and 4 are selected for collateral development until such time as one system is shown to be clearly superior to the other. Systems 1 and 4 meet the contract NO_x target of 0.2 lb/million Btu and System 6 meets ABB's optional target of approximately 0.05 lb/million Btu. Both systems can be designed for SO_x and particulate emissions lower than the contract targets. Also, since Systems 4 and 6 both produce saleable by-products, they both meet the waste reduction objective.

However, for the following reasons none of the subsystem technologies should be abandoned at this time: (1) They may be more suitable for a particular project or customer. (2) They may be commercially available now or further along in development. (3) They would be fallbacks if a selected technology proves unsuccessful. (4) There is insufficient information to reject or select some of them at this time. (5) Their development will continue under other programs. (6) Air toxics emission limits and control technologies, when established, may favor these subsystems. It is entirely possible that the final output of the Project is one system design with a menu of options for emission control subsystems.

PLANS

Continue work as defined in the contract and as further defined in this paper. In particular, Tasks 3 and 4 activities will confirm or reject some technologies which remain as options, e.g. high-temperature SNCR. Current plans are to proceed with the preconceptual design of the CGU in Task 5 based on Advanced Burners and the SNOX Hot Scheme. This work should be completed in the second quarter of 1994.

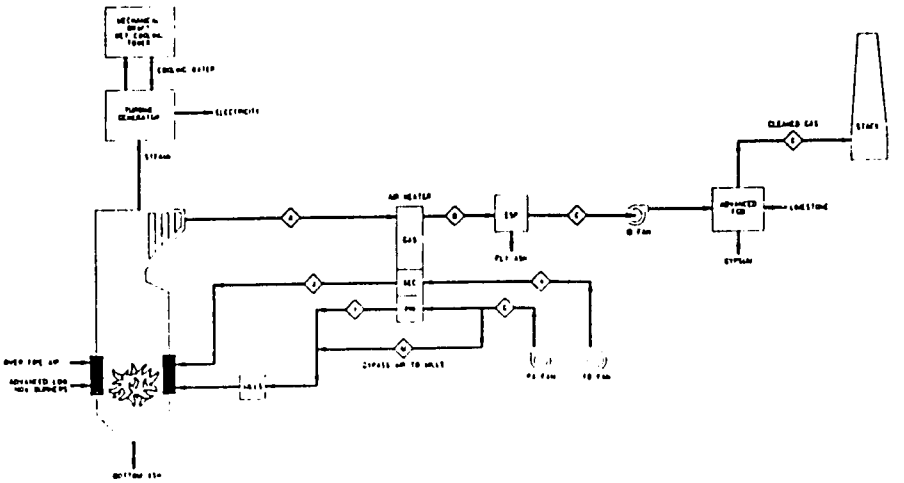

Figure 1 - System 1: Advanced Burners, EP, and Wet Limestone FGD

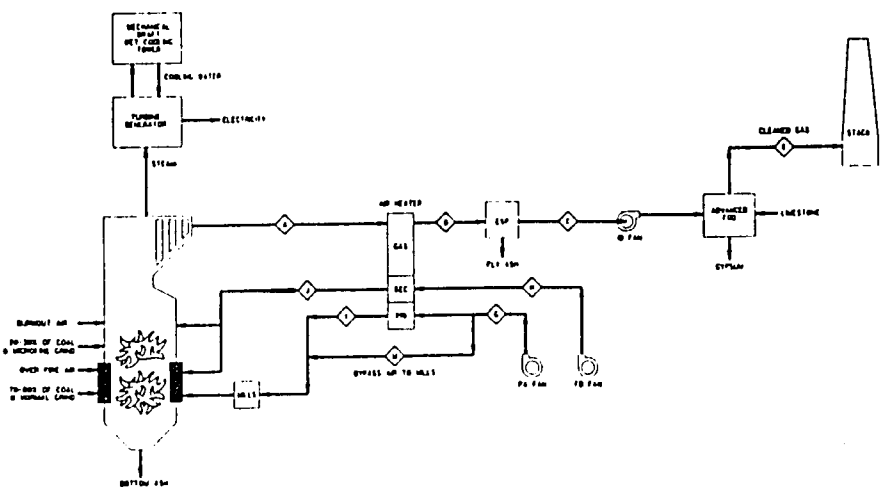

Figure 2 - System 2: Advanced Burners, Coal Reburn, EP, and FGD

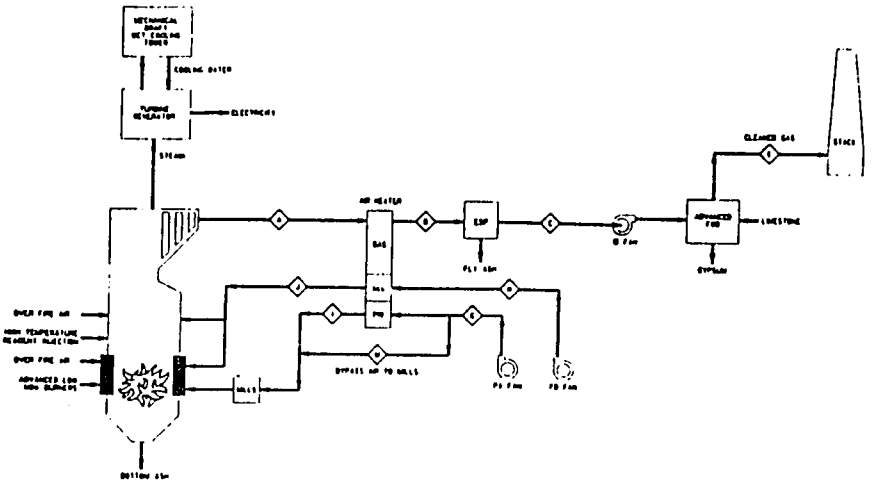

Figure 3 - System 3: Advanced Burners, High-Temperature SNCR, EP, and FGD

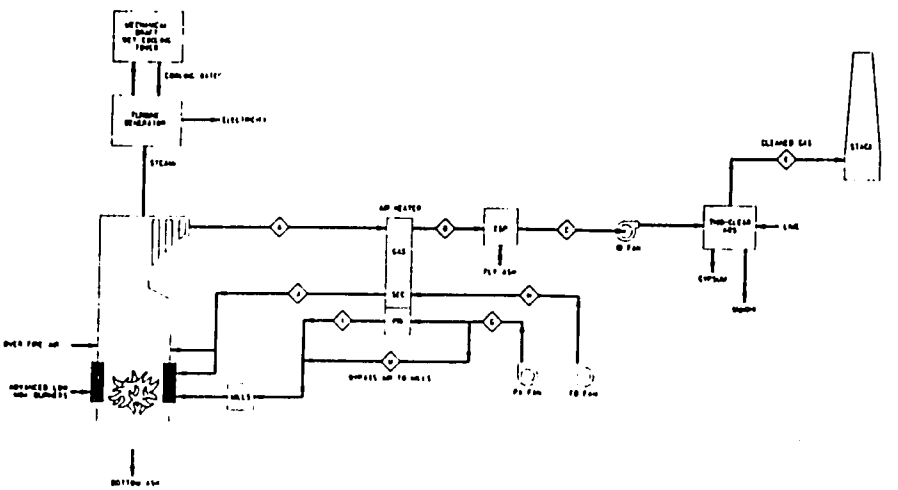

Figure 4 - System 4: Advanced Burners, EP, and ThioClear FGD

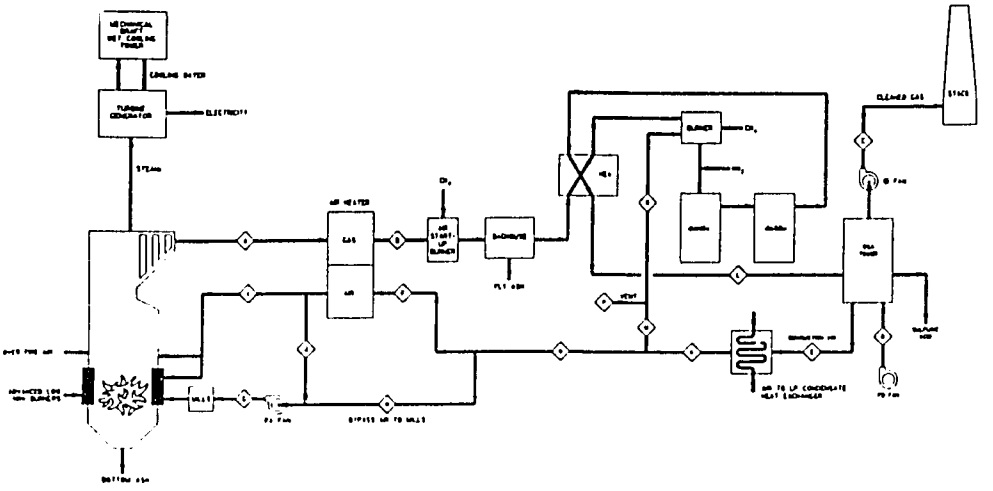

Figure 5 - System 5: Advanced Burners, and SNOX Process

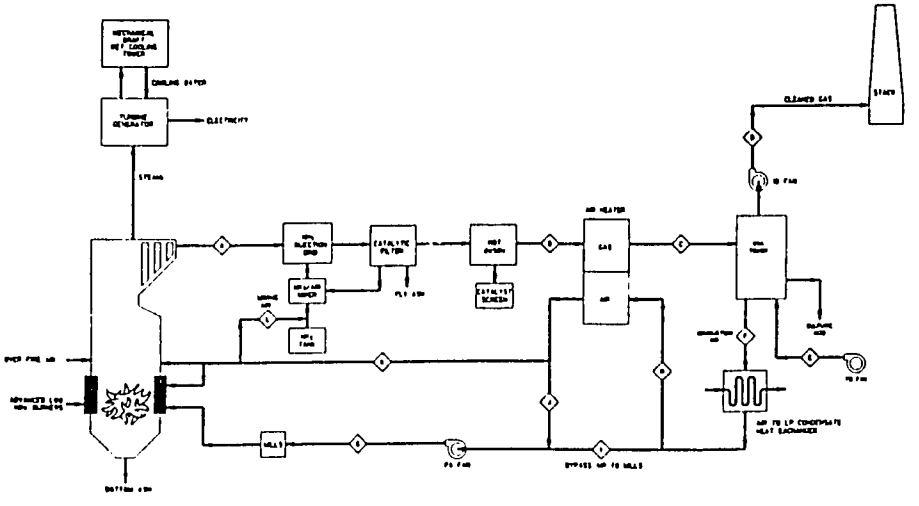

Figure 6 - System 6: Advanced Burners, and SNOX Process Hot Scheme

WORKSHOP B1

CO-OPERATION AND PARTNERSHIP

IEA SECOND INTERNATIONAL CONFERENCE ON

THE CLEAN AND EFFICIENT USE OF COAL AND LIGNITE :

ITS ROLE IN ENERGY, ENVIRONMENT AND LIFE

30 November - 3 December 1993

Technology Transfer

"IMPROVING COAL USE IN DEVELOPING COUNTRIES THROUGH TECHNOLOGY TRANSFER"

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ABSTRACT

World population will double within another thirty years, mostly in developing countries. Combine this with a desire to improve quality of life and the result is a rapid increase in energy consumption. In many developing countries coal will be a prime source of fuel for domestic, industrial and above all power sector use.

The challenge for an environmentally aware world community is to affect improvements without going through the high peaks in energy consumption that characterised industrialization in OECD countries. This implies massive transfer of the best currently available coal use technologies and newer technologies as they become commercially proven.

A key role in facilitating technology transfer is being played by governments and multilateral funding agencies. There is a need to streamline procedures, particularly with respect to countries emerging from the former Communist Bloc where aid programmes are relatively young.

The coal use situation in China, India, the rest of the Pacific Rim and the former centrally planned economies of Eastern Europe and the CIS are reviewed - together representing around two-thirds of world coal use. The UK's Coal Research Establishment is active in providing technical assistance and know-how transfer in all of these regions. Projects range from energy efficiency studies on whole cities through strategic studies on coal use in all major markets to specific investigations of particular fuels for specific technological applications.

Coal use options are reviewed in the light of the perceived needs of developing countries.

IMPROVING COAL USE IN DEVELOPING COUNTRIES THROUGH TECHNOLOGY TRANSFER

1. INTRODUCTION

The energy consumption per head of population in the OECD countries is far higher than in the developing world, and excluding North America, is roughly comparable with the former centrally planned economies [1], see Figure I. As the less developed countries (LDCs) contain the major proportion of the world's population, and they have higher population growth rates, world energy consumption will rise if their living standards are improved to OECD standards.

Historically, a country's energy use, relative to production, has risen during the first decades of industrialisation, but then decreased markedly with improvements in efficiency and structural changes in the economy, see Figure II [2]. The prolonged initial rise in energy intensity that normally occurs during industrialisation, if it were to occur as the LDCs developed, would result in unnecessary fuel wastage. It should be possible for developing nations to bypass this peak in energy intensity if they can take advantage by technology transfer of advances already made in the industrialised world.

Coal reserves substantially exceed other fossil fuels, see Figure III [1]. Analysis of the supply of energy throughout the world shows clearly that the areas where population growth will be fastest to be the same ones which rely heavily on coal as a fuel. Just three countries, China, India and the former USSR, represent almost half of world coal production. They use most of their production internally but often inefficiently and with much pollution. A 20% gain in efficiency of use in these countries is technically credible and could save over 400 mtpa of coal.

Clean coal technologies for helping to attain both better efficiencies and much lower environmental impact are becoming available for the power sector. However, widespread application would require investment on a scale which will be difficult to acquire and manage. It has been estimated by the World Bank [3] that the plans of 70 developing nations for 384 GWe of capacity before the year 2000 will cost US$750 billion, with the overall non-OECD total being 550 GWe which would imply > US$1,000 billion. Spending on this scale is considerably higher in real terms than in the past and so the ability of the developing nations to pay for such massive development must be questionable.

A complementary approach is to adopt suitable technologies in the domestic, commercial and industrial sectors which represent as much as half the coal used in some developing countries. The technologies for these applications tend to be less difficult to manufacture, are more amenable to setting-up of modest sized production units and require less initial investment. On the other hand many units have to be installed to obtain the same effect as replacing a power station operating at 20% efficiency with another having an efficiency of perhaps 35%.

2. TECHNOLOGY TRANSFER ISSUES

The term TECHNOLOGY TRANSFER warrants definition. One definition of technology transfer [4] is:

> "All the activities necessary to secure the successful transfer to, and adoption by, developing countries of technologies, techniques and practices, both existing and in prospect, which enhance the ability of an economy to meet the needs of its consumers."

This definition will include not just transfer of designs and hardware but also human skills, management and finance as well as technical know-how.

It needs to be recognised that technologies are generally owned by companies, who have to operate in a commercial environment. There is little incentive for a company to 'give' their technological advances to developing nations, or to seek business opportunities in countries which do not have the ability to pay for the purchase of their technology. There needs to be appropriate international or governmental frameworks to facilitate technology transfer by encouraging technology owners to transfer their equipment and expertise to developing nations. In the commercial world this encouragement needs to be financial reward or assistance, in short, payment for their technologies and protection or appropriate payment for their intellectual property rights. Without such rewards and protection technology transfer will never become a useful component in increasing the welfare of developing nations. Therefore, it is necessary for governments in the industrialised countries to take the initiative in mobilising global finance for technology transfer.

In terms of the receiver of the benefits of technology transfer it is important that the technologies they receive are both appropriate to their needs and capable of being introduced effectively. What is good for an industrialised nation is not necessarily good for a developing nation. For instance, technologies which are highly automated using high-tech components will often require highly skilled staff and will invariably require spare parts to be imported. Whereas, developing nations generally have a growing population, cheap labour and a lack of hard currency to pay for imported goods.

Furthermore, it is important that technologies which are transferred to developing nations are capable of being supported by the indigenous population, either by training of the existing workforce or by the introduction of suitable institutional arrangements to promote the development of the necessary infrastructure.

Developing nations will encourage financing from industrialised nations if they have a stable political environment and adopt appropriate market structures. Energy subsidies and international barriers need to be phased out to encourage the free movement of finance around the globe.

To achieve successful technology transfer generally needs facilitators and/or funders. Facilitators assist the matching of technology sellers to recipients. A key role is the determination of the correct technology to be transferred. Funding agencies play an important role in this aspect by funding technical assistance projects and training programmes and so

help developing nations in making judgements about their requirements. The funders of technology transfers are pivotal to the whole process of technology transfer and organisations like the World Bank, Asian Development Bank and others are vital to provide funds or soft loans to assist developing nations with specific projects.

Trade financing has proved particularly difficult and many developing countries have been unable to service the mountainous debts which they have incurred. This has become a subject of considerable international debate and review. The UN Conference on Trade and Development in 1991 identified a number of aspects requiring general attention. For developing countries these included limiting export credits to a manageable extent, and protecting creditors. For lenders a greater targeting of finance to favour export sectors (ie promote self-help), extending credit to buyers of goods from developing countries, and use of simple procedures.

Companies with strong domestic and/or western markets may not see a pressing need to investigate business possibilities in impoverished LDCs and eastern Europe or they may be put off by the slowness and complications of obtaining financial help. Simple procedures and widely available support from overseas aid agencies for feasibility investigations would encourage a better response since it is often funding the "business development" stages which put off all but large multi-national companies.

British Coal's Coal Research Establishment (CRE) has recognised the importance of sharing technology developments with less developed nations, and has first hand experience of transfer of CRE technologies and experience, and intends to expand such technology transfer in the immediate future.

The use of coal in LDCs and the former centrally planned economies (CPEs) is reviewed below and examples of the Coal Research Establishment's involvement with a number of technology transfer initiatives is described.

3. COAL USE IN THE DEVELOPING NATIONS AND THE FORMER CENTRALLY PLANNED ECONOMIES

Efficiencies of coal use in developing countries and the former centrally planned economies tend to be poor compared to OECD countries. In the latter a new power station might operate at an efficiency in the high 30s%. In some countries (Japan, US, Denmark) use of supercritical steam conditions is upgrading efficiencies above 40%. Some of the clean coal technologies now coming into operation will achieve over 40% and by the end of this decade systems approaching 50% efficiency could be installed. Similarly in industrial and domestic sectors appliances are available which will give boiler efficiencies around 80% and 75% respectively. All this is in marked contrast to developing countries and eastern European experience where efficiencies can be around half of these levels.

3.1 Asia

Coal use in Asia is around 1,250 million tonnes per annum and constitutes 47% of primary energy in the region. By far the largest coal producer and consumer in Asia is China.

China

In China coal production equates to over 900 mtpa with over half being used in the residential, commercial and industrial sectors.

Recently there has been a recognition in China that coal-related air pollution, which is very severe in many Chinese cities, will have to be tackled. Improving efficiency of use has a direct benefit in this respect. Impressive gains could be had by concentrating investment on the 400,000 small industrial boilers in China which consume 300 million tons coal per year [5]. Potential reduction in coal use by improved efficiency could be 90 million tons per year.

CRE is active in technology transfer with China and has just completed environmental and energy efficiency demonstration project in Taiyuan city. This project was funded by the UK Overseas Development Administration. The objective was to identify improved methods of coal use to enhance energy efficiency, reduce pollution, and thereby to generate financial savings and to assist the Chinese authorities in identifying cost-effective ways of reducing pollution of a whole series of Chinese cities.

CRE in conjunction with associate organisations has undertaken a wide range of activities in Taiyuan which include examination of gasification of coal for cooking gas supply; coal preparation and distribution; briquetting; energy efficiency in buildings; district heating; energy economics/systems modelling; investment financing; and training programmes.

The benefits of the project will include improved methods of coal use, especially energy efficiency, and reduced pollution. The financial savings associated with greater energy efficiency will be used to finance pollution control works. The use of coal for countertrade to raise finance for implementation of the project is also being considered. The project will demonstrate techniques that can be replicated in other Chinese cities.

Another project for the World Bank has involved examining the Chinese Industrial boiler market to:-

- survey the market for industrial and residential/commercial boilers in 1995, 2000 and 2010
- review boiler production systems and impediments to production of high efficiency units
- evaluate options for improved designs and develop investment proposals.

India and other Asian Countries

India is the second highest coal producer in Asia and produces approaching 200 million tonnes per year, mostly by Coal India from the central and eastern regions. About one fifth of the reserves are coking coal, the balance being steam coal. Nearly all Indian coal is of low quality. 60% of the reserves have ash contents in the 25-45% range. Coal preparation is mostly crushing and screening; there is little coal washing. Steam coal is of variable quality with attendant problems for consumers in operational reliability and efficiency. In 1988 India

had some 32 GWe of coal fired power station capacity, about 60% of its total, with an average utilisation of less than 50% due to a combination of poor reliability, variable fuel quality and fuel delivery problems. The system is also characterised by chronic distribution losses. Over half of Indian coal is used in other sectors with iron and steel the largest other user. The iron and steel sector is already moving away from traditional high energy consuming blast furnaces into more efficient coal fired direct reduction units and construction of mini-mills.

Thus it would seem that immediate improvements in coal use in India lie in improving coal quality and obtaining reliable supply. There is also a role for the more efficient fluidised combustion systems coming into the power market now designed for low quality variable fuel.

Estimates of coal usage by other developing Asian countries by 2000 [6] are given in Table I. CRE has developed good links with a number of Asian countries including Indonesia and South Korea. For instance, in the former advice has been provided on means and costs of briquetting Indonesian coals for domestic use as a potential replacement for kerosene.

TABLE I

ESTIMATED COAL USE IN SOME DEVELOPING ASIAN COUNTRIES

	mtpa
Indonesia	12-21
South Korea	15
Malaysia	3-3.5
Thailand	16-21
Philippines	16-21
Vietnam	5-6
North Korea	100+

3.2 Former centrally planned economies of eastern Europe and the Commonwealth of Independent States (CIS)

A different situation applies in the former Centrally Planned Economies (CPEs) of eastern Europe. Large scale coal usage has been a major feature of most of these economies, almost entirely without regard to air quality and general environmental protection. Soviet coal consumption until recently exceeded 600 Mtpa and in a review of coal prospects in non-Soviet eastern Europe (including East Germany) production was estimated [8] to be 865 Mtpa of hard and brown coal, representing 18% of world production. Of this about three quarters is low quality brown coal. Only Poland has a history of significant exports. Russia wishes to become a significant exporter mainly because of the need to generate hard currency to pay for much needed investment.

Much of the brown coal in this region is high in sulphur, exacerbating the environmental problems. Significant proportions are burned in the industrial and domestic markets in urban locations with serious consequences for air quality and health. There is a growing environmental awareness in all of these countries which is being directed towards switching to natural gas where available, and fitting of flue gas scrubbing. There is also interest in smokeless fuel production and burning in more advanced clean coal power processes.

CRE is active in all the main coal using countries with contracts in Russia, Ukraine and Kazakhstan.

In Russia a major study is underway, funded by the UK Government on coal industry restructuring, redeployment of miners and improvements in coal quality and use. CRE are leading the latter portion. Another EEC funded project with partners from Germany and Denmark is investigating the feasibility of introducing western highly efficient units for coal burning in the residential and public buildings sector.

In Kazakhstan an examination of the whole coal fired power sector is being supplemented by two feasibility studies on specific sites to introduce SO_x and NO_x abatement in one case and fluidised bed technology in the other.

The Ukraine and the EEC are supporting a project to look at the design specification of a proposed circulating fluidised bed combustion power station and to evaluate the available fuels for such a station.

All of the above projects not only provide technical assistance, but also include significant elements of familiarisation and training to effect know-how transfer.

4. COAL USE TECHNOLOGIES AND THEIR APPLICABILITY TO TECHNOLOGY TRANSFER

There are a whole range of coal use technologies available for the benefit of LDCs. Alternatively, the expertise which went into developing solutions for the OECD countries is generally available to help developing countries tailor solutions to their own needs. Since the techniques are extensively reviewed in the literature, comments below are largely restricted to applicability to developing countries.

4.1 Pulverised Fuel Combustion (PF) - Figure IV

Pulverised fuel (PF) combustion is the established method of power generation at utility scale. It has been developed over a number of decades to large unit sizes (900 MWe) and its efficiency has been improved through progressive developments in boiler design and steam conditions. PF technology can be considered as the reference against which other power generation technologies should be assessed.

In terms of PF plant fitted with Flue Gas Desulphurisation recent advances are leading to improved designs in which efficiencies of around 45 % are possible with supercritical steam conditions.

There are a number of factors which make PF suitable for technology transfer to LDCs:

- As mature technology it is available now and would not incur any significant technical risk
- There are many manufacturers of the technology worldwide and hence competitive supply could be ensured
- The hundreds of operational plants mean that availability of experienced staff for training purposes would not present problems
- Improved environmental performance in terms of sulphur and nitrogen oxides abatement can be included using proven technology

Set against the above: PF technology is not best suited to low grade, variable quality fuels; environmental emission controls are an expensive add-on feature and solid residues need careful disposal.

4.2 Circulating Fluidised Bed Combustion (CFBC) - Figure V

There are over 200 CFBC units either in place or on order around the world from a number of suppliers.

In the context of technology transfer CFBC has a number of merits including:

- Ability to burn low and variable quality feedstocks and good multi-fuel capability
- Good environmental performance without additional capital cost
- Commercially established
- Economic at the unit sizes which could be appropriate for LDCs
- Has already been successfully deployed in some developing countries

However, the relatively limited commercial deployment makes at least some on-site development more likely than a conventional PF plant. Additionally, rapid, widespread adoption would mean that availability of appropriate staff for training and commissioning purposes could be constraining because of the low number of suppliers.

4.3 Pressurised Fluidised Bed Combustion (PFBC) - Figure VI

Several small commercial PFBC plants are now in operation based on ABB Carbon's 80 MWe modular design. The plants in operation are at Stockholm, at Escatron in Spain and at Tidd in Ohio, USA. All these plants are configured around an 80 MWe gas turbine/PFBC module and were commissioned in 1990 or 1991. Plans for a unit in Ostrava in the Czech Republic have also been announced. A much larger unit at a modular size of around 300 MWe has been designed and is expected to be installed in the mid 1990s.

In the short to medium term, PFBC technology should become sufficiently proven to merit consideration for technology transfer to LDCs and the main features which it possesses which will make it a potential candidate include:

- The ability to utilise low quality fuels
- Enhanced efficiency of combined cycle plant over steam only plant
- Inherently good environmental performance

Because only one company is developing commercial utility scale PFBC plant there could be constraints on rapid commercialisation. On the other hand PFBC is a candidate for a development project for a country with adequate technical and engineering resources, the plant to be built in Ostrava is a good example of this.

4.4 Integrated Gasification Combined Cycle (IGCC) - Figure VII

IGCC processes are being introduced to commercial operation. Over the next few years they could be considered for technology transfer. The characteristics of the technology which will be particularly appropriate to technology transfer include its high efficiency with low ash coals and good environmental performance. However, IGCC plant is rather more complicated than some other technologies due to the gas cleaning and associated plant and hence there would need to be a more highly skilled workforce. In some cases it may be less appropriate than the fluidised bed based systems since use of high ash coals in a number of the IGCC variants available would be associated with significant efficiency penalties.

4.5 Topping Cycles - Figure VIII

Topping cycles are an advanced power generation concept currently under development. The first utility scale plant design is expected to be available by the late 1990s.

Topping cycles offer an excellent medium term prospect for technology transfer to LDCs. They will have high efficiency and good environmental performance. The British Coal version will be particularly attractive to LDCs because of its relatively low cost and its ability to process a wide range of low quality solid fuels.

4.6 Industrial Process Heat

Amongst developed countries few have widespread well developed technologies for clean, efficient use of coal in the industrial as well as the power sector. The UK is one of the exceptions having maintained a substantial industrial coal market and developed, in the 1970s to mid 1980s, a range of equipment to provide cleaner, more efficient burning of coal and handling of coal and ash. Most of these developments have been undertaken by British Coal in collaboration with UK suppliers.

Stoker firing is the most common coal combustion technique in industrial use. Developments in stoker-fired equipment have been aimed at improving the intensity of combustion, their reliability, ease of operation, and their adaptability to low grade fuels. Such improvements have been made for the underfeed stoker, the drop tube stoker, coking stoker, and the chain and travelling grate stokers.

In parallel with work on improving conventional firing equipment, CRE has undertaken a large development programme for applying FBC to a wide range of industrial boiler and furnace applications [9], Figure IX gives an example. The incentive has been the lower combustion temperatures compared to other systems. This offers the potential for low NOx emissions and effective capture of sulphur by direct feeding of limestone to the fluidised bed. Also, it offers the prospect of much greater fuel flexibility with the capability of burning efficiently a wide range of coal types and quality together with industrial wastes.

4.7 Domestic Coal Use

Improved domestic usage of coal is potentially important in LDCs and Eastern Europe not only because of energy efficiency gains but more importantly in some urban areas because of the contribution to easing health problems associated with polluted air. Two approaches may be necessary:

- Development of smokeless fuels for burning in conventional appliances, Figure X

- New appliances that will burn high volatile matter coal more efficiently and in a near smokeless manner, Figure XI

CRE has been active over many years in developing both fuels and appliances and has been using this expertise in several of the technology transfer projects referred to in Section 3 above.

5. CONCLUSIONS

Worldwide, coal will continue to be the major supplier of primary energy for the foreseeable future. In the next century, well over half of world coal usage is likely to be in developing countries or in eastern Europe. The likely population growth and relative magnitude of coal reserves in relation to other fossil fuels make it important that the most efficient, environmentally friendly ways of using coal are exported at the earliest opportunity from

OECD to these other coal using countries. The technologies needed are not confined to the power market, there are significant needs in the industrial and domestic sectors as well.

A key stage in the technology transfer process is the selection of the appropriate technology to be transferred. Developing nations are generally not well placed to make decisions relating to technologies for which they do not have practical experience. There is a need for receiving nations to become familiar with the ranges of technology available through training programmes, study tours and technical assistance projects. There is also a need for the companies or institutions in the industrialised nations providing technology to understand fully the needs of the receiving nation. The ability of nations to absorb and adapt coal technologies to their specific needs is variable. In eastern Europe and the CIS there is more likely to be the necessary technical and scientific staff than in the developing nations.

To facilitate transfer of clean coal technologies there needs to be a flexible approach adopted by governments, funding agencies and technology providers and recipients. This is particularly important in the early investigative stages. International trade arrangements to facilitate investments are needed and in the case of fossil fuel suppliers contemplating counter-trade arrangements, associated exchange guarantees will be necessary.

There is a wide range of coal technology and expertise appropriate for technology transfer. Key priorities should be improvements in energy efficiency and environmental clean-up technologies, whether it be by rehabilitation of existing equipment or by the introduction of newer technology.

There is a continuing need for the international community to improve the mechanisms by which the industrialised nations assist the developing nations in improving their standards of living. The key areas are :

- technology transfer mechanisms
- training
- mobilisation of investment funds

Governments and international aid agencies are pivotal in the above processes, but there are also vital roles to be played by bankers, entrepreneurs, politicians and consumers. The desire to assist developing nations exists but the mechanisms to make it happen require substantial improvement and augmentation. In particular, funding procedures in the UK and Europe are bureaucratic, some of the rules are not sensible and above all the lack of urgency in proceeding from first idea to contract placement is affecting credibility.

For the foreseeable future coal will play a major role in primary energy supply worldwide, so if global resources and the global environment are to be nurtured, then the best coal technology needs to be available to all nations.

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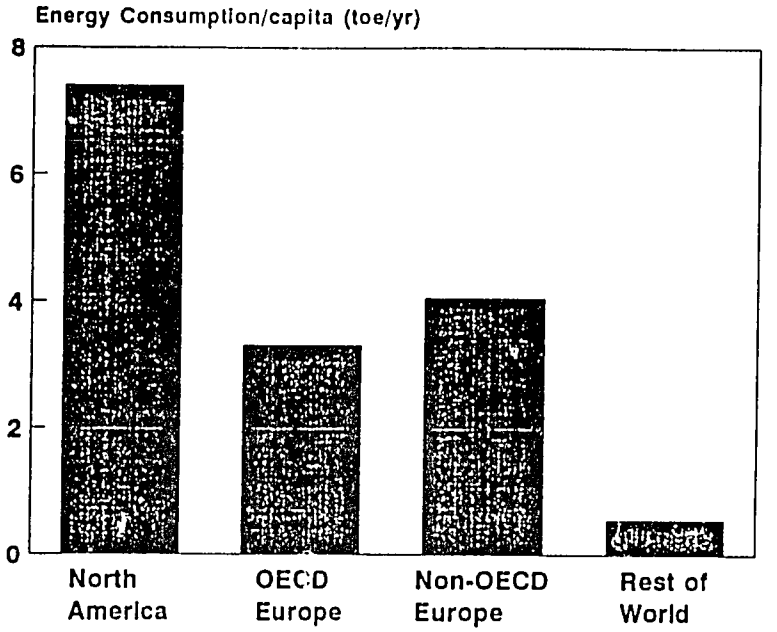
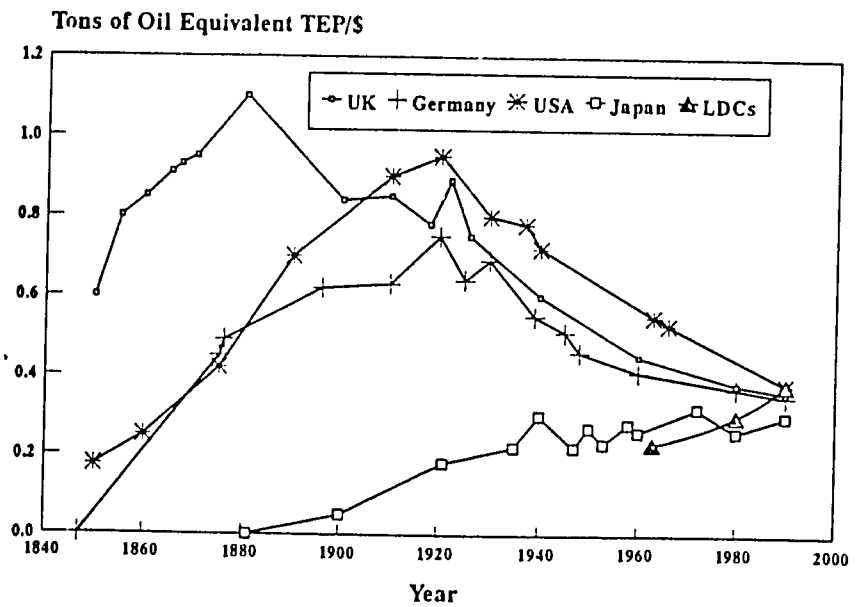
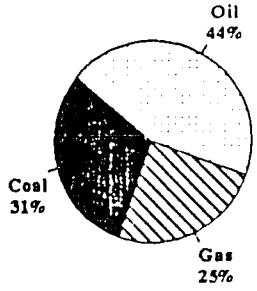
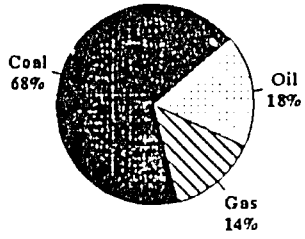


FIGURE II : ENERGY INTENSITY

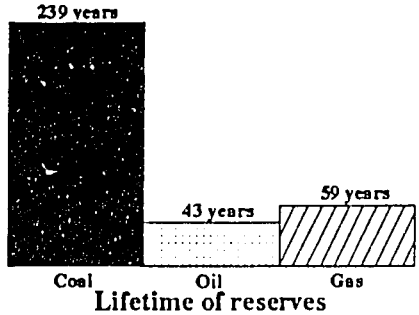




Consumption in 1991 7,100 mtoe

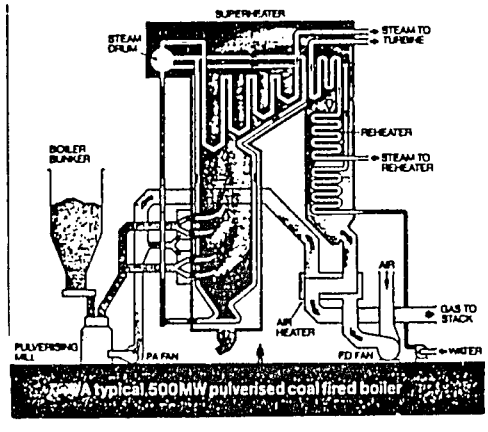


Reserves 768,000 mtoe



Lifetime of reserves
(based on reserves/production)

FIGURE IV : PULVERISED FUEL COMBUSTION



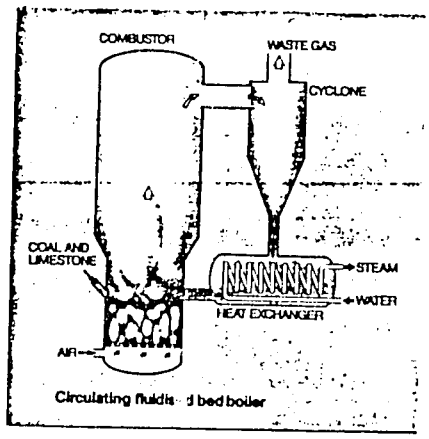
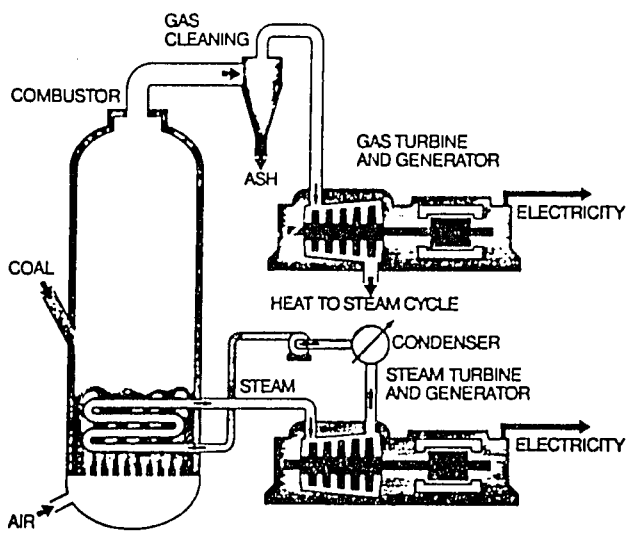


FIGURE VI : PRESSURISED FLUIDISED BED COMBUSTION (PFBC)



PFBC system for power generation using a combined cycle

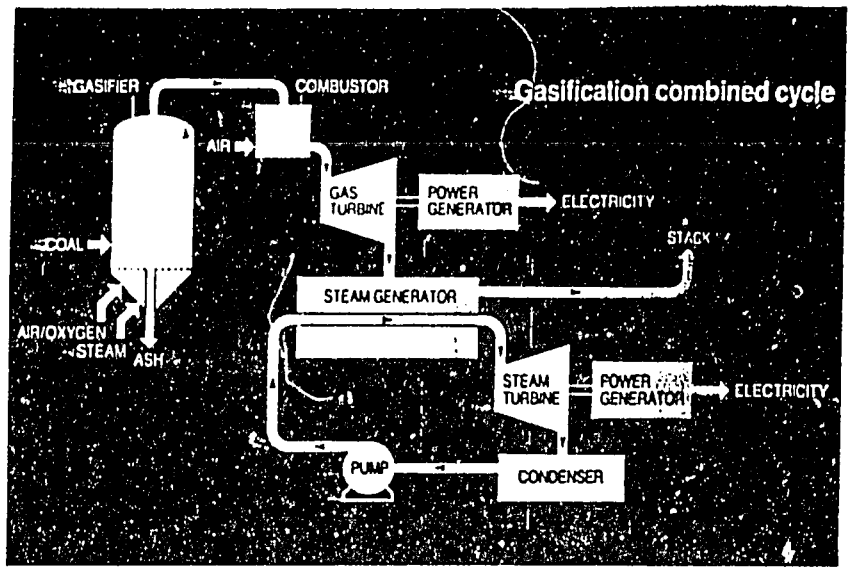
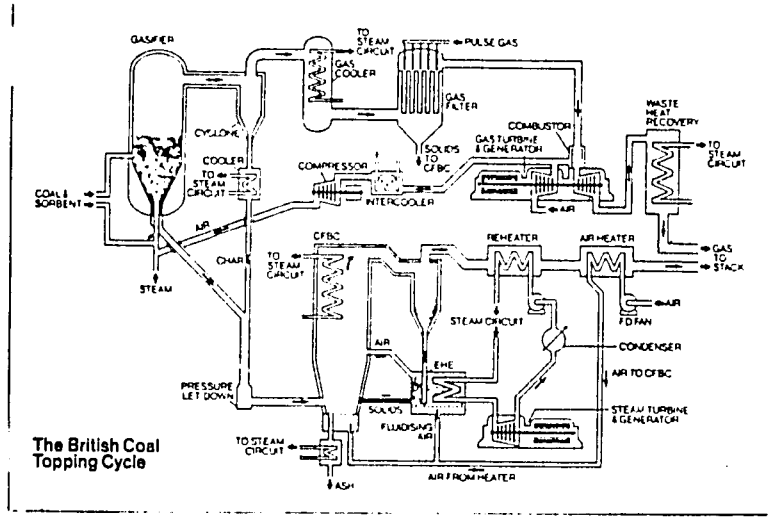


FIGURE VIII : BRITISH COAL TOPPING CYCLE



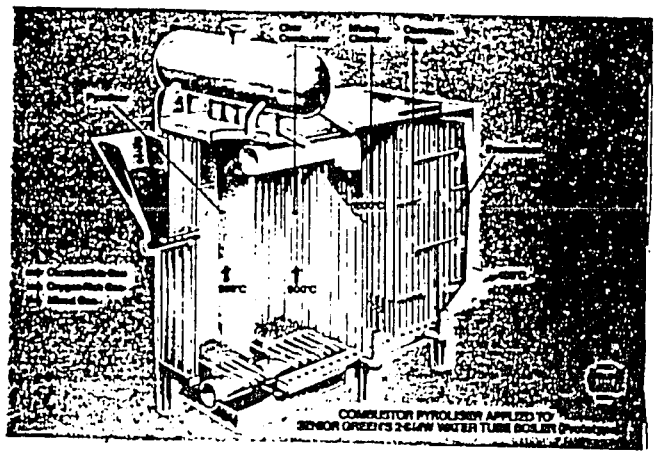


FIGURE X : MILD HEAT TREATMENT BRIQUETTING PROCESS

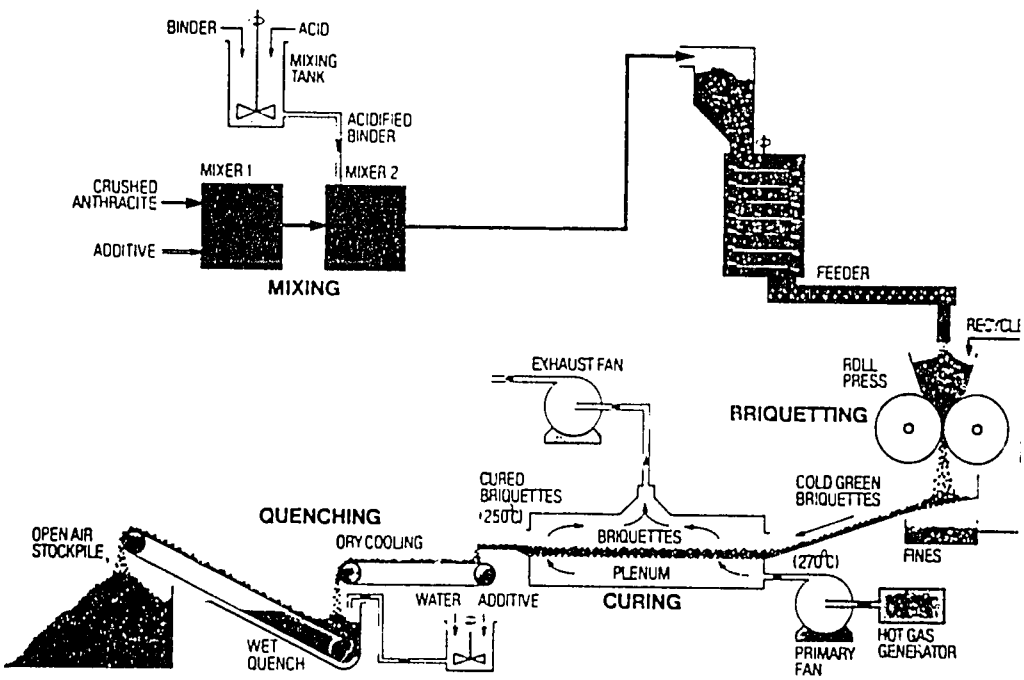
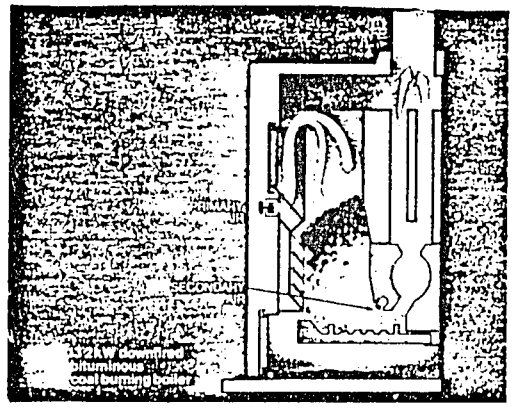


FIGURE XI : DOWN DRAUGHT DOMESTIC FIRE



IEA Second International Conference on the
Clean and Efficient Use of Coal and Lignite

Workshop B(1): Cooperation and Partnership

USAID EXPERIENCE IN COOPERATION AND PARTNERSHIP

by

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1. INTRODUCTION

The implementation of clean and efficient coal technologies in developing countries and transitional economies requires more than just finding the right technology. Numerous pre-conditions must first be in place. USAID links overall development strategy to project implementation and establishes the partnerships to accomplish this.

Today, I would like to share with you some of this USAID experience, accumulated over the past five years from working in over 20 developing countries around the world. We have gained this experience as a result of much learning and trial and error. There is not enough time in this entire session to dwell on the many perils, pitfalls, and failures that USAID has experienced over the years. But, our past missteps have helped us to refine and sharpen our approaches and to expand our efforts to develop supportive partnerships.

I will begin by quickly reviewing the nature and the enormity of the energy shortage problem facing developing countries and nations with transitional economies. Then, I will set forth the key goals of USAID's development strategy and our approach toward establishing the pre-conditions for successful clean coal project development, with some particular attention to how we have relied on partnerships with the private sector. Finally, I will provide you some concrete examples of how, in this process, USAID has cooperated with other development partners.

2. THE NEED FOR COOPERATION AND PARTNERSHIP: THE ENERGY DILEMMA

An adequate and reliable supply of electricity is essential for social and economic development. The industrial, commercial and service sectors of the economies are highly interdependent on this form of energy. Therefore, it is not surprising that the demand for energy in developing countries has been growing at rates of over 5.5 percent per year during the past 15 years, and the demand for electricity, has been growing at over 7 percent per year.

Yet, developing countries, on the average, use only 500 kWh of electricity per capita per year compared to over 10,500 kWh per capita in the United States and 6,000 kWh per capita in Europe and Japan. Over 75 percent of the world's population consume only 18 percent of total electricity.

Faced with high demand growth rates, many countries now experience power shortages of over 10 percent of their generation capability. In Pakistan, for example, during the past 5 years, power shortages have been over 25 percent of the demand, in India, over 10 percent, in the Dominican Republic over 15 percent. Similar situations exist in many other countries.

Today, however, the combination of record population growth and resource consumption rates are creating environmental stresses and social problems that are also of previously unimagined proportions. The global dimensions of these problems have resulted in a flurry of international dialogue, several important multi-lateral agreements and cooperative initiatives addressing environmental problems.

Expanding energy production and consumption, in response to growing population size and economic expectations, is a leading cause of major threats to the environment, including global climate change (due primarily to burning carbon-based fuels), and local effects such as air pollution and ground contamination from mining and acid rain.

Even with dramatic supply and end use efficiency improvements and strict energy conservation, the need in developing countries for additional generation capacity is projected to total at least 700 GWs through the year 2008 at a cost of $1.4 trillion. This "least cost" strategy -- which many observers believe is overly optimistic in its projections for energy conservation and efficiency improvements -- would require investments on the order of $70 billion per year for this additional generating capacity.

Even assuming that the developing countries, donor nations and multilateral development banks combined can provide around 60 percent of the capital needed, and if conservation and efficiency improvements are successfully implemented, this scenario would lead to an investment shortfall or "gap" of about $300 billion during the next 20 years.

Yet, as demand for electricity has grown in developing countries, many governments have found it increasingly difficult to allocate sufficient resources to the power sector to ensure that demand is met. In many countries the power sector consumes more than 20 percent of the government's total development budget. Foreign borrowing for the power sector is often greater than 30 percent of total country foreign debt.

Most developing countries face a devastating "triple bind" in the energy sector that seriously constrains them from achieving sustainable economic and social development:

- Local, regional and global environmental degradation from energy use;
- Inadequate energy policy and institutional frameworks; and
- Insufficient capital for investments needed to expand energy capacity.

3. PRE-CONDITIONS FOR CLEAN COAL PROJECT DEVELOPMENT AND THE USAID EXPERIENCE

As I mentioned, USAID has learned by trial and error what can help and what can hinder the successful implementation of energy projects in developing countries. Often we have tried to assist the implementation of specific energy technology projects where the policy and regulatory climate was not ready.

This approach does not work well. In some cases, we were proposing technologies that the host governments and their staffs simply did not understand, or that they viewed with unwarranted skepticism. In other cases, even where there existed sophisticated knowledge of the technology and a supportive regulatory framework, the major institution -- the state-owned utility -- was unwilling and unable to accept new ideas and technologies. And, when we finally had developed institutions, projects we assisted failed because the financial and backup security requirements for the investments would not solidify.

Consequently, we now concentrate on assisting developing countries to establish all of the pre-conditions for project implementation.

- Information Transfer and Technology Cooperation,
- Policy, Fiscal and Regulatory Reform,
- Public/Private Institutional Capacity Building,
- Financial Strengthening, and
- Project Identification and Implementation.

I will discuss each of these briefly, the key participants in each area, and the USAID's assistance tools. Then, I will give you some examples of how our comprehensive approach has worked in India, Armenia, the Dominican Republic and the Philippines.

Information Transfer and Technology Cooperation

USAID has sponsored efforts to help create a common base of information and understanding about available clean coal technologies, market opportunities and the requirements of foreign investors. We have conducted market assessments and studies that identify barriers to the introduction of new energy technologies. Also, we sponsor seminars and conferences for the primary purpose of exchanging information about how new technologies, such as clean coal technologies, can be applied to situations in developing countries. These meetings bring together developing country governmental and utility officials, multilateral development banks, USAID field mission, host country private sector representatives, and U.S. engineering firms, equipment and service suppliers, and consultants.

Policy, Fiscal and Regulatory Reform

There must be a strong, explicit public policy commitment to encourage the introduction of new technologies into the local power sectors, especially since the sector has been viewed by many as biased toward very conventional technologies. Laws and regulations should if possible, encourage innovation approach and encourage private investment. USAID has

provided legal and regulatory advisors to help review existing statutes and regulations and to draft new ones. We have also provided training for utility officials and legal advisors on new policy approaches.

Public/Private Institutional Capacity Building

Often, the government staffs in development have little familiarity with new technologies or new approaches that involve private sector investment. USAID has conducted in-country training, study tours to the United States and focussed technical assistance missions overseas in a effort to bolster the capacity of local institutions to understand new technologies and to integrate them into their national and utility planning.

Financial Framework Strengthening

Since energy projects are capital intensive, their success is closely linked to complex financing arrangements. USAID has provided training and advisors who can assist host countries and project developers to identify sources of public and private sector investment and debt financing. Also, USAID has provided technical advisors to assist multilateral development banks establish new funding mechanisms to support the financing of energy technology projects.

Project Identification and Implementation

Finally, USAID has frequently worked with host countries and prospective project developers in identifying viable project opportunities. Then, with its pre-investment support funding programs, USAID has cost-shared with private companies studies that assess the feasibility of specific projects. Not uncommonly, USAID has also acted as a facilitator in helping resolve negotiations between developing country utilities and companies proposing innovative energy technology projects.

4. INDIA

In partnership with the Government of India, the Ministry of Energy and the USAID Mission in India, we have launched a $5.3 million technical assistance initiative to support the Government of India to implement environmentally sound private power projects, including clean coal technology projects. Titled the "India Private Power Initiative" (IPPI), the program will provide technical assistance and training in the areas of information exchange about the benefits and approaches to private power, the required legal and regulatory framework, new institutional changes and approaches, project financing, and project-specific contracts and agreements.

Information Transfer and Technology Cooperation

To build a base for the program, USAID and the Government of India hosted a private power development conference for a delegation of high level Indian government officials, as well as representatives from India's largest private and public electric power utilities. Also, USAID completed in June 1993 a major definitional mission that made recommendations on short-

term and long-term needs of the government India, forming the basis of a joint USAID/Government of India implementation plan. Additionally, USAID is acting as conduit to provide ongoing interactions and information exchange on private power opportunities between the public and private sector in India and U.S. private power developers, including those proposing to utilize India's vast coal resources for environmentally sound power generation.

Policy, Fiscal and Regulatory Reform

The IPPI program is working with the central government of India to improve the legal and regulatory structure for soliciting, selecting and contracting for private power projects. This will involve the review and analysis of the existing laws and policies with the intent of recommending changes that will better support private investments in the power sector.

Public/Private Institutional Capacity Building

The IPPI program will be providing training and technical assistance directly to those State Electricity Boards that desire to develop their own institutional capability to manage private power projects within their system. The Government of India recognizes that its State Boards must have staffs that are knowledgeable about, and capable of administering, private power development programs. Creating financially viable partnerships of this nature requires trained personnel at the State Electricity Boards who are confident in their abilities to contract with private power providers.

Financial Strengthening

To create partnerships between the financial institutions, Indian officials and potential project developers, USAID has sponsored a banker's conference in New York City that brought these three parties together. Although not large enough to actually finance projects, the IPPI program will assist in matching developers with potential investors and lenders, and in removing barriers in India to project financing for power projects.

Project Identification and Implementation

The Government of India and its State Electricity Boards are currently reviewing, with USAID assistance, over 40 private power project proposals. The IPPI program will attempt to help them identify and fashion the soundest proposals, so that they can proceed to actual implementation. Additionally, USAID is providing funding directly to U.S. project developers to cost share pre-investment studies for specific projects.

5. DOMINICAN REPUBLIC

In the Dominican Republic, USAID Washington is cooperating with the Government of the Dominican Republic, the publicly owned electric utility, the World Bank, the InterAmerican Development Bank, and the local USAID Mission to implement an electric power sector reform plan.

Information Transfer and Technology Cooperation

Under this program, USAID will help to inform and orient high level officials of the Government of the Dominican Republic and the staff of the electric utility about the benefits and the need for private power investment.

Policy, Fiscal and Regulatory Reform

The Dominican Republic program will lock in the policy reforms by the drafting and passage of a new electricity law and associated regulations. Under this new legal framework, the Government of the Dominican Republic will corporatize the electric utility and split it into three components: generation, transmission, and distribution. The distribution companies will be privatized right away.

Additionally, this program will develop environmental norms and standards applicable for privately constructed power facilities.

Public/Private Institutional Capacity Building

Under the new law, a new regulatory body will be created to oversee the operations of the electricity sector. USAID will provide technical advisors to develop and structure the regulatory body and train it and other related regulatory agency personnel on operational policies and practices.

Financial Strengthening

As part of this program, the Government of the Dominican Republic will gradually raise the electricity tariffs. This will enable the new utilities to cover all of the financial requirements, allowing them to operate on a commercial basis. The World Bank and the InterAmerican Development Bank, if necessary, may establish a Private Sector Energy Development Fund -- similar to those established in Pakistan and Jamaica -- to lend capital to private project developers.

Project Identification and Implementation

Regarding specific projects, the Government of the Dominican Republic will be seeking bids from the private sector for two new, 125 MW, build-own-operate electric power plants. USAID and the World Bank will provide the technical assistance for establishing the solicitation bidding process. These plants will complement $300 million of possible investment in the power sector by the World Bank and the InterAmerican Development Bank.

6. ARMENIA

Armenia has been facing extreme electric power shortages due to its war with Azerbaijan. Fuel suppliers have been interrupted; transmission lines severed; existing power plants poorly maintained; and new construction suspended. USAID Washington, in conjunction with the Government of Armenia, the state electric utility, the European Bank for Reconstruction and

Development, and the local USAID Mission, have established an energy assistance program targeted specifically at accelerating the completion of the much needed 300 MW, gas/oil-fired Hrazdan No. 5 power plant. Once built, this plant will be operated by the state utility. In this case, USAID assistance is focussed almost completely on financial strengthening and project implementation.

Financial Strengthening

To obtain funding to complete the Hrazdan plant from the European Bank for Reconstruction and Development, the Government of Armenia needed to have a pre-loan assessment providing a full technical and commercial evaluation of the project. If the analysis proved the project viable, the European Bank for Reconstruction and Development would provide a $58 million loan to complete the facility.USAID allocated $300,000 for this analysis.

Project Identification and Implementation

At the request of the Government of Armenia, USAID provided $300,000 to undertake to assessment, which subsequently verified the viability of the project. Consequently, the loan was approved and a U.S. firm received the construction management contract to complete the plant, which should be operational in the Spring of 1995.

7. PHILIPPINES

The National Power Corporation (NPC) of the Philippines has been struggling to end the nagging power shortages that have left much of Manila without power for over six hours per day for months at a time over the past five years. Plagued by deteriorating facilities and inadequate investment in new power generating equipment, NPC and the Government of the Philippines has turned to the private sector to build, own and operate electric power plants.

USAID has been working with the government, NPC and multilateral development banks to provide the pre-conditions and framework for private power generation, and to encourage foreign private project developers and investors to propose environmentally sound, independent power plants for inclusion in the electric power grid.

Information Transfer and Technology Cooperation

Early on during the power shortage problems of the Philippines, USAID sponsored an information-sharing seminar on the pros an cons of privately generated electric power. Regulators, equipment suppliers and project developers offered their experience to NPC staff and other government officials.

Policy, Fiscal and Regulatory Reform

When the Government of the Philippines decided it needed new legislative authority and regulations to implement a private power and cogeneration program, it turned to USAID to provide legal and regulatory experts to provide examples from other countries and to review drafts of the documents. This culminated in statutes that set in place a full fledged program

wherein private companies could construct generating plants and sell power to NPC.

Public/Private Institutional Capacity Building

To help the staff of the Office of Energy Affairs and NPC to understand the intricacies of private investment in independent power facilities, USAID organized study tours for Philippine officials. They were able to meet and learn from U.S. state regulatory boards, U.S. utilities and private power developers. Also, we provided them a number of training opportunities to educate the NPC staff of their private power working group. Additionally, USAID worked with the Asian Development Bank and the Government of the Philippines on improving the long-term power generation and transmission expansion plan and on the fine tuning the regulatory framework for third-party private power transactions.

Financial Strengthening

The USAID Mission in the Philippines worked to include private power generation projects included in a special infrastructure improvement fund for the Philippines. Also, the earlier work on the regulatory framework and institutional strengthening helped clear the way for the Asian Development Bank and the International Finance Corporation to provide equity and debt funding of individual power projects.

Project Identification and Implementation

Over the past years, USAID has provided assistance to a number of energy project developers who sought to identify opportunities in the Philippines. Funds to assist private companies to prepare pre-investment studies were also made available. Through a special technical assistance mission, USAID provided a feasibility study to NPC for the development by the public or private sector of a 400 MW oil/gas-fired power plant on Luzon.

8. CONCLUSION

The experience of USAID shows that there is no set prescription for the development of an implementable project. Neither the top down ("policy approach") nor the bottom up ("technology approach") is necessarily correct. Each country and specific project needs to be considered on a case by case basis.

We have also learned that brokering between all participants and leveraging all available resources is a critical element in our assistance. Thus, close coordination and partnerships with host countries, their utilities, other donors and the multilateral development banks can be effective in paving the way for project implementation. This is especially true when mapped out early. This enables each partner to assume responsibility for handling specific pre-conditions for energy project implementation. The result can be a relatively smooth flow toward the ultimate objective of financing, constructing and operating a clean coal power project.

IEA Second International Conference on the Clean and Efficient Use of Coal and Lignite

Workshop B(1): Cooperation and Partnership

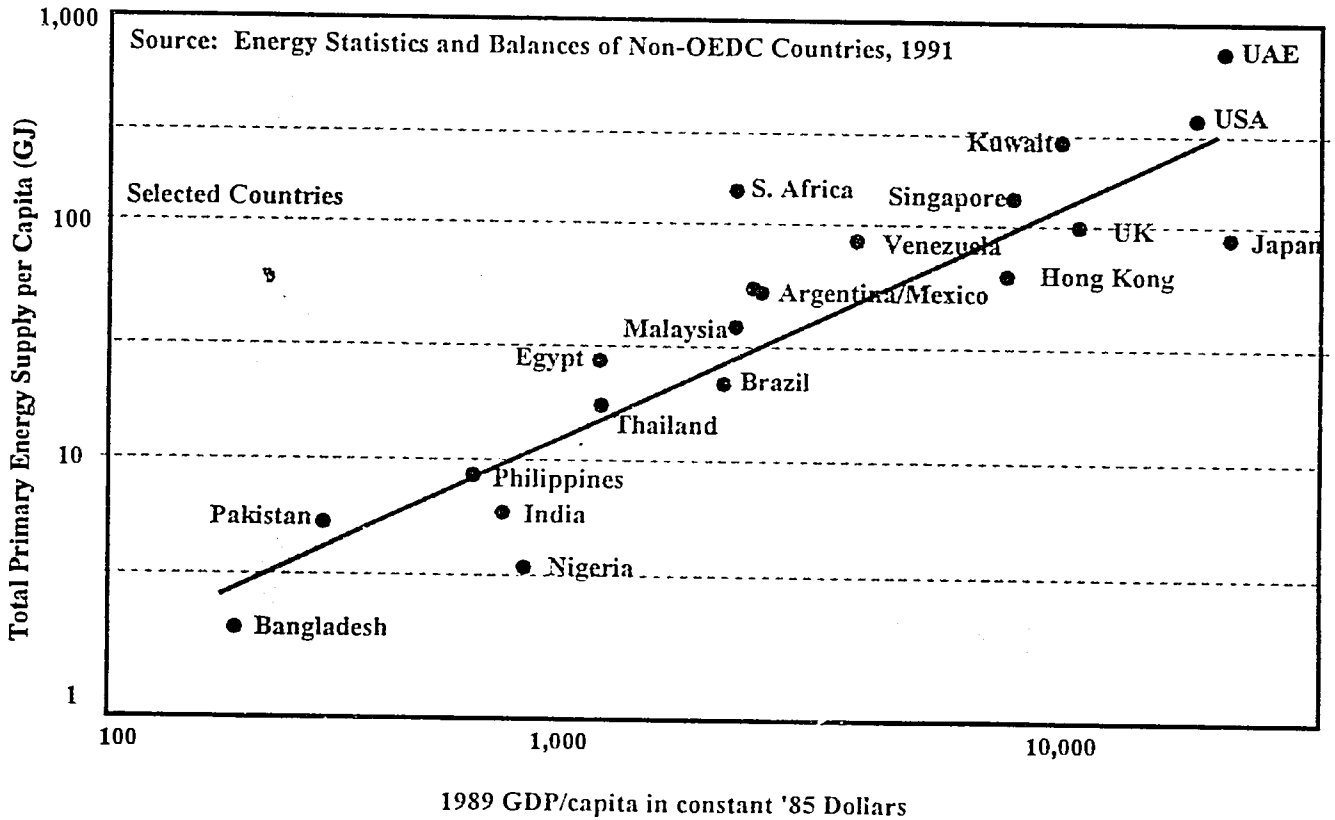
USAID Experience in Cooperation and Partnership

Dr. Samuel Schweitzer, Chief
Energy Innovation and Private Sector Division
Office of Energy and Infrastructure
U.S. Agency for International Development

Hong Kong
December 3, 1993

Per Capita Energy - Income Link

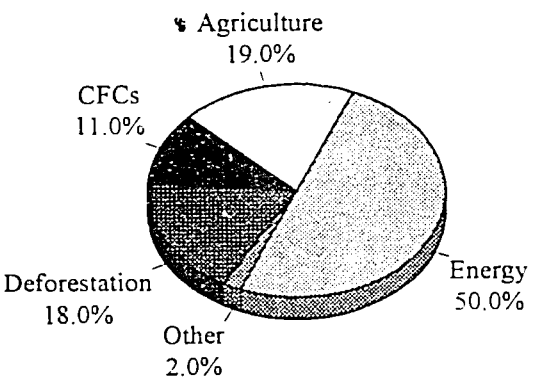
The Empirical Relation Between Energy Use and Economic Output



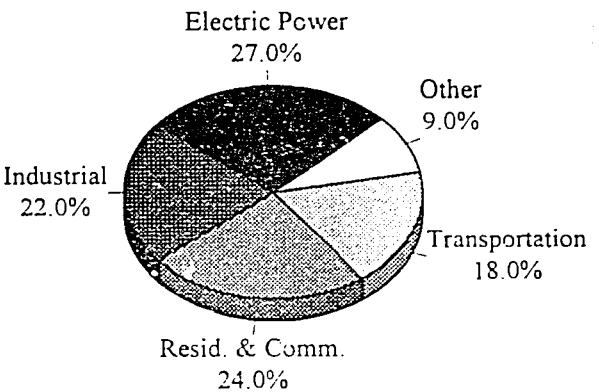
USAID Office of Energy and Infrastructure

Sources of Greenhouse Gas Emissions

All Sectors

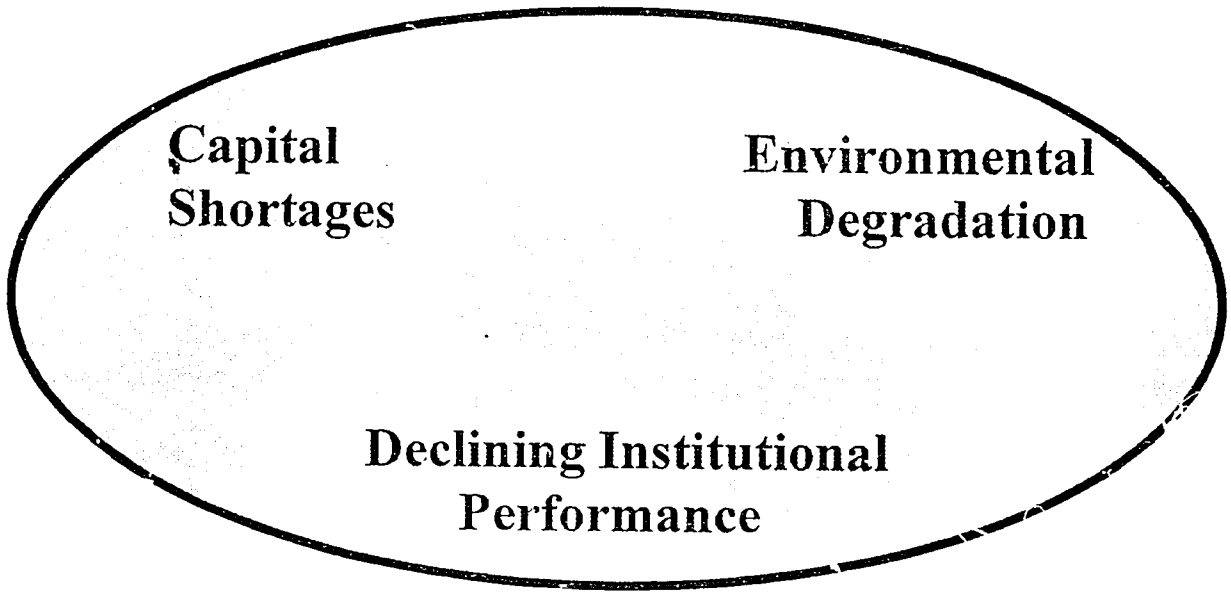


Energy Sector



USAID Office of Energy and Infrastructure

The Triple Bind



USAID Office of Energy and Infrastructure

Pre-conditions for Clean Coal Technology Project Implementation & The Role of USAID

	INFORMATION TRANSFER & TECHNOLOGY COOPERATION	POLICY, FISCAL & REGULATORY REFORM	PUBLIC/PRIVATE INSTITUTIONAL CAPACITY BUILDING	FINANCIAL FRAMEWORK STRENGTHENING	PROJECT IDENTIFICATION & IMPLEMENTATION
Key Participants	Host Country Public & Private Sectors U.S. Public & Private Sectors	Host Country Government Entities Host Country Priv. Sector Entities Multilateral Orgs. & Bilateral Donors	Host Country Government Entities Host Country Private Sector Entities	Host Country Entities Project Sponsors Investors & Lenders	Host Country Government Entities Project Sponsors Investors & Lenders
USAID Tools	Info Transfer & Technology Coop. Seminars Market Assessments Technology Options & Cost Analyses Study Tours Trade Missions	National Planning Assistance Legal/Policy Assist. Regulatory Assist. Privatization Assist. Training & Internships Document Prep.	Financial Advisor Technical Assistance Training & Internships Study Tours Conferences	Financial Advisor Cooperation with Multilateral Lenders Guidance to Private Investors Information-Sharing Seminars	Brokering with Host Country Gov't. Entities Feasibility Study Support Guidance to Project Sponsors

Continuous Support for Public-Private Partnerships

USAID Office of Energy and Infrastructure

India Private Power Initiative (IPPI)

- IPPI Supports the Government of India (GOI) in Achieving Sustainable Environmentally Sound Private Power Development through a $5.3 Million USAID Program

- USAID Assesses the Technical Assistance and Training Needs of the Private Power Development Program of the GOI through Definition Missions

- IPPI Provides Technical Assistance and Training in Advancing the Establishment of a Coherent Legal and Regulatory Framework, Building Institutional Capacity, and Creating an Environment for Investment in Private Power

- USAID Provides an Information Exchange Forum on India's Private Power Development Program through Conferences, Workshops, and Study Tours for Government Officials, Developers, and Investors

Dominican Republic
Power Sector Support

- USAID, The World Bank, and the InterAmerican Development Bank are Cooperating to Implement Power Sector Reform in the Dominican Republic
- IDB Providing Consultants to Write New Electricity Law and Regulations
- Government-owned Utility to be Split into Generation, Transmission, and Distribution
- USAID Providing Training and Institutional Support to New Regulatory Body
- Tariffs to be Raised Gradually Based on USAID, World Bank, and IDB Analyses
- USAID Providing Assistance Preparing Solicited Bidding Process for Two 125 MW Private Sector Plants, Complementing $300 Million of Possible Funding by IDB and The World Bank
- USAID also to Develop Environmental Norms and Standards for Private Power Facilities

Armenia

- Armenia Applied to EBRD for a Loan to Complete a Partially Built 300 MW Gas/Oil-fired Power Plant.
- USAID Funded Pre-Loan Assessment Providing Technical and Commercial Evaluation. Cost was $300,000.
- EBRD Approved a $58 Million Loan to Complete Hrazdan No. 5.
- U.S. Firm Competitively Awarded Construction Management Contract.
- Power Plant will be Operational by Spring 1995.

Philippines Private Power Development

- USAID has Cooperated with the WB, ADB, Government of Philippines (GOP) to Support Energy Sector Reform
- USAID in Cooperation with Lenders Assessed Technical Assistance and Training Needs of GOP
- USAID Hosted a Private Power Conference to Provide a Forum for the Exchange of Information Between the Private Sector and GOP
- USAID in Cooperation with ADB and GOP, Provided a Long-Term Power Generation and Transmission Expansion Plan
- USAID, Cooperating with ADB, Provided Regulatory Framework for Third-Party Power Transactions
- USAID Funding Feasibility Study for Development of 400 MW Oil/Gas-fired Power Plant

Promoting International Cooperation of Coal Patent Technology Development

Lin Jian , Engineer

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The international patent document is the most important technical resource in the world. It is a technology treasurehouse in which we can gain a lot of jewelleries. Of course, it is also invisible riches of all humankind. In order to use this intelligence treasurehouse enoughly and promoting international cooperation of coal patent technology development, author introduce some information of China patent system and talk about international cooperation of coal patent with every friends in this paper.

From April 1, 1985, on that day China patent law was performed, to March, 1993 , China Patent Bureau accepted 294620 pieces of domestic and foreign patent application. The situation of three patent application: invention patents, 21% ; utility patents, 66% ; design patents, 13% . As an important analysing basis , through the situation of patent applications according to International Patent Classification we car know China industry development level, technological structure and how foreign countries pay close attention to China technological market.

In all applications of invention and utility patent, human necessities, 26% ; performing operation, transporting, 22% ; chemistry, 8% ; textiles, paper, 2% ; building (include coal mining) , 7% ; mechanics, 15% ; instruments, nuclear science, 10% ; electricity, 10% . If classifying detail, we can gain below statistics:

In applications of invention patent, according to number order, chemistry, 28% ; human necessities, 20% ; performing operations, transporting, 17% ; instruments, nuclear science 10% ; electricity 9% ; mechanics, 9% ; building, 4% ; textiles, paper, 3% .

In applications of utility patent, according to number order, human necessities, 28% ; performing operations, transporting, 24% ; mechanics, 17% ; instruments, nuclear science, 10% ; electricity, 9% ; building 8% ; textiles, paper, 2% ; chemistry, 2% .

Analysing the applications of domestic and foreign patent, there are more different on technological field distributed. Domestic application are majorly distributed in the fields of human necessities, performing operations, transporting, mechanics, instruments . They are 70% of total China patent applications. Foreign applications are majorly distributed in the fields of Chemistry, performing operations, transporting, electricity, instruments and nuclear science.

Until the end of February, 1993, China Patent Bureau accepted 41023 pieces of patent applications of 72 countries and regions, it is 13.9% of total quantity. Among them, invention patents are 36448 pieces, 88.8% ; utility patents are 1123 pieces, 2.7% ; design patents are 3452 pieces, 8.5% . According to statistics number of applications, six countries and region are located at head, i.e. United states, Japan, Hongkong, Germany, United Kingdom and France. Since foreign trade of

China are further developing, there is an increase trend of application quatity for foreign patent.

According to above statistics material, we can find that patent application quatity of China coal industry is fewer than other fields. Its character: First, starting research level is lower. Second, also have few high quality patents. Third, inventors must increase the quality of patent application. For example, China has 32 research institutes of coal science, there are only several hundreds patent applications during 8 years. The quatity and quality of patent technology are important basis for researching the situation of enterprises operating. China is a large country which produces and consumes the most coal in the world recently. For example, China produced 1.08 billion tons coal on 1992, meanwhile, it also consumed more than 1 billion ton coal too. It is not correspondence between large country of producing coal and fewer coal patents. As China is opening to the world, China government and enterprisers have paid attention to the important of intellectual property. Now, let me continue to talk about my idea.

1. Import advance technology of foreign countries

China is a developing country. There is a big distance between advance industrial country and China on coal science and technology. It is very important to import and learn advance patent from foreign countries. We must learn from the success experience of Japan on this point. From the end of second war, Japan spent 20 years to obtain great development of economy. Analysing its developing process, it is an important reason that Japan pay attention to economic and patent information.

According to statistics material, on 1952, The Japan export amount of money was only $ 0.8 billion USD. As Japan spent $ 5.7 billion USD to purchase a lot of economic informations and patent technology during 20 years, it promoted the economy development quickly. Until 1990, Japan export amount of money reached $ 286 billion USD, it increased 356.5 times than 1952, and it located at third after America and Germany. From 1970 to 1986, America sold patent to Japan about increasing 19% . This decade, Japan has more and more ability of economic competition relying on its patent superiority. From 1980 , Japan has exported products of high science and technology to America about increasing 266% . " Outstanding patent technology equal glory future. " many Japan enterprisers said.

In order to develop China coal industry, we must use advance science , technology and method of management. We often search and learn excellent technology from international patent document. We also hope IEA, Australia, Japan, United Nations and United States to supply information to us, such as clean coal technology, the method of generating electricity with high efficiency. China is a huge technology market and it has high value to research how opening for foreign friends.

2. Export excellent patent technology of China

There are 1.1 billion population in China, it is one fifth of world population. This is a huge intelligence resource, and relying this substance foundation China will become a largest country of patent certainly. Now , this intelligence resource is just opening. I believe, When inventing and creating ability

of 1.1 billion population are bring into play enoughly, Chinese will create many miracles of the world. Eastern huge dragon will jump into sky. China will become eastern economic giant.

There are also some splendid jewels which have modern technology level in 294 thousand pieces of China patent. The foreign enterprisers who have outstanding foresee will pay attention to China patent technology.

There are two difficulties to hinder China patent into international technology market: First, the inventors of China do not have enough money for patent applicating ; Second ,they are short of investigating and contacting to the international market. Until the end of 1992, the patent applications of foreign countries in China reached 40,000 pieces, while China patent application in the foreign countries were only 170 pieces. We warmly welcome foreign enterprises, companies cooperating with Chinese inventors. The operating method may be: Chinese inventors supply patent technology, foreign company pay for patent application and invest to develop and manufacture for commerce in their country. The profit are divided according to partnership agreement. This is a good method for developing China patent in which two partners bear risk and enjoy interest.

3. Establish Nanjing International Coal Patent Research Institute of China

I am planning to establish a private information organization. It is called Nanjing International Coal Patent Research Institute of China. Its aim: Research and popularize coal patent technology, supply patent information of international coal industry for domestic and foreign research organizations, enterprises and inventors, promote international cooperation.

The constitution of institute: 3-5 managing staffs, employ some researchers who work in sparetime.

The work content of 1994:

(1) Supply information service of international coal patent

(a) Edit and publish "Patent Technology Extract of United States" . Its information resource is official gazette of the United States Patent Office. Introducing new inventions of America to the technology research organizations, enterprises, companies and inventors of China.

(b) Special service about China patent information. Its information resource is patent gazette of China. Supplying service for foreign technology research organization , enterprises, companies and inventors. Such as: search, duplicate and translate patent specification of China; assistance to investigate, statistics, forecast the delelopment trend of technology; supply technology standard, commerce, trade and other relative information; assistance to purchase product sample and publication from China, etc.

(2) Set up high intellectuals store

Contacting with high intellectuals from China coal research organizations, universities, institutes and enterprises. Working at international coal industry patent information, analysing and forecasting technology development trend. Supplying consultative service for foreign companies about

invest, technology trade, product sale. Recommending specialists to work at agency office of foreign company in China.

(3) Educate staff of international coal patent information

Now, the specialists and staff of international coal patent information are lack in China. Organizating a training class in 1994. Major training content: science and technology English, international patent knowledge. Students are technicians of coal industry. I hope international specialists to help us and teach in China.

Other hand, when institute gain some money through service, I think to set up " Invention Fund ", helping Chinese inventors who have excellent ideas but do not have enough money to research.

Establishing Nanjing International Coal Patent Research Institute, I also face many difficulties :

(a) It needs some fund for establishing institute.
Resolve method: First, supplying patent information service for domestic and foreign organizations and enterprises, gaining service reward; Second, researching new patent technology and transfering to enterprises, gaining patent transfering fee ; Third, hoping to gain international aid from foreign organizations, enterprises, companies and individualism.

(b) There are some difficulties that science and technology researchers of China go to abroad to attend international meeting and technology exchanging activities.

(c) Lacking good equipment of communication and office.

It is a new career to research and serve about international coal patent information in China. Patent specification is law right and market information, meanwhile, it is important invention information. Through patent document, we not only learn the situation of new coal technology, but also know the research and development trend in future. China enterprises eagerly enter international market and foreign enterprises eagerly enter China market, they all need high quality information of patent technology.

I look forward eagerly coal industrial officials of IEA, Australia Japan, United Nations, United States and China government pay attention to this basic work, and look forward eagerly to obtain helping and aid from every friends.

Our Chinese often said: " Where there is a will, there is a way." Also, there is a famous maxin of America: " If we can dream it, and we can do it. " Under the helping of every friends, I will realize my dream.

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US-AEP: A MODEL FOR PUBLIC/PRIVATE COOPERATION

Lewis P. Reade

Director General, United States Asia Environmental Partnership

for presentation, Hong Kong, Friday 3 December

Workshop on Cooperation and Partnership

IEA Second International Conference

The Clean and Efficient Use of Coal and Lignite:

Its Role in Energy, Environment and Life

Co-Chairs, Fellow Panelists, Ladies and Gentlemen:

It is an honor to join such a distinguished group in this timely discussion of what may be the critical aspect of furthering the use of clean and efficient coal and lignite: partnership and cooperation. And doubly so to represent the United States-Asia Environmental Partnership and to share US-AEP with you as an example of how such cooperation and partnership can work to everyone's benefit.

We can all cite examples of the problems. Shanghai with its 10,000 coal-fired boilers is just one of the many burgeoning Asian cities that sit under a thickening pall. The coal-fired Mae Moh Power Generation Station in northern Thailand produces 27% of that country's electricity and emits dangerous levels of sulphur dioxide.

We also all know examples of how this degradation can be turned around. Take Pittsburgh, Pennsylvania, one of the steel manufacturing centers of the world, for instance. A quarter-century ago, in Pittsburgh the middle of the day was like late evening because of the smoke. The air was barely breathable. The rivers running through the city were nearly dead. Everything was perpetually grimy. Human health suffered. So did plant life. So did the economy.

Pittsburgh's recognition that there needed to be smoke control goes back before the turn of the century. But early ordinances were not effective and frequently thrown out by the courts. In the 40's and 50's Pittsburgh changed home heating from coal to gas. The city and surrounding Allegheny county formed the Bureau of Air Pollution Control in 1957. Although at that time the community began to address industrial pollution, the prime impetus came in 1970 with the passage of national legislation: the Clean Air Act. As a consequence, major manufacturers switched to new technologies for coke production and for scrubbing smoke stacks. Since then, enormous changes have taken place. Present-day Pittsburgh may not sparkle, but people see the sun.

But what does this mean in the context of our present discussion? Pittsburgh's cleanup demonstrates that technology alone -- although it is important -- is not enough. A combination of regulation, community, even national, will and public and private sector partnership are required.

Which is what makes our discussion today timely and where US-AEP comes in. Throughout the world there is a growing recognition of the necessity of reversing the costly trends of environmental degradation that accompany unbridled economic growth. The will to address these issues is increasingly apparent on both sides of the Pacific. All over Asia, governments are setting ambitious priorities not only to clean up the degradation but also to introduce clean technologies as a key to sustainable economic development.

Likewise, in the United States, we continue to strengthen patterns of environmental protection regulation that started at the turn of the century and, as a result, to spawn new, more environmentally sound technologies. The Clinton Administration is committed to improving the environment at home and abroad in the clear recognition that such improvement is mutually beneficial.

A range of actions illustrate the seriousness of the Administration's intent to put our own house in order. Last month, the President released his Climate Change Action Plan. This plan is the cornerstone of the commitment to reduce U.S. greenhouse gas emissions to their 1990 level by the year 2000 in accordance with the United Nations Framework Convention on Climate Change.

Internationally, improving the environment is one of four priorities Brian Atwood, administrator of the United States Agency for International Development (USAID), lists for the Agency's programs.

Environmental improvement is win-win. It is a development objective of USAID for the obvious reason that the countries involved benefit. But also, because US technology is appropriate and competitive, there is great potential for US exports. Celebrating Earth Day last April, President Clinton pointed out that "America can only maintain its lead in the world economy by taking the lead to preserve the world environment." Consequently, he challenged the Trade Promotion Coordinating Committee under the US Department of Commerce to come up with a plan that would promote U.S. environmental technologies around the world. The result, spelled out in Environmental Technology Exports: A Strategy for US Leadership, calls for a new strategic approach that coordinates US government and private sector efforts to facilitate environmental exports and technology cooperation.

Meanwhile, in August of '93, at the request of the US Congress, the Department of Energy released a report entitled Clean Coal Technology Export Finance Programs. This report recommends that the U.S. provide a clearinghouse for information about clean coal technologies, projects, and financing.

As these illustrate, there is a growing determination throughout the US government to help solve global environment problems through the application of US technologies, including clean coal technologies (CCTs). Although agencies such as USAID, the US Department of Commerce and the US Department of Energy have different mandates, they increasingly have a common agenda in promoting of US CCTs abroad.

This common agenda gives force to the United States-Asia Environmental Partnership (US-AEP), which I represent. The US-AEP was established in 1992 as a new, cooperative way of doing business with core funding from the United States Agency for International Development (USAID). US-AEP's purpose is to help provide leadership for clean energy and the environment in Asia and the Pacific -- economically, the fastest growing region of the world but, unfortunately, one that often seems to be losing its battle to preserve its environment.

The United States-Asia Environmental Partnership works by living up to its name: That is, by creating partnerships focused on critical environmental problems from among 25 cooperating US government agencies, private sector companies and non-governmental organizations with their counterparts in 34 Asian nations and territories. US-AEP is, in effect, a matchmaker.

While the US-AEP works in many ways on a range of issues, let me detail some of its activities relating to clean coal technologies and projects, and illustrating mechanisms that foster partnership and cooperation.

Let's begin with finance -- often a determining factor in bringing any project to fruition. Last month, US-AEP opened the Infrastructure Finance Advisory Service or IFAS. IFAS is a cooperative effort of the US Agency for International Development (USAID), Export-Import Bank (EXIM), Overseas Private Investment Corporation (OPIC), US Trade and Development Agency (TDA) and the Small Business Administration (SBA). How does it work? A country in Asia needs to build, say, a clean power plant. IFAS provides US companies which produce environmentally sound technologies with timely information about that project and other energy and environmental infrastructure project requirements in the region. IFAS helps those companies identify viable sources of finance. Moreover, it encourages the US financing agencies to share project information with each other and to coordinate the use of their resources.

But capital for CCTs and other environmental projects will increasing come from private sources. Therefore, US-AEP has also established a Private Finance Circle -- a network of commercial banks, venture capital firms, and other financial institutions interested in working with the US-AEP to expand private lending and investment in energy and environmental projects.

The Department of Energy (DOE) report on financing clean coal that I mentioned earlier recommends that the US government have a clearinghouse of information about CCT projects and finance. IFAS is already serving this important function for US companies and US-led consortia pursuing projects in Asia and Pacific.

Also in the financial arena, to complement IFAS, the US-AEP joined forces with the US Department of Commerce to support a new service called AXCAP, which stands for Access to Capital. Managed by the Bankers Association for Foreign Trade (BAFT), AXCAP serves as a matchmaker between banks that provide trade finance and exporters, including CCT companies. These "one-stop shop" information and advisory services are a first step in encouraging more US companies to explore Asia for opportunities to apply, and even transfer, their appropriate clean coal technologies.

US-AEP also works with and supports programs of other US agencies to promote new partnerships. A recent grant to the US Department of Energy supports innovative proposals to transfer CCT and other environmental technologies to developing countries through the ADEPT or Assisting the Deployment of Energy Practices and Technologies program. To further increase the prospects for technology transfer of CCT and other environmentally sound technologies, US-AEP has joined forces with Overseas Private Investment Corporation (OPIC) to launch the Environmental Enterprises Development Fund. This new fund is expected to result in at least eight new environmental enterprises in Asia during the next 12 months.

To improve its information system and to help foster technology cooperation between US and Asian companies, US-AEP, collaborating with the Department of Commerce's United States and Foreign Commercial Service, has opened nine regional environmental technology offices. They are located in India, Thailand, Indonesia, the Philippines, Malaysia, Singapore, Taiwan, Korea and Hong Kong. These offices, which are headed by environmental engineers, have begun to work with industry and utilities to identify appropriate solutions to environmental problems, including those that result from the burning of coal and the disposal of fly ash. In addition, US-AEP has placed an environmental engineer in the US & Foreign Commercial Services office of the Asian Development Bank (ADB). The first priority of US-AEP's ADB environmental representative is to help US companies identify and pursue major energy and environmental infrastructure projects at the earliest stages of conception and development.

The Clean Coal Technology Export Finance Programs report recommends that the US develop an ongoing interagency program. In response to this and earlier calls for better interagency cooperation, the US-AEP is designing a clean energy effort that could strategically focus the resources of US government agencies including USAID, DOE, and EPA, private organizations, like the Electric Power Research Institute (EPRI), and private industry in high priority coal countries such as India, Thailand, Indonesia.

In India, the Partnership is working with the USAID Mission to support an Indian Private Power Initiative (IPPI). Specifically we are exploring ways that the US-AEP could help US companies to defray pre-investment costs associated with developing privately owned coal preparation plants, and we are looking at ways of having these monies leverage other US government and private resources to cover related costs, such as coal testing and evaluation.

Back to Mae Moh, which I mentioned at the outset. At the request of the Royal Thai Government, US-AEP supported a team of experts from the EPA, DOE, and the World Health Organization to travel to northern Thailand to last January to evaluate the causes of health problems resulting from the Mae Moh's lignite power plants. A follow-up mission was recently concluded. US-AEP is also working with USAID/Thailand and the US Foreign Commercial Service in Thailand to build a true public/private partnership between the Electric Generating Authority of Thailand (EGAT) and the US, including key government agencies, US utilities, and private industry.

In response to President Clinton's Climate Change Action Plan released last month, US-AEP is also supporting a private effort to help US utilities develop greenhouse gas reduction strategies by creating "carbon sinks" in Asian countries and through partnering arrangements with Asian utilities.

You can see, therefore, that US-AEP has launched a range of activities in an effort to promote intergovernmental and public/private partnerships in support of the Asian environment. We believe these efforts are an important first step in responding to Asia's environmental needs and to the Administration's call for a more unified, strategic US approach. We invite all of you here today to contact us to learn more about the US-Asia Environmental Partnership. We look forward to working with you to solve your energy and environmental problems. Thank you.

IEA Second International Conference on
the Clean and Efficient Use of Coal and Lignite:
Its Role in Energy, Environment and Life

Cooperation and Partnership

"Technology Options and Technology Transfers -an Indian experience"

K. RAMAKRISHNAN
Director (Engg.,R&D)

BHARAT HEAVY ELECTRICALS LIMITED
NEW DELHI (INDIA)

3rd December, 1993

Extracting coal from the ground involves tearing up landscapes with opencast mines, or risking human health and lives in deep mines. The traditional way to unleash coal's energy is by setting fire to it, a reaction that produces sulphur dioxide, nitrogen dioxide, carbon monoxide, a brew of aromatic hydrocarbons laced with toxic metals, to say nothing of carbon dioxide, the most notorious greenhouse gas. On top of all that, conventional power stations waste about two-thirds of the coal's energy.

Why bother? Because coal is the only fossil fuel available in quantities that for practical purposes are inexhaustible. It is the only fuel capable of providing the electricity needed for the economic development of central and south Asia. Despite its drawbacks - and barring remarkable and unexpected breakthroughs in research on fusion - coal will be driving the world's power stations well into the next century. But the power stations needed to achieve these goals, and to replace those inefficiently belching out pollutants in the Americas, Europe and Asia, will look very different in the future.

Coal is a very versatile fuel. It can be burned as a solid, a liquid, or a gas. The hot gases that combustion releases drive steam generators in today's power stations, and they will probably power gas turbines in the next generation of stations. Further into the future, the gases may produce electricity directly when they stream through a magnetic field, while hydrogen from coal could be generating electricity in battery-like fuel cells. Many of these technologies are far less polluting and capture coal's energy more efficiently than conventional power plants. But few are commercial yet.

Despite the energy glut in the developed world since the mid '80s, researchers around the world have made much progress on coal over the past decade, and are now beginning to demonstrate that their efforts are commercially viable.

All over the world, funds for research in clean coal programmes are being liberally provided, with a hope that these subsidies will promote a revolution in the way coal generates electricity. Tougher environmental laws will force power companies to adopt such new technologies. There is realisation that for coal to be fully used as primary fossil fuel, environmentally responsive, economically competitive, advanced coal using technologies and systems have to be developed and commercially deployed.

The situation is the same in my country, India, with the estimated coal reserves around 120 billion tonnes. Indian coals are generally characterised as medium volatile, high ash content and low calorific value coals. 40 to 50% ash content in our coals is common with average calorific value not more than 3200 to 3500 Kcal/kg. Silica and alumina constitute 85 to 90% of the ash. Most of the silica exists in the form of Alpha Quartz. These factors have made the Indian coals highly abrasive and erosive in nature. Indian coals generally have low sulphur content. In one way it is a boon that we have negligible SOx pollution, but lower SOx content in the flue gas reduces the conductance over the fly ash particles, thus giving an overall high resistivity.

Coal utilisation for electric power generation in India has to be viewed in the context of our ambitious plans to increase the power generating capacity substantially in the coming years. From the present installed capacity level of 71000 MW, the country aims to reach 100,000 MW in the next few years. At least 60% of these will be coal based. If we continue to use existing technologies for generating this much thermal power, we will be producing 0.2 million tonnes of fly ash and nearly 0.6 million tonnes of carbon dioxide per day besides NOx. Besides polluting the environment, we will also have a big problem of disposing the ash. We, in India, are thus in a paradoxical situation. We have plenty of coal - we need plenty of electricity - as such, this coal has to be the main fuel for our power generation. However, burning this coal in the conventional way, we will be very badly polluting our environment. We have, therefore, no alternative but to go for clean coal technologies. Realising this, we in India, especially my Company, the Bharat Heavy Electricals, have been actively carrying out research and development work in this area. Starting from the development of atmospheric bubbling fluidised bed boiler technology, we have been continuously working on various clean coal technologies and beyond these even on Magneto-Hydro Dynamics and Fuel Cells.

Bharat Heavy Electricals Limited (BHEL) with a turnover of Rs.35 billion is a leading successful Engineering Company in India, with a workforce of 75,000, engaged in Power, Industry, Transmission, Transportation and Telecommunication Sectors. 76.9% of total installed thermal power generating capacity in India is by BHEL alone, besides major contribution in Nuclear and Hydro Power plants. Almost all the main equipments required in a power plant are manufactured in various plants of BHEL.

BHEL has been carrying out R&D work on bubbling fluidised bed since 1977. For the development of fluidised bed combustion, test facilities for start-up system, and Pneumatic feeding system, alone with a 500 x 500 mm combustor were created at BHEL, Tiruchi. Joint research was also initiated with other national laboratories and institutes. A prototype 10 t/hr FBC boiler was set up at BHEL, Tiruchi. In addition, a test facility for studying the performance of free-board in a fluidised bed combustor was installed at Tiruchi with the assistance of USAID. Besides serving as a boiler to perfect various systems, gaining operating experience, with different coals, washery rejects and agricultural wastes, training operators and demonstration, it has yielded considerable amount of data to design large size boilers. Based on the test results from test rigs and the data from 10 t/hr prototype boiler, BHEL has perfected the atmospheric bubbling fluidised bed boiler technology. BHEL has sold more than 25 boilers of various capacities (maximum 95 t/hr steam generation), firing variety of fuels which are working satisfactorily in the country. Even the washery rejects with 73% ash have been used at Tata Iron & Steel Company, Jamadoba, for producing 10 MW electric power. Four more similar units have been set up for Coal India Limited at Kathara and Moonidih. A design for 30 MW bubbling FBC boiler has been developed for Indian coals. The Bubbling Bed Fluidised Bed design of BHEL has attracted a lot of attention. While for lower ranges, some Indian companies have entered into sub-licensing agreements for the technology, enquiries have been received from developed countries for this technology.

For units of capacity higher than 30 MW, it is found that circulating fluidised bed combustion technology will be more economical for high ash coals and high sulphur coals. BHEL initiated a joint R&D programme with Technical University of Nova Scotia, Canada, with part funding through IDRC, Canada. Under this programme a pilot plant (8 t/hr steam generation) was set up with the objective to test high ash, low grade coals and washery rejects and to evolve basic design parameters. Also, technology tie-up with an experienced company is on the anvil. Retrofit of fluidised bed combustion on conventional old stoker fired boilers is catching up in our country.

The new advanced clean coal technologies for power generation aim at higher conversion energy of fuel to electricity through combined cycle power generation system i.e. a combination of Brayton Cycle of gas turbine and the Rankine Cycle of steam turbine. The efficiency achievable with combined cycle is of the order of 40 to 45% as compared to 30 to 37% for conventional steam cycle. This combined cycle requires either clean fuel (like natural gas) or clean flue gases at high temperatures and at high pressure. Using coal as fuel, the alternatives are:

a) Gasification of coal and cleaning of coal gas before introducing in gas turbine.

b) Pressurised fluidised bed combustion and cleaning of gases under high pressure and high temperature before introduction to gas turbine.

Gasification of coal can be done through oxygen/steam or air/steam to produce medium calorific value or low calorific value gas respectively. The various gasification processes possible are fixed bed, fluidised bed and entrained bed.

Simultaneously, environment friendly advanced technologies aiming at higher efficiencies are also being pursued at the National level as part of the R&D programme.

After an in-depth study of various gasification systems in late '70s, BHEL opted in-house development for a moving bed gasifier as a first phase of IGCC technology development and demonstration. A Combined Cycle Demonstration Plant (CCDP) of 6.2 MWe capacity comprising 4 MWe gas turbine and 2.2 MWe steam turbine was commissioned in 1987. The coal gasification plant (150 t/day capacity) consists of a moving bed gasifier coupled to wet gas clean up system. The coal is gasified with steam and air at a pressure of 10 ata. The designed coal feed rate is 6 t/hr and generates 12000 Nm^3/hr of coal gas. The calorific value of the fuel gas is about 1250 kcal/Nm^3. The carbon conversion achieved is in the order of 87% and gasification efficiency is in the range of 75-80%.

Indian Institute of Chemical Technology, Hyderabad, has also tested a number of Indian coals in their pressuried moving bed gasifier of 24 t/day coal capacity. Two of the typical coals were also tested on 150 t/day moving bed coal gasifier at BHEL. The results have confirmed the validity of the design methodology adopted for scaleu-up design.

For development of pressurised fluidised bed gasification for Indian coals, a Process Equipment Development Unit (PEDU) has also been installed and is being operated. The plant has a coal throughput capacity of 18 t/day with air and steam as gasifying media. Coal size of minus 6 mm. The gasifier is being operated at around 900°C and pressures upto 10 ata. The gas produced is water quenched and scrubbed to free it from particulates in the venturi scrubber and demister. It is then burnt in the flare stack. The plant has been undergoing test trials and logged around 1500 hours of operation so far.

Based on the extensive operating data obtained from 18 t/day gasifier unit, BHEL has upscaled and designed a 150 t/day to be installed at coal based Combined Cycle Demonstration Plant at Tiruchi (in South India) to provide coal gas to the existing gas turbine and steam turbine unit. The plant is being partly funded by USAID under PACER (Programme for Acceleration of Commercial Energy Research) programme and is planned to be commissioned by September, 1994.

The Government of India (Department of Power) is actively considering to instal a 30 MW Coal based IGCC plant in the country.

In the field of low pressure moving bed coal gasification with air/steam, considerable expertise exists in the country, Low Calorific Gas (LCV) coal gas produced being used in industrial furnaces. Gasifiers upto 3 metre diameter are quite common. Recently, a 3.8 metre diameter gasifier has also been tested at Ennore Thermal Power Station. The LCV gas produced has been used for low load coal flame stabilisation in pulverised coal fired 60 MW boiler. The major problem faced in this type of gasifiers is the difficulty in getting sized coal with the particle diameters in the range of 25 to 50 mm. The coal received has to be sieved necessarily to separate the fines and use them somewhere else.

A 5 MW (thermal) pilot plant for R&D work on Magneto Hydro Dynamics (MHD) has been set up at BHEL in cooperation with Institute of High Temperature, Moscow, under Indo - USSR S & T Programme. The plant has high temperature air pre-heater, an MHD channel with a 2-Tesla iron core magnet, controls and DAS, and seed recovery system. No bottoming cycle exists for this plant. Fuel used presently is LPG though the earlier experiments were done with Blue Water Gas. So far, 15 major trial runs of the pilot plant have been conducted; 10 out of these were with power generation. Feasibility studies conducted for the next phase of R&D indicate that it may be possible to retrofit 20 to 25 MWe MHD System in an existing 60/100 MW power plant if funds are made available.

BHEL is also working for development of slagging coal combustors for low grade Indian coals. A test rig with 3 million Kcal/h combustor has been installed and few coals have been tried. Modifications on this facility are being carried out with USAID assistance.

Corporate R&D Division of BHEL is working on development of phosphoric acid fuel cells (PAFC). A number of modules upto 1 kW rating have been developed and demonstrated. Work for a 10 kW module has been taken up. The ultimate aim is to go for molten carbonate technology.

In talking about all the above technological options, one creates the feeling that the capability exists in an organisation like BHEL and a country like India to do research and development satisfactorily and implement them successfully. It is necessary to examine how this capability was built over the years and what were the strategies adopted. Taking the Power Sector scenario in 1948 when India got its independence, the installed capacity was 1400 MW. For accelerating the industrial growth in the country, it was evident that availability of electricity has to be increased multifold very quickly. Linked with the country's then policy of focussingon capital intensive mother industry and self reliance strategy, the industry pursued an overall strategy of technological self-reliance, emphasis on technology absorption, assimilation and adoption; development of ancillary industries and setting up of research facilities. Heavy Electrical Industry had also an urgent mandate in these lines and BHEL went about acquiring the

best of the the technologies in those days from world leaders in the power field. The objective of technology management in BHEL is to keep its products and systems continuously upgraded to contemporary international levels through a judicious blend of in-house development and selective collaborations. Collaboration agreements on technology transfers in areas like Boilers, Electrostatic Precipitators, Fans, etc. were entered into with renowned foreign manufacturers and the Company went about assimilating the technologies within a short time. The role of companies like the then Combustion Engineering of USA and Siemens, Germany, in helping BHEL to quickly absorb the technologies and gain capability to design must be acknowledged. At one time BHEL had 40 on-going collaborations for various products enabling it to get established as a leading power equipment producer. This method of acquiring technology through licensing agreements which was the order of the day in the 60's to 80's was one way of becoming self-reliant.

However, acquiring more technologies in this method was not found sufficient when they had to be applied in the Indian conditions. The case of the boiler technology is a striking example. While the sound basics on design of boiler were learnt from the collaborators, the effect of wide variation in the coal characteristics in the operation and performance of boilers in conjunction with local operating conditions, operation and maintenance capability to handle sophistications, and other infrastructural facilities could be well understood only over a period after the equipment had gone into operation. In-house R&D test rigs helped to understand the problems of handling and burning high abrasive ash coal. [The steam generator designed for burning Indian coal handles nearly 125 kg of ash per million kcal of heat input to furnace which is near about seven times the quantum of ash handled by boilers designed for same capacity in Western countries.] Sizing of furnaces and low gas velocities to reduce erosion had to be tried out often before the optimum selection could be evolved. It was thus clear that a mere technology import alone will not help in such areas, strong inhouse R&D facilities are also simultaneously needed to effectively gain design capability.

In fact, this has become a continuous process in view of the ever deteriorating quality of the Indian coal. To enhance reliability and availability, continuous improvements on the boilers have to be carried out. Alternate methods of burning poor quality coal had also to be thougnt of.

With the advent of awareness of environmental issues like the green house effect, acid rain etc. the cry for clean coal technologies picked up. In a country which burns more than 180 million tons of coal every year for power generation, this subject became vital. With the design experience of burning inferior coal effectively, BHEL decided to look for new environmentally friendly technologies in utilising coal for power generation. Since this area was relatively new, established commercially successful technologies were very few in the world. Even there, experience on Indian type of coal

was lacking. It became clear that in-house R&D efforts had to be put in to develop advanced technologies. However, without the basic knowledge of such technologies, time taken to establish on our own would have been enormous. This is where the collaborative approach of technology transfer has helped BHEL in a big way. Enthusiastic active support of Government agencies like the Pittsburgh Energy Technology Centre of US Department of Energy, the Oakridge National Laboratory of USA, the Technical University of Nova Scotia, Canada, etc., with financial assistances from their Governments has enabled us to carry out experiments in almost all of the clean coal technologies currently talked about. Training facilities offered by them to our Engineers and Scientists in specialised areas have created a core of experienced R&D Engineers in the Company.

To quote a few of such joint projects in this area:

1. To collect data on free board combustion heat release and heat transfer coefficient for high ash Indian coal in a Fluidised Bed Boiler, research test facility was set up with the help of USAID (United States Agency for International Development) sponsored project supported by multiple US agencies involved in the power field. Experiments helped to establish optimum efficient designs in FBC boilers.

2. Funded by USAID and supported by PETC, ORNL and TVA, pollution control strategies for abatement of NOx/SOx emissions were developed and operating parameters could be defined.

3. A state-of-art 3 million BTU/hr Fuel Evaluation Test Facility is being set up in BHEL to develop a data base on Indian coals for slagging, fouling, erosion, heat transfer and other aspects so that they can be corelated to predict performances. The same agencies are associated with BHEL in this project. Hands-on experience of conducting such tests in a similar test rig available at PETC, USA, will enrich the knowledge of our R&D Engineers in this area.

4. A cooperative research project on Circulating Fluidised Bed Combustion between Technical University of Nova Scotia, Canada and BHEL with financial participation from International Development Research Centre, Canada, helped us to establish a test rig and gain hands-on experience in utilisation of Indian coals in a CFBC system and live evaluation of CFBC components.

5. As a part of Science & Technology Cooperation between India & USSR, research work in the field of Magneto Hydrodynamics (MHD) was initiated in BHEL Tiruchi with the cooperation of Institute of High Temperature, Moscow. A 5 MW(th) MHD Pilot plant has been set up at BHEL, Tiruchi. Number of trial runs have been conducted and large amount of data has been generated from the pilot plant. R&D part

of the MHD Programme has been funded by Ministry of Non-Conventional Energy Sources (Government of India) and executed by BHEL.

6. Under the Programme for Acceleration of Commercial Energy Research (PACER) for which funds have been provided by US Government agencies to the Indian Government, a 150 t/day Pressurised Fluidised Bed Gasification Development and demonstration plant is taking shape adjacent to the first IGCC (fixed bed gasifier) demonstration plant in operation. With the assistance of the System and Engineering Analysis Group of the Pittsburgh Energy Training Centre and with a review of the Gasifier Reactor by the ASPEN Simulator developed by MIT, the PFBG design will be examined.

During all these collaborative projects, besides gaining access to the latest clean coal technologies, BHEL has gathered valuable experience with our Engineers and Scientists getting numerous opportunities to interact with many foreign experts working in Universities, private research institutions, consultancy firms and Government funded technology centres. Widening of our knowledge base has been a major gain in this method of technology transfer which helps us to become self-reliant in the long run. This has been possible due to the excellent outright support we got from the various collaborative agencies.

CONCLUSION

Having benefited from both ways of obtaining technology, we have been able to strengthen our in-house R&D capabilities. In future also where advanced technologies show promise, we can choose any one of these options. To handle our coal under strict environmental regulations, we have to continue our research work and quickly establish the most efficient and economical clean coal technology for our country. With the technological inputs we have got, we hope to achieve this quickly and be in a position to offer this technology to other developing countries.

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Role of Multilateral Co-operation in Technology Development and Deployment - The IEA Experience

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Introduction

One of the key factors behind the growth in economies around the world has been the successful adoption of new or improved technologies in the marketplace. This driving force has long been recognised by OECD Member countries and has resulted in considerable effort being devoted to enhancing the effectiveness and efficiency of the technology development and deployment processes. This is particularly so in the energy area.

For nearly 20 years, the International Energy Agency (IEA) has been actively involved in energy research and development activities. Our experience tells us that no single country is likely to achieve the leading role in every aspect of energy-related technology. Consequently, we have seen considerable benefits emerging from multilateral collaboration on research and technology development -- costs and intellectual resources can be shared, more effective and efficient technologies can be developed, and development and deployment timescales can be significantly shortened. Above all, this collaborative process provides a mechanism for dissemination of information about the capability of technologies and options available to solve current and emerging problems. We believe this dialogue plays an important role in facilitating and speeding up technology deployment in the market place.

Before outlining our specific experiences with collaborative activities in the coal sector, I want to say a few words about the IEA and its technology policies.

The International Energy Agency

The International Energy Agency (IEA) was established in the aftermath of the first oil shock in 1974, to increase the energy security of the OECD region, through energy policy co-operation, development of energy supply alternatives, and augmented energy conversion and end-use efficiency. At present, IEA membership comprises 23 OECD countries and the Commission of the European Communities.

Over the last two decades, there have been dramatic changes in the world energy market and new challenges have emerged within the OECD region and elsewhere which have impacted on energy markets. IEA members have actively worked to address these challenges. The goal of energy security, which remains a primary one, has been complimented in recent years by increasing awareness of the significance, for energy policy and for energy security of two further factors: concern over the environmental impact of energy-related activities, and the growing globalisation of energy issues, as different countries' economies and energy markets become increasingly interdependent.

A fundamental element of the international energy programme of the IEA has been, and continues to be, collaboration in energy research and technology development. This collaboration has allowed Member countries to pool and coordinate their efforts, to exchange information, and to facilitate progress in development of new and improved energy technologies and their introduction to the market.

The initial objectives of the IEA technology collaboration paralleled and complemented the overall objectives of the IEA, namely to reduce dependence on imported oil through the development of alternative sources of energy supply while improving energy efficiency. In the 1970s and the early 1980s coal supply and use technologies were essential features of the programme.

During the second half of the 1980s and the early 1990s a number of factors led to changing energy technology priorities. Lower oil prices have changed the economics of some technologies, economic restructuring and political change have created new international interdependences, and growing environmental considerations have added new dimensions to technology priorities.

The history of the IEA's energy technology collaboration programme has followed these broader policy shifts. After a strong start to R&D collaboration in the 1970s, interest in many projects waned in the mid-1980s. Under the energy prices prevailing at the time, many of the developed and demonstrated technologies proved to be too expensive to catch the interest of buyers and manufacturers other than those with a very long-term outlook. The situation was exacerbated by the private sector's inability, or lack of willingness, to allocate manpower and financial resources to energy R&D. More recently we have seen a growth in demand for collaborative activities associated with the sharing and dissemination of information about available and new technologies, together with a demand for technologies capable of addressing broad-ranging environmental concerns.

Notwithstanding these shifts in policy focus, the IEA's experience of nearly 20 years of international co-operation points to three main factors which, we believe, should guide energy market development and help shape the nature of energy technology collaboration and eventual technology deployment:

- first, energy market forces must be harnessed, not stifled;
- second, in working towards their common goals, countries should be free to develop their own national strategies which build on their particular energy and industrial situations;

third, we need partnerships of many countries if we are to find and deploy technologies which are cost-effective.

If governments set the right framework conditions, we believe that private investors, operating in open, transparent markets, can deliver what is expected of them.

The IEA's International Technology Collaboration Programme

The IEA's energy research and technology development activities include reviews and surveys of national policies, specific studies on the status of technologies, conferences and workshops on priority technology issues and collaborative projects. These collaborative energy technology projects and programmes are established under special legal mechanisms, called Implementing Agreements. The Implementing Agreements set down the commitments of the Contracting Parties and establish a management structure for ongoing activities. The Contracting Parties "implement" the energy R&D and technology collaboration by undertaking one or more Tasks which are identified as an Annex or Annexes to the Implementing Agreement. The Agreements contain provisions concerning the handling and protection of information and intellectual property rights and they record arrangements for commercial exploitation and distribution of the benefits to participants.

Nearly 60 Implementing Agreements have been established and currently there are over 40 in operation, of which seven are directly related to coal technologies. Several other Implementing Agreements include activities relevant to the coal sector.

While most participants are government organisations or semi-public entities, the Implementing Agreements are open to any public or private organisations that are formally designated by their national governments. Additional mechanisms have recently been introduced to facilitate the involvement of private sector organisations. Associate participation is open to organisations from countries which are not Members of the IEA, subject to the approval of the IEA's Governing Board.

Over the last few years we have also sought to involve various non-IEA countries from the Asia-Pacific region and elsewhere in these collaborative activities on an "equal partner" basis. In each case we expect there to be mutual benefits from the collaboration. We are starting to see the results of these efforts with Korea joining a number of activities, and discussions in progress with China in other areas. Participants from Eastern Europe and Russia have already joined some activities and further possibilities are in prospect. Discussions with countries from other regions are also underway. In addition, there are on-going, less formal contacts with a wide range of experts in non-IEA countries through technical level contacts on specific issues and through conferences and workshops sponsored by particular Implementing Agreements. Some Agreements also have specific information dissemination activities aimed at making data and information available to non-participating countries.

The IEA does not have central funds to finance these projects and programmes -- all resources are supplied by the Contracting Parties which nominate one of their number to be the Operating Agent. The Operating Agent is responsible for coordinating the activity of the project or programme, for supplying the infrastructure as needed, and for ensuring that all

participants respect their obligations and receive the benefits due to them from the project. When projects are financed by a central fund, the Operating Agent's task includes collecting contributions and fund management. The initiative for establishing new Implementing Agreements is usually provided by the prospective Contracting Parties, which elect a lead country to coordinate preliminary contacts with the IEA secretariat. Proposals are first considered in the IEA Committee on Energy Research and Technology, a plenary committee consisting of delegates from all the IEA Member governments, in close consultation with its relevant expert Working Party. They are then submitted for adoption by the Governing Board, the IEA's main decision making body.

Once the Implementing Agreement has been drafted and adopted by the Governing Board, Contracting Parties are responsible for planning, managing and carrying out the project through an Executive Committee, or a Steering Group, appointed by them. Executive Committees meet periodically and representatives of the IEA Secretariat attend the meetings in an advisory capacity, providing the Contracting Parties with technical advice and legal support through all stages of the R&D and technology collaboration. Where advanced technology is involved and industry participates, the IEA assists with the development of complete and precise provisions on handling of information and intellectual property, such as identification and use of pre-existing information and R&D, licensing of pre-existing and arising proprietary information, and inventions and patents. The Contracting Parties that sign the Implementing Agreement have exclusive rights to the results.

In the IEA's experience Implementing Agreements have proved very flexible, able to deal with all phases of the energy technology cycle including basic R&D, demonstration and testing, information exchange and project co-ordination.

The protection of commercially sensitive R&D results and the issue of intellectual property continues to be a central issue in the success of the collaboration. The primary goal of the collaborative activity is that benefits should accrue first to the participants. However, there is a delicate balance between ensuring the protection of R&D results and inhibiting the necessary dissemination of useful information to a wider circle. In recent years increasing emphasis has been placed on improving the dissemination of useful information and hence deployment of technology within the OECD group of countries and to the wider global community. One of the difficulties we have been grappling with is how to expand the mandate and the facilities of participants in the collaborative programme for the commercial application of R&D results. Continuing efforts are being made to enhance the incentives to transfer the knowledge and experience gained to the market through closer government-industry partnerships or private sector participation in the evolution of the collaborative activity.

Participation in International Collaborative Activities

Many factors influence the way governments participate in international technology development collaboration. The goal may be simply to establish government competence in planning and regulation, or buyer and user competence within utilities. The country may only need access to limited external technology information. This is often easiest to acquire with

a combination of domestic R&D activities and international collaboration, exchanging ideas and results.

If national policy objectives include the establishment or development of industrial supplier competence in certain technology areas, one important means is a higher standard of national technology development activity in that area. In this case the agreement to participate in international technology collaboration must take the exchange of know-how and intellectual property into consideration, lest international competitiveness be endangered. In such cases there may be a desire to restrict collaboration to pre-competitive R&D.

In many countries the role of national R&D as a means of developing new technology is declining with the increasing development costs and internationalisation of technology. Very few countries or companies can develop new technology independently at the necessary speed. As a consequence we have seen a growing tendency for national R&D activities to aim more at technology application than initial technology development. Even the largest countries are turning out not to be technology developers in all areas, with the result that they are technology importers or adapters in some areas.

These different motives and ambitions have helped shape the nature of the IEA's energy technology collaboration over nearly 20 years. They have created both problems and opportunities in the collaboration. Our experience to date has highlighted a number of benefits arising from the IEA's energy technology collaboration programme which go well beyond the benefits of bilateral or regional co-operation. There has been improved efficiency in the development of technologies through collaboration among numerous players in the use of resources or knowledge which has led to cross-savings through avoidance of duplication of equipment, work or mistakes. Collaborative activities have resulted in an improved quality and reliability of results which has led to cross-savings through more reliable validation of technology and consequently reduction of risks. Technology development has also been accelerated leading to potential cross-savings by way of reduction of time needed for the technology to penetrate the market. Collaboration between various players from different countries, such as R&D research entities, equipment vendors, utilities and energy end-users, has helped demonstrate the competitiveness of technologies.

Different players in the energy market have also been able to gain benefits from the technology collaboration programme. Governments have been able to acquire information to improve the knowledge basis for policy analysis and decisions concerning institutional changes in the energy market, technology development programmes, and strategies to remove barriers to market deployment of new technologies. Energy suppliers have been able to obtain better and more independent information on new and improved technologies thereby helping to improve decision making on investments, operation and maintenance of energy services. Energy consumers have been able to acquire better information for decision making on acquisition and utilisation of processes and equipment. Energy equipment and system vendors have been able to obtain better or cheaper information on the technical, environmental and economic design and performance of new energy equipment and processes, thereby reducing risks in development and marketing of new products.

Coal Technology Collaboration - Progress and Achievements

Since 1975, nine separate technology collaboration programmes have been set up in the coal technology area. Some of these have now terminated and others have changed their priorities and focus on several occasions. The programme has focussed on coal mining, preparation and transport, technology development as well as combustion of various types of coal in more efficient and environmentally acceptable ways, substitution of coal liquid mixtures for oil in existing installations, coal gasification and the production of synthetic fuels from coal and similar materials.

Further information on the achievements and objectives of these activities can be found in the IEA publication *Collaboration in Energy Technology 1987-1990* and in the annual reports issued by each of the Implementing Agreements, and the Strategic workplans prepared by the Executive Committees of the various Implementing Agreements.

A cost-sharing Agreement on **Pyrolysis of Coal** began in 1978 and was completed in 1992. Originally oriented towards the development of a process for synthetic fuels, it changed direction to more basic work, including the production of chemicals. Coal, and later peat, have been tested in a small process development unit. Assessment studies have shown that currently the pyrolysis processes are not competitive in the field of fuel production, but they might be more competitive for chemical production.

A task-sharing Agreement on **Fluidised Bed Combustion** was initiated in 1980. Exchange of information has been undertaken on technical issues and the operating experiences from a number of AFBC installations, including their emission characteristics. The collaboration has been broadened to include work on pressurised fluidised bed combustion.

The cost-sharing Implementing Agreement on a **Low Nitrogen Oxides Coal Burner** was initiated in 1980. It has demonstrated and evaluated techniques for the control of NO_x and SO_x emissions from pulverised coal in five wall-fired commercial utility burners.

A task-sharing Agreement on **Coal/Liquid Mixtures** was initiated in 1981. Under this agreement an exchange of technical and cost information and research programmes has taken place. Long-term (up to a year) storage of highly loaded coal-water slurry has been successfully demonstrated. Numerous demonstration tests of coal-water slurry have been completed in industrial and utility boilers and a cement kiln.

The Implementing Agreement on **Coal Combustion Sciences** started in 1985. It undertakes basic and applied research related to environmentally favourable coal combustion on a semi-industrial scale. The initial stages of combustion have been studied and mathematical models have been validated against experiments. Design studies of low-NO_x staged burners have been performed. A task-sharing Implementing Agreement on **Fossil Fuel Multiphase Flow Sciences**, signed in 1987, has dealt with basic research and measurement techniques on friction and erosion phenomena in pipeline transports of coal powder and coal slurries. It was recently extended to research on flows of oil-gas mixtures.

A cost-sharing Implementing Agreement on **Testing of High Temperature, High Pressure Filters** for coal combustion and gasification was signed in late 1990. It has involved the

testing of two different types of filter with high dust collection efficiency under different operating conditions applicable to PFBC and integrated gasification combined cycle plants .

The cost-sharing Implementing Agreement on **IEA Coal Research** was established in 1975. It functions as a common study and information services centre. It publishes reports on a wide variety of coal technology issues as well as providing abstracting and database facilities. The more recent activities have an increasing emphasis on coal utilisation and environmental issues.

A cost-sharing Implementing Agreement on **Technologies Relating to Greenhouse Gases Derived from Fossil Fuel Use** was signed in November 1991. The collaboration is undertaking assessments of technologies for control, capture, utilisation and disposal of CO_2 and other greenhouse gases derived from fossil fuel use. The assessments of the technology options are evaluating, on a full fuel cycle basis, technical and economic feasibility, technical performance, and the environmental benefits and impact of available or prospective technologies.

The newest feature of the IEA's technology programme is the **IEA/OECD greenhouse gas technology information exchange -- GREENTIE**. It is expected that GREENTIE will soon be able to facilitate access to technical data and information on technologies to reduce and control greenhouse gases, including in the coal area. It will provide an open access information network containing sources for information on such technologies. The system should help to give all countries of the world access to the institutions, agencies and centres where information is available on technologies already applied and developed. It aims to contribute to the transfer of technology and technology co-operation.

The participation by IEA Member countries in these Implementing Agreements has varied over time and with the nature of the collaborative activities. The information sharing and dissemination activities have generally attracted the most involvement, with representatives from up to 15 Member countries participating from all the OECD regions. The more specific technology development activities (such as the filters testing, multiphase flow, and coal/liquid mixtures activities) have generally involved fewer participants, reflecting the more specialised interest of selected countries in particular technology development fields. Attention is continuously being given to options to encourage additional participation in all these activities. As mentioned earlier, discussions are also underway with a number of non-IEA countries about participation in these coal-related activities, and I would expect several countries -- including some from the Asia Pacific region -- to become actively involved in a selection of these projects over the next year or so.

Concluding Remarks

The international commitments made by IEA Member countries and non-Member countries in the IEA Implementing Agreements have constituted a cohesive force in many energy technology areas. The participants in these activities have focussed work on critical cost-related issues, systems aspects, and more recently environment-related objectives. The IEA collaboration programme has provided, and can continue to provide, an important mechanism for developing and maintaining competence in energy technologies, particularly in the coal area.

IEA Second International Conference on the Clean and Efficient Use of Coal and Lignite: Its Role in Energy, Environment and Life

Workshop B(1)-Cooperation and Partnership

"Comprehensive Promotion of Coal Use Technology and International Cooperation for Transfer of Appropriate Technology"

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3rd December , 1993

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1. Abstract:

The Center for Coal Utilization, Japan(CCUJ) was established in June, 1989, by more than 100 companies, including coal suppliers process manufacturers, trading companies and coal users.

Aiming at securing a stable supply of energy sources for Japan and contributing to the sustainable development of its industries and economy with the efficient and comprehensive use of coal, CCUJ is engaged in the following activities:

- Research and study on coal use
- Development of clean coal technology which preserves the environment
- Promotion of international cooperation on coal technology
- Promotion of pilot businesses called "Model Enterprises," based on advance coal technology
- Public relations activities to encourage coal use

To meet the growing demand from the world and to promote the comprehensive use of coal, CCUJ is undertaking a Clean Coal Technology project with governmental assistance.

This project aims at finding solutions to environmental problems involving the use of coal and way to the transfer of fully developed clean coal technology to other countries.

This paper highlights some appropriate clean coal technology applicable to the Asia Pacific countries for their clean and efficient use of coal and lignite.

2. Outline of Coal Utilization Technologies

The scope of coal utilization technologies covers wide range subjects, from pretreatment of coal to the utilization of ash.

Coal is pretreated, handled and then fired or converted to for various applications. Coal utilization technologies are related to these processes and, futhermore, to treatment of flue gas and by-product (ash) utilization.

In addtion, absorption and fixing of CO_2 discharged by firing or conversion of coal are also included. The status of individual technologies is outlined as follows.

(1) Pretreatment Technology

In Japan, about 2 million and 1.5 million tonnes per year of briquette fuel and oval briquettes respectively were used for home use and steam locomotives in 1965. Now, production of briquettes has decreased to about 10,000 tonnes only. Recently, briquetting technology has revived as a clean fuel use of coal.

It is an advanced coal cleaning technology by which impurities (ash, sulfer, etc.) are removed more effectively than conventional coal pretreatment methods normally performed during the coal mining.

(2) Handling

A coal cartrigde system (CCS) and coal water mixture (CWM) are being studied as " model enterprises " in order to expand the uses of coal for rather smaller users.

Feasibility study on CWM is also being conducted for large electric power generating companies.

(3) Utilizations and Conversion Technology

Applications of coal cover a wide range, from energy to raw materials. Technologies of combustion, baking, melting, steel making, gasification, liquefaction and thermal decomposition are being developed now. NEDO is promoting the development of gasification, such as integrated coal gasification combined cycle (IGCC) and liquefaction. CCUJ is developing positively some technologies other than IGCC or liquefaction and so on.

(4) Flue Gas Treatment

This kind of technology, involve the three elementary technologies desulfurization, denitrification and dedusting, along with simultaneous desulfurization and denitrification.

Low cost desulfurization is now required, especially for applications in developing countries.

For this purpose, semi-dried desulfurization with desulfurization rate of about 80% has been developed, in which calcium carbonate is blown into the boiler furnace, together with humidification.

These technologies have substantially been completed and therefore are expected to be extended especially to developing countries.

(5)Utilization of Coal By-products

The amount of discharged coal ash is the largest among coal by-products.

Prospective applications of coal ash include a raw material of cement or concrete and aggregate for civil work for roads, harbors, airports, etc. In addition, R&D for utilization of flue gas desulfurization slugde, fluidized bed boiler ash, etc. has been carried out.

(6) Technology to Preserve the Global Environment

Development of carbon dioxide gas absorption and fixing technology has just started.

Suppressing the amount of N_2O created along with the analysis of occurrence mechanism have not been achieved, so further study is needed.

These development efforts have been managed by NEDO under the leadership of MITI (Ministry of International Trade and Industry) in cooperation with universities, national institutes and private enterprises.

3. Current Status of Comprehensive Promotion of Coal Utilization Technologies

CCUJ is an organization supported by 126 private companies in Japan related to coal utilization. Development of clean coal technology, which has been mainly carried out by CCUJ, is shown in the following.

(1) Coal combustion technology

① Combustion furnace technology

One of the principal objects of developing this is to obtain a high efficiency of power generation using coal. This technology is also intended to be applied to boilers used by general industries.

Especially, the fluidized bed combustion system has been attracting wide attention, in which desulfurization is conducted in the furnace. Some new types such as circulating and internal circulating types, beginning with the bubbling type, have been developed with improved desulfurization rates and lower NO_x emmisions.

Aiming at further improvement of power efficiency, the pressurized combined cycle power generation system is now being tested.

CCUJ has been developing:

- Atmospheric fluidized bed combustion (AFBC)
- Internal circurating fluidized bed combustion (ICFBC)
- Pressurized fluidized bed combustion (PFBC)

② Industrial furnace technology and cement manufacturing

Regarding industrial furnace technology (cement production), a 20 t/d pilot plant using the fluidized bed cement baking furnace is tested. Futhermore, demonstration plant (200 t/d) was launched in this year by CCUJ.

Thus, the basic heat unit of a cement manufacturing system will be reduced by more than 10% by applying this system.

(2) Study of Coal Slurry and Coal Handling Technology

It is sometimes difficult for a small or medium user to convert to coal because of difficulty of coal handling, etc. As a solution, new technologies for coal handling have been developed, such as coal water mixture (CWM) in slurry and coal cartridge system (CCS) to transport fine coal powder by cartridges. Some of these technologies is practically introduced as follows;

- Test of CWM demonstration plant
- Test of distribution and transfer system
- Test of CCS technology

THE STATUS OF FBC TECHNOLOGY DEVELOPMENT

(FBC Technology) Purpose of Development	Scale of Plant	Schudule of Development	Developing Organizations	Location of Plant
(AFBC Boiler) Reliable Technology of ・In-furnace dessulfurization ・Controll of denitrification ・Combustion efficiency	① Pilot Plant Evaporating Rate:20t/h	Testing already finished in 1983	CCUJ, EPDC, KHI Babcock-Hitachi	WAKAMATSU
	② Demonstration Plant Evaporating Rate:160t/h (50MW)	Testing carried-out during 1987-1991	CCUJ EPDC (Electric Power Development Company)	WAKAMATSU Coal Utilization technology Center
	③ Commercial Plant Power Generating Rate: 350MW	Plant under contruction and to be commisioned in 1995	EPDC	TAKEHARA Power Station of EPDC
(ICFBC Boiler) Technology of Small-size coal firing boiler with high efficiency and low pollution	Demonstration Plant Evaporating rate:10t/h	Plant to be tested to make less NO_x, SO_x flue gas and to study of pressurized cold model	CCUJ. Ebara Coporation Idemitu Kosan Co	Boiler Research Center of Ebara Coal Research Center of Idemitu
(PFBC Boiler) Combined cycle power generating technology which decreases CO_2 generation and achieves compactness by pressurising	Demonstration Plant Power Generating Rate: 70MW	Plant now being under designed and will be tested during 1994-1996	CCUJ EPDC	WAKAMATSU
(Industrial Furnace) Cement sintering technology with high thermal efficiency and low NO_x emmision	① Pilot Plant Cement production Capacity :20t/d	Plant constructed in 1989 and now being tested	CCUJ KHI Sumitomo Cement Co	TOTIGI Works of Sumitomo
	② Demonstration Plant 200t/d	Plant now being designed and will be tested during 1994-1995	CCUJ Japan Cement Association	AKAHO Works of Sumitomo

Coal-Water Mixture (CWM)

R & D of CWM technology for higher economic performance and easier equipment maintenance and handling was launched in 1983. After finishing basic researches and pilot plant tests, various demonstration tests have been conducted and various data has been accumulated.

In fact, CWM technologies for production, storage, transportation and combustion are satisfactory for practical applications.

However, users, especially general industries, are less interested in shifting to CWM at present because of the fall in oil prices, uncertainty about such new fuel, and so on.

Under these circumstances, a test for a CWM distribution relay system, West Japan Project, was launched in 1991 to present CWM to users as a more attractive commodity.

In this demonstration test, emphasis is placed on a distribution relay system of CWM, produced in China and transported to Japan. In this project, it is intended to supply CWM to users more economically and stably through a relay station in Japan. TAYCA Co., one of the major Japanese titanium oxide producers, is the first user, using 40,000 tons per year. Thereby, it is planned to increase annual handling amount of CWM from 40,000 tons to 250,000 tons within two or three years by increasing the number of of users year after year.

On the other hand, the Nakoso project has been conducted by Japan COM and Joban Joint Power Co. since 1987. Annual CWM consumption is 70,000 tons at present and the consumption will be expanded to 500,000 tons from this year.

Coal Cartridge System (CCS)

Coal is pulverized so that about 80 % of it passes through a 200 mesh screen. It is stored in a tank and transported to users by a truck with a sealed tank filled with nitrogen gas to prevent burning. CCS is advantageous particularly for smaller users because coal pulverizers are not required.

Extensive tests have been made by CCUJ jointly with many companies with the support of MITI. The first commercial use of CCS started at Nichiha Co's Nagoya plant in 1991 for a 100t/h boiler to generate 10.8 MW electric power. The storage tank at the the Nagoya plant is made of steel and has capacity of 1,180 m^3 and is filled with N_2 gas to maintain O_2 at a low level.

The tank has an equipment to fluidize the powdered coal by using N_2 gas.

At the Nagoya plant of Nichiha Corp., fly ash is utilized to produce construction material.

From plants which do not utilize fly ash, the ash can be sent back to the CCS production plant by the CCS truck. Nisshin Textile Co. will also use CCS.

(3) Study on the Technology for Effectively Utilizing Coal Ash

At present, a lot of coal ash can be utilized only as admixture of a cement and concrete or a raw material of cement. In order to develop other applications, such as aggregate for civil work for harbors, airports, etc., a joint development organization has been set up.

Regarding desulfurization sludge, it was utilized in roads, banking walls, etc. in Omuta on a trial basis and was favorably evaluated.

Gravel artificially made of ash from a fluidized bed boiler will be tested in Shikoku.

CCUJ has developed:

- Unused resource utilization technology
- General industrial coal ash utilization technology
- Study on hardened material
- Fluidized bed boiler combustion ash utilization technology

The amount of discharged coal ash and its applications, in 1991 (unit: 1,000 ton/year)

	Amount of Discharged Ash	Amount of Applications	Uses		Disposal
			For Cement・Concrete	For Others	
Power Generation	4,000	1,720 (43%)	1,200 (70%)	——	2,280
General Industries	1,600	1,120 (70%)	1,120 (100%)	——	480
Total	5,600	2,840 (51%)	2,320 (82%)	52 (18%)	2,760

The Contents of Uses in Coal Ash Applications (unit: 1,000 ton/year)

Contents of Uses	Amount of Applications	Detailed Contents of Uses
For Cement・Concrete	2,300	Cement Material, Cement Admixture, Concrete Admixture, Ready Mix Concrete, Special Concrete (Hardened Material)
For Civil Industry	360	Road Material, Landfilling, Foundation Amendment, Fly Ash Board, Fly Ash Milk, Backfilling of Mine Sites, Artificial Aggregate
For Agriculture・Marine	50	Fertilizer, Snow Melting Material, Soil amendment, Marine Structure
For Others	——	Desulfurizer for Flue Gas, Artificial Zeolite, Recovery of Valuable Substances
Disposal	2,760	Landfilling, Sea Reclamation

(4) Study on Coal Partial Combustion Technology

This technology uses small combustor in which coal is partially fired in a high-temperature, high-thermal load, reduction atomosphere and then fired in a boiler combustor. This technology features lower NO_x emmision and ash removable as fused slag. Testing of a 2t/h pilot plant has been completed. A demonstration plant is planned at present.

(5) Study on the Direct Iron Ore Smelting Reduction Technology

Pig iron is smelted directly from non-caking coal and iron ore using a fusion reduction furnace, with using a blast furnace. This technology is modified from a converter. A pilot plant of 500 t/d is now under construction. This technology has the possibility to realize reduction of basic energy unit, higher flexibility of production, etc.

(6) Environmentally Safe Coal Combustion Technology

- Topping cycle coal combustion

The working temperature of the gas turbine is about 850°C in a pressurized fluidized bed combined cycle. In order to make this temperature higher and the cycle efficiency higher, a simplified gasifier is provided to partly gasify the coal, and this fuel gas and the combustion gas of the fluidized bed combustor are mixed in the topping combustor. Thus, the inlet temperature to the gas turbine increases to about 1200-1300°C, and the cycle efficiency is improved to 43-45%.

CCUJ has begun to study this technology.

- Oxygen injected coal combustion

At a coal fired boiler, a part of the exhaust gas is recirculated. Oxygen is injected into this recirculated gas and this mixed gas is burned. In this system carbon dioxide in the exhaust gas becomes concentrated and can be recovered more easily. CCUJ has beggun to study this technology.

- CCUJ has also beggun now to study coal flash pyrolysis and advanced coal cleaning technology.

4. International Cooperation for Transfer of Appropriate Technology

CCUJ is positively exchanging information with governmental organizations both in developing countries and advanced countries. In addition, CCUJ is also promoting international cooperation, together with NEDO or other domestic organizations.

(1) Cooperation with Advanced Countries

Information is exchanged according to technical cooperation agreements on IEA among advanced countries.

(2) Cooperation with Developing Countries

It is most significant to transfer appropriate technology to developing countries to meet the economical and technical situation of the candidate project sites.

High cost of technology is not necessarily appropriate if it can not be actually utilized by the recipiant.

Therefore some modification of Japanese technology may be required to fit each recipient country' situation and joint development may be an ideal case.

CCUJ is carrying out "Research cooperation for development of simplified desulfurization for coal-fired boiler" with Indonesia.

Furthermore, technologies for environmentally sound coal utilization are planned to be transferred to the Asia Pacific countries aiming at improvement of efficiency in coal utilization and decreasing of air pollution in immediate future. Demonstration tests of the following technologies are planned for their transfer.

- Simplified desulfurization for coal-fired boiler
- Fluidized bed boiler
- Manufacturing of briquette fuel

(1) Simplified desulfurization for coal-fired boiler

In Japan, all desulfurization equipment used at present employs either wet limestone gypsum processor, wet magnesium hydroxide process. The capital cost of such equipment is too expensive to spread this desulfurization equipment to smaller coal boilers, and additional equiping of FGD is far and away the allowable limit of such users.

Under such circumstances, Japanese manufacturers have been developing a simplified FGD system.

In addition, with the increasing tendency towards worldwide environmental protection, the government is strengthening the technical cooperation with developing countries.

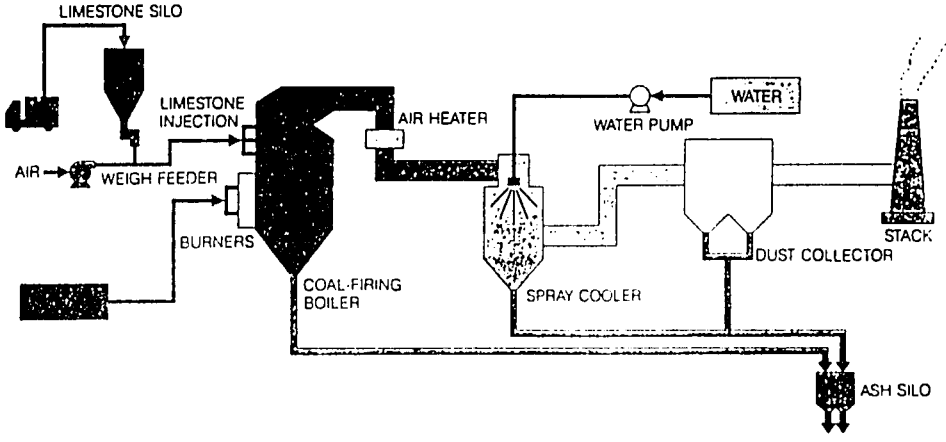
As one example, furnace limestone injection / water spray system is shown in the sheet of "SO_2 Removal Process Flow and Features".

As one of Japan's ODA projects, CCUJ is now conducting a cooperation test with Indonesia for a boiler installed in Ombilin mine power station. This desulfurization plant is now under test operation. Flue gas is separated from the IDF (induced draft fan) of the flue gas duct and stack, and then goes through a spray cooler. Thus, refined gas is returned to the gas duct and exhausted from stack.

Process Outline

This semi dry type SO_2 removal system for coal firing boiler consists of two-stage desulfurization technology; one is limestone injection into the furnace and the other is water spraying into the flue gas.

■ Process Flow



● Primary Desulfurization

$$CaCO_3 \xrightarrow{\text{Over } 900^\circ C} CaO + CO_2 \uparrow$$

$$SO_2 + CaO + 1/2\ O_2 \xrightarrow{\text{Under } 1{,}200^\circ C} CaSO_4$$

Limestone ($CaCO_3$) injected into a coal firing boiler thermally decomposes into calcium oxide (CaO) and carbon dioxide gas (CO_2). Then, sulfur dioxide (SO_2), which obtained from the burning sulfer (S) contents of coal, reacts with calcium oxide (CaO), finally forms calcium sulfate ($CaSO_4$) after being oxidized.

● Secondary Desulfurization

$$SO_2 + CaO + 1/2\ H_2O \rightarrow CaSO_3 \cdot 1/2\ H_2O$$

Further desulfurization is performed by positive utilization of calcium oxide (CaO) in the flue gas. Injected water accelerates reaction of sulfur oxide (SO_2), and produces calcium sulfite ($CaSO_3$).

Features

- Semi dry and non-effluent waste water process
- High SO_2 removal efficiency
- Simple and economical process (low installation and operation costs)
- Compact—not required much space
- Easy operation and maintenance with no slurry handling

Data of Pilot Plant

- Boiler type : Stoker Type Boiler (32T/H)
- Gas volume : 50,000m³ N/H
- SO_2 : ~500ppm
- Plant manufacturer : Kawasaki Heavy Industries, Ltd

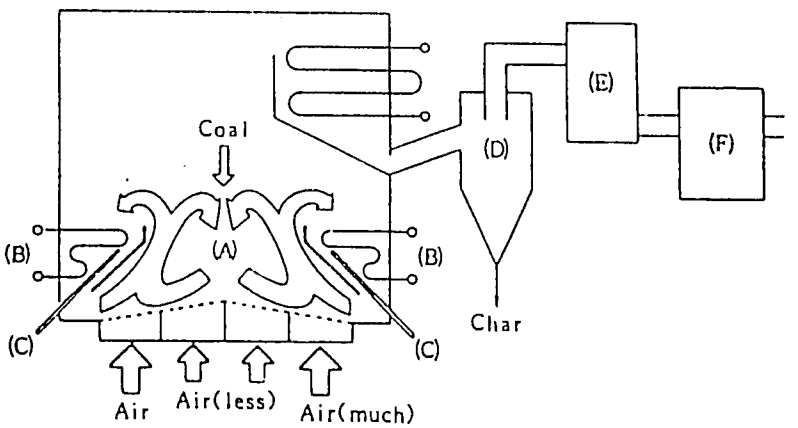
(2) Internally Circulating Fluidized Bed Boiler (ICFBC)

Ebara Corp. developed an ICFBC which is being applied for municipal solid waste incineration. CCUJ, jointly with Ebara Corp. and Idemitsu Kosan, has started tests on coal firing with a subsidy of MITI. The concept of ICFBC is shown below. Crushed coal and silica sand are fluidized in the main combustion zone with a gas velocity of 1-3 m/sec., similar to that of a conventional bubbling bed.

The boiler is designed so that the combustion gas circulates through the heat recovery zone at both sides.

No erosion of the heat transfer tubes occurs because the gas velocity is small in the heat recovery zone. Unburned char in the gas is caught by a cyclone and is returned to the combustion zone.

The boiler operation load can be changed over a wide range without difficulty. The system may be suitable for relatively small boilers.



(A) Main combustion zone (B) Heat recovery zone
(C) Air nozzle (D) Cyclone
(E) Economizer (F) Bag house

Concept of ICFB for coal combustion

Tests with a 10t/h coal-fired boiler have been made since 1990 using 2-4mm limestone as the absorbent. By combustion of coals with about 0.5% sulfur and 1.7% nitrogen at 800-830°C, both SO_x and NO_x concentrations were kept at around 50 ppm, while the combustion efficiency was kept at 99%.

The boiler load can be changed easily.

The advantage of ICFBC is that it can burn inferior quality of coal, sludge, coal refuse, lignite and even waste materials.

(3) Manufacturing of briquette fuel

Briquette fuel is a mixed form fuel of coal, and saw dust and so on with a little amount of binder.

It is effective for decreasing flue gas emission and widening utilization of coal.

There are methods of manufacturing these briquette fuels:

① Briquetting by carbonization.

② Briquetting with a high compressive force. This method is applied to Bio-coal.

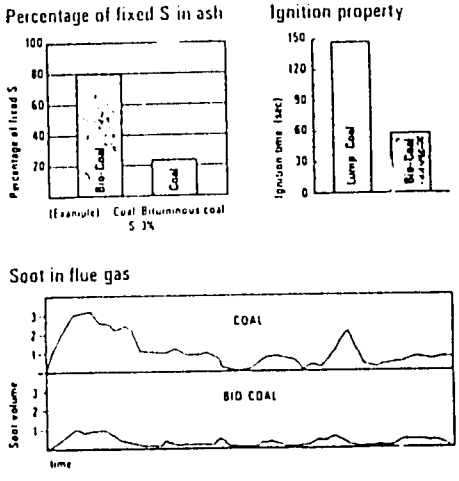
These methods are now being investigated by NEDO and CCUJ as a project for the international cooperation.

Bio-coal is shown in the following.

Bio-coal is a mixture of biomas material (vegetable matter), such as wood fibre or bagasse and a 10 % to 25% coal that is briquetted with a high compressive force.

Depending on the coal grade, a small amount of binder and desulfurizing agent may be required.

The Bio-coal may be suitable as a clean burning fuel for stoves, boilers or cooking, as well as industrial applications; such as greenhouse boilers, and boilers for offices or institutions.



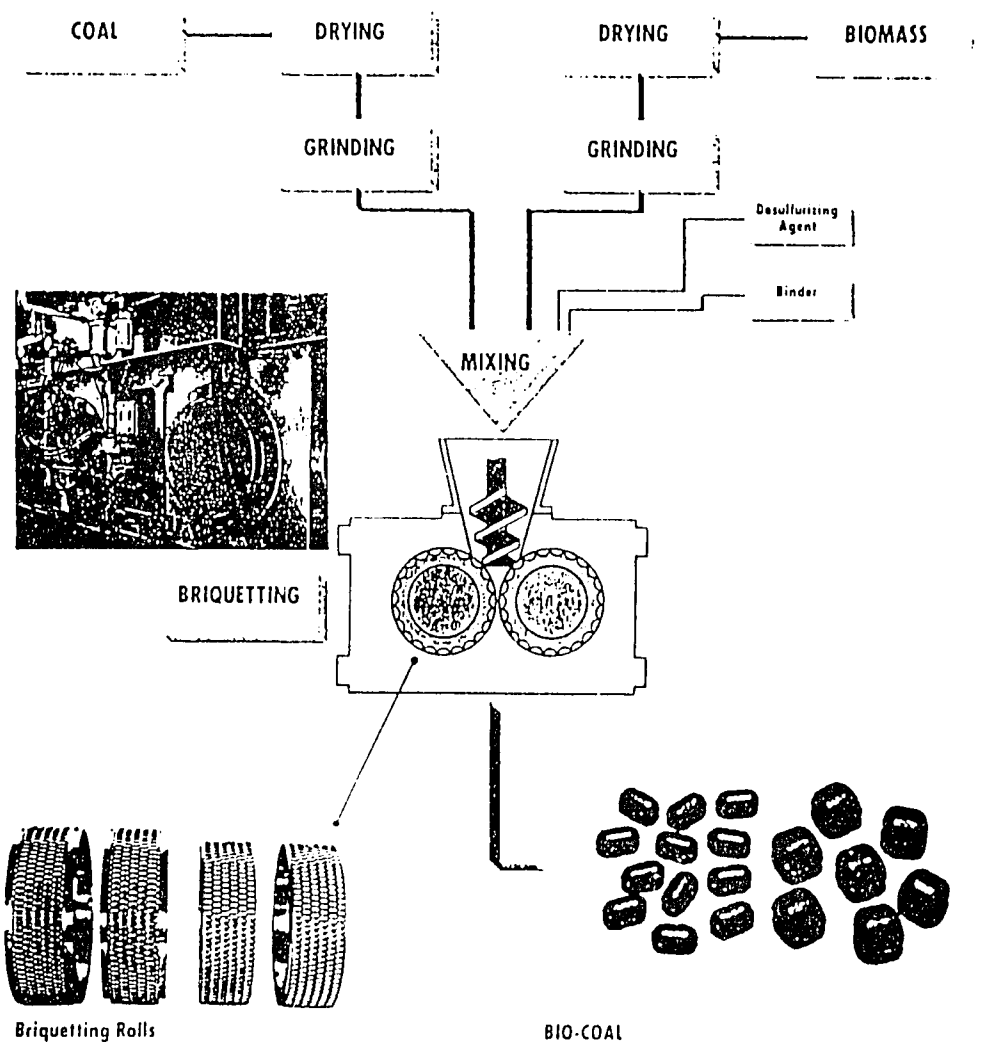
According to a leading manufacturer of briquetting machines the features of Bio-coal are as follows:

- Little smoke generation

The smoke generation rate of Bio-coal is reduced to 1/5 to 1/10 of the rate of unblended coal. Since each Bio-coal briquette has been formed by a high compressive force, during combustion, briquettes will not disintegrate to cause separation of coal particles and wood fibre.

- Less SO_x emission in flue gases

Since Bio-coal has been formed by high compressive force with a desulfurizing agent such as $Ca(OH)_2$ dispersed between coal particles, catalytic reaction between the sulfur content and desulfurizing agent is achieved effectively during combustion, thus leading to the fixation of 60% to 80 % of the sulfur in the coal.



WORKSHOP B2

TECHNOLOGY OPTIONS: DESULFURISATION AND INTEGRATED DEGASIFICATION COMBINED CYCLE

FLUE GAS DESULPHURISATION FOR COAL-FIRED POWER GENERATION IN THE ASIA-PACIFIC REGION: AN OVERVIEW OF BEST AVAILABLE OPTIONS

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ABSTRACT

Legislation to reduce SO_2 emissions is becoming more stringent and more widespread. In many countries, flue gas desulphurisation (FGD) is the chosen option to meet these standards. Following an early start in Japan, there are now FGD installations in mainland China and Taiwan. Plans for FGD units are also progressing in other countries in the Asia-Pacific region. There is a range of FGD systems, developed to suit the differing needs in the various countries. Wet FGD systems provide a mature technology which has attained the lead in the SO_2 control market. A simplification of the process has resulted in considerable cost reduction. Wet FGD systems producing gypsum have the advantage of a widely used, saleable product. The lower capital cost of many spray dry scrubbers and sorbent injection processes make them attractive for smaller plants burning low to medium sulphur coal. Sorbent injection processes are relatively easy to retrofit and the SO_2 removal efficiency has been improved in recent years. Fewer applications have been found for the more variable residues from both spray dry scrubbers and sorbent injection processes. Regenerable processes are complex, costly and result in greater energy consumption due to the need to regenerate the sorbent. Many combined SO_2/NO_x removal processes currently cost more than the equivalent conventional FGD/selective catalytic reduction systems. However, emerging processes have the potential to become competitive with the conventional systems. They produce a saleable by-product such as sulphur, sulphuric acid or fertiliser. The advantages and disadvantages of an FGD system are largely determined by site-specific conditions.

INTRODUCTION

Sulphur oxides (SO_x), specifically sulphur dioxide (SO_2) and sulphur trioxid (SO_3), are emitted from coal-fired combustion through oxidation of the sulphur contained in the fuel. Unless low-sulphur coals are used, SO_x emissions must be controlled to meet environmental regulations. Control technologies such as flue gas desulphurisation (FGD) systems reduce SO_x emissions either during or after combustion. FGD processes use an alkaline sorbent which reacts with the SO_2 in the flue gas in specific locations depending on the system.

National regulations limiting SO_2 emissions were first introduced in the early 1970s in Japan and the USA. During the 1980s and 1990s, emission standards have become progressively more stringent and more widespread, including most European countries, Korea and Taiwan. The trend is expected to continue to include other countries in the Asia-Pacific region. The national emission standards for new and existing coal-fired power plants introduced in selected countries are shown in Table 1. There is a considerable variation in the standards applied to new and existing plants in many countries such as Germany. Large new plants generally have to meet the strictest emission limits while existing plants are usually required to meet the same targets after a specified period of

time (Soud, 1991). More lenient standards may be applied to use of indigenous coal as in Korea. National emission standards are being introduced or formulated in mainland China and Thailand.

Regulations have led to a widespread growth in the use of FGD systems in the USA and Japan, followed by Europe, and now in other Asian countries. There is a variety of systems adapted to suit specific needs and considerable experience of their operation in the many installations in different countries. Information on commercial, demonstration and laboratory scale FGD systems and commercial FGD installations worldwide is collated on two computerised databases, at IEA Coal Research (1993 b,c). This paper provides an overview of the different systems in operation, highlighting recent technological improvements, and discusses the types of FGD system chosen in different countries.

FGD SYSTEMS

Commercial FGD processes may be classified simply as: wet scrubbers, spray dry scrubbers, sorbent injection processes, regenerable and combined SO_2/NO_x processes.

Wet scrubbers are the most commonly used FGD system, accounting for over 80% of the total FGD capacity worldwide. About 10% of installed systems are spray dry scrubbers, and the remainder are sorbent injection, regenerable, and combined SO_2/NO_x systems.

In the last decade, conventional FGD systems have undergone considerable development in terms of improved SO_2 removal efficiency and reliability, as well as reduced costs. Those processes which satisfy the following criteria are defined as advanced FGD systems:

- SO_2 removal greater than 95%
- reliability greater than 99%
- power consumption less than 1.5% of power station output
- use of integrated single and no spare absorber (for wet scrubbers)
- a saleable by-product

Demonstration projects for advanced FGD systems within the Clean Coal Technology Demonstration Program are summarised by the US Department of Energy (1993). The brief descriptions of commercial FGD systems which follow are based on detailed reviews from IEA Coal Research on FGD systems on coal-fired plants (Takeshita and Soud, 1993; Soud and Takeshita, 1993) and on FGD residues (Clarke, 1993).

Wet scrubbers mostly use alkaline slurry as sorbent, commonly limestone, slaked lime, or a mixture of slaked lime and alkaline fly ash. The sorbent is sprayed into the flue gases in a separate vessel after the boiler, generally in an open spray tower although a packed tower may sometimes be used. The sulphur oxides react with the sorbent forming a wet mixture of calcium sulphite and sulphate. An oxidation step, either as an integrated part of the scrubbing process (*in situ*) or in a separate vessel (*ex situ*), results in gypsum as a by-product. Processes producing gypsum are favoured due to superior dewatering characteristics and marketability of the by-product.

Simplification of the system configuration has largely been responsible for the progress made in the 1980s, from separate pre-scrubber, absorber and oxidation vessel to the integrated oxidation vessel and finally to the integrated single absorber. The first

development from *ex situ* oxidation to *in situ* oxidation prevented gypsum scaling, improved SO_2 removal efficiency and limestone utilisation, and reduced wastewater treatment. Design of the large capacity, integrated, single absorber reduced power consumption to <1% of net electricity production, compared with about 2% in earlier systems. It reduced capital costs by 30–50%, without loss of reliability in systems with no spare absorber (Ando, 1991). The integrated single absorber has been popular in Germany since the mid-1980s and is likely to be favoured worldwide because of these advantages.

Requirements for a minimum of 95% SO_2 removal efficiency can be achieved in a matured technology, through better understanding of FGD chemistry and proper absorber design. Additives such as dibasic acid (DBA), formates, and magnesium compounds may be used to increase SO_2 removal efficiency, especially for high sulphur coal. Additives can also reduce power consumption and allow the absorber to be smaller in volume, if they are part of the initial design.

Other wet scrubbers, which do not use lime or limestone as sorbent, include the dual alkali process (used only in the USA in the 1970s and 1980s), and those using sodium carbonate, seawater, magnesium or ammonia. These processes have generally been employed in relatively small power plants and industrial boilers. Seawater scrubbers take advantage of the fact that seawater is naturally alkaline since it contains bicarbonates. The absorbed SO_2 is in the form of sulphate ions which are a natural constituent of seawater. The effluent may therefore be discharged into the sea after neutralisation. Seawater scrubbers offer potential advantages as they are simple, require little or no bulk chemicals and have low capital and operating costs. The reagent in magnesium scrubbers is magnesium hydroxide which is produced by adding slaked lime to seawater in order to enhance alkalinity. The process has become popular since the early 1980s, replacing sodium scrubbers, because magnesium hydroxide now costs less than sodium hydroxide or carbonate as a reagent. The magnesium sulphate by-product can be discharged into the sea because it is a constituent of seawater. Hence, this process is suitable for plants located near the coast. The ammonia wet scrubber can achieve high efficiencies and produces ammonium sulphate which is a saleable fertiliser.

Spray dry scrubbers evolved as an alternative to wet scrubbers in the early- to mid-1970s reaching commercialisation on a coal-fired power station in the USA in 1980. An alkaline solution or slurry is sprayed in fine droplets into the reaction vessel, drying as it reacts with the SO_2 in the flue gases. As the slurry or solution is evaporated, salts are precipitated and the remaining solids are dried. The solids and fly ash, entrained in the flue gases, are carried out from the spray dry scrubber to a particulate collection device, either an electrostatic precipitator (ESP) or fabric filter (baghouse). In Europe, a fly ash pre-collector is common because there is a major emphasis on the use rather than disposal of fly ash. Slaked lime is used generally as sorbent although sodium carbonate is used in a few installations. Spray dry scrubbers are designed to achieve 70–95% SO_2 removal but the process has the potential to remove SO_2 up to 98%. The SO_2 removal efficiency and ESP performance can be improved by chloride which is provided from coal or additives such as $CaCl_2$ and sea water. The by-product is a dry mixture of calcium sulphite, sulphate, fly ash, and unreacted lime. Generally, part of it is recycled and mixed with fresh lime slurry to enhance sorbent utilisation as not all of the lime reacts with SO_2.

Spray dry scrubbers are used mostly for relatively small to medium capacity boilers burning low to medium sulphur coal. The high cost of lime relative to limestone precludes

its use on plants burning coal with a high sulphur content. Spray dry scrubbers have lower capital costs but higher sorbent use compared with wet scrubbers. For this reason and because of their smaller area requirements, they are preferable for retrofits and for peak load operation. Reliability of operation can be 97–100% in a well-maintained spray dry scrubber, owing to the simplicity of the process and the redundancy built into the system. The absorber is operated at 10 to 20°C above the approach-to-saturation temperature, hence the cleaned flue gas does not generally require reheating as in wet scrubbers. The construction material of the absorber is usually carbon steel which means that the absorber is less expensive than that used in the wet scrubber. The power consumption of a spray dry scrubber is low at 0.5–1% of net electricity production.

Disposal and utilisation of the spray dry scrubber product has caused problems in the past. The residues are composed of calcium sulphite, with some sulphate, unspent sorbent and flyash. Some residues may require stabilisation before disposal. Residues rich in sulphite have been unsuitable for uses normally associated with residues (road-base, foundations and other building materials) because expansion often occurs as they harden (Clarke, 1993).

Sorbent injection processes include furnace sorbent injection, duct sorbent injection, hybrid sorbent injection and fluid bed dry scrubbers. Furnace sorbent injection has a limited SO_2 removal efficiency of 50–60% using limestone/lime as sorbent and 70% using refined trona (a naturally occurring sodium bicarbonate). It is used commercially in relatively small, old existing plants burning low sulphur coal because of its low capital costs, ease of retrofitting, and low power consumption (<0.5%). Its reliability has been nearly 100%. The SO_2 removal is improved to 70–90% by recycling the reaction product. Emerging duct sorbent injection processes aim to achieve improved SO_2 removal from 50% to 70–95% without appreciable additional capital costs and operational difficulties, based on a better understanding of duct sorbent injection. Hybrid sorbent injection can improve the performance of furnace or duct sorbent injection to over 80%. This involves humidification in the duct or in a specially designed vessel to reactivate the unreacted calcium oxide. Fluid bed dry scrubbers can achieve >90% SO_2 removal efficiency. Wastewater treatment is not required for sorbent injection processes. The variability of sorbent injection residues limit their use.

Regenerable processes include systems in which the spent sorbent is regenerated thermally or chemically for reuse and a useful by-product such as elemental sulphur or sulphuric acid is obtained. The SO_2 removal is high, normally 90–98%. Some processes are commercially available but they have not been used widely due to their high costs, complexity, and large energy requirement to regenerate the spent sorbent and to convert concentrated SO_2 to a useful by-product. New processes, for example, using amines as sorbent are emerging to overcome these disadvantages. Also, the costs may be offset to some extent where there is a market for the by-product.

Combined SO_2/NO_x processes are now operating commercially on some coal-fired power stations burning medium to low sulphur coal. Many are in the development stage and have the *potential* to become equivalent or preferable to conventional FGD/SCR (selective catalytic reduction) systems in terms of costs and removal efficiency. This depends on site-specific requirements, such as limitation of process water, land space, waste disposal, and by-product. Combined SO_2/NO_x processes aim to provide both a 95–99% SO_2 removal efficiency and a NO_x removal efficiency of over 90%. Additionally, they produce a

saleable by-product such as elemental sulphur, sulphuric acid or fertiliser. However, many of these processes currently cost more than conventional FGD/SCR probably as a result of their greater complexity, their higher power consumption and the numerous components required to produce the by-product. In principle, combined SO_2/NO_x removal processes can be divided into: solid adsorption/regeneration (desorption); gas/solid catalytic operation; electron beam irradiation; alkali injection; wet combined SO_2/NO_x scrubbers.

The choice of FGD system is influenced by features such as those shown in Table 2. Spray dry scrubbers and sorbent injection processes are characterised generally by low capital costs but high operating costs because lime sorbent is expensive. Wet scrubbers generally have high capital but moderate operating costs due to using limestone as sorbent and the marketable by-product. Sorbent injection processes, spray dry scrubbers and some of the combined SO_2/NO_x removal processes are more compact, and hence are suitable as retrofits where space is limited. Sorbent injection processes are easier to retrofit than the other processes. Wet scrubbers require large wastewater treatment facilities. One way to reduce the amount of wastewater involves injecting part of it into the flue gas duct, upstream of the ESP, for evaporation.

Sorbent injection processes have the advantage of less power consumption. Electricity requirements in wet scrubbers can be reduced by up to about 1% of electricity production in advanced wet scrubbers through simplification of the system. Reheating of the cleaned flue gases is required in wet scrubbers and sometimes in spray dry scrubbers to improve dispersion from the stack, depending on the regulations in each country.

The actual costs of retrofitting a FGD system depend on individual plant-specific conditions such as plant size, coal sulphur content and retrofit factors. Retrofit factors are especially important and include space and access limitations, major modifications to existing equipment (ductwork and so on), age and condition of the unit, and any additional engineering due to the difficulty of the retrofit. According to the NAPAP study (Emmel and Jones, 1987) surveying 200 lime/limestone and lime spray drying FGD plants in the USA, most cases have limitations with retrofit factors ranging from a low of 1.19 to as high as 3.0 compared with the cost of a new plant. A medium retrofit difficulty factor is about 1.3. This means the capital costs of retrofitting a FGD system are higher by 30% compared with the case of installing a FGD system during the first stage of power plant construction.

FGD INSTALLATIONS

The first FGD installations were fitted in the USA and Japan in the early 1970s. Introduction of stringent environmental legislation in several countries, especially in W Europe, led to a rapid increase in FGD installations during the 1980s. In Japan and the USA, the number of FGD installations on new plants is about equal to the number retrofitted on existing plants. By contrast in W Europe, where many utilities were forced to reduce SO_2 emissions rapidly, FGD has been retrofitted on nearly 80% of the installations there.

Existing installations amount to a total capacity of nearly 170 GWe (to end 1992) on over 640 coal fired-units in 17 countries. The largest number of installations on coal-fired units are in the USA (308), Germany (208) and Japan (51). Other countries in Asia, mainland China, India and Taiwan also have FGD installations (*see* Table 3).

Wet scrubbers comprise over 80% of the total capacity of existing FGD installations (*see* Table 3). Just over half of these produce gypsum, the majority being located in Europe and Japan. The policy in many countries encourages use of wet scrubbers which generate the saleable by-product gypsum. Wet scrubbers producing gypsum have also been chosen for the first installations in mainland China and Taiwan. Other types of wet scrubber, mostly located in the USA, generate a sludge requiring disposal (mainly in landfills).

Other FGD systems are used mostly in Austria, Germany, Japan, Sweden and the USA (*see* Table 3). Spray dry scrubbers are favoured for smaller sized plants burning lower sulphur coals although there are some spray dry scrubbers fitted on larger plants burning higher sulphur coal. Most sorbent injection processes are retrofitted to smaller boilers and are favoured for use in older plants burning lower sulphur coals and where space is limited. Regenerable systems, used for the removal of SO_2 only, are installed on 17 units (4.7 GWe) in Germany and the USA. Combined SO_2/NO_x removal systems are installed on 18 units (3.0 GWe) in Denmark, Germany, Italy and the USA.

Planned installations amount to a future increase of over 60% of the total FGD capacity as it was in 1992. FGD systems are under construction or planned for the future in 20 countries on 240 coal-fired units and on a total capacity of over 100 GWe. The wet scrubber producing gypsum will have a 60% share of the new market, including installations in Hong Kong and Taiwan. In addition, 600 MWe of a lignite-fired power plant in Thailand is in the process of being fitted with a wet limestone gypsum process to start operation in 1995. There are also plans to fit further units with FGD (Ukawa, 1993). Cho (1991) reports that the wet limestone gypsum process is favoured in Korea and that at least 28 coal-fired power plants there are to be fitted with FGD by the year 2006. Other wet scrubbers remain a popular choice of FGD technology but mainly in the USA (IEA Coal Research, 1993c).

Spray dry scrubbers, currently used in 11% of existing FGD capacity, are the choice in only 5% of the new installations, including one in Taiwan. A spray dry scrubber has also been chosen for a power plant in mainland China (Shandong), where high sulphur coal is used. Demonstration tests are to start there in 1995 (Ukawa, 1993). The outlook for sorbent injection processes depends mainly on the results which are awaited from the various demonstration programmes but there are plans for 10 new installations in W and E Europe, Russia and in the USA. Two installations of regenerable systems are planned in Poland and the USA. Finally, there are also firm plans to fit FGD installations on a total capacity of over 16 GWe of coal-fired units in several countries where the system types have not yet been specified or selected (IEA Coal Research, 1993c).

In the Asia-Pacific region, there will be an expansion of the use of the wet scrubber producing gypsum and some use of spray dry scrubber systems. However, other FGD systems may be chosen for specific needs. For example, several demonstration plants using different processes are to be assessed in China as a basis for further applications there (Ju-Gen, 1993).

CONCLUSIONS

The trend to more stringent regulations for SO_2 emissions favours the installation of FGD technology on coal-fired power plants. FGD is a mature and reliable technology. The number of coal-fired power plants fitted with advanced FGD technology is expected to continue growing while coal-fired power generation increases to satisfy electricity demand

in the Asia-Pacific region. The market share for the advanced wet scrubber is expected to increase further because of its improved reliability and efficiency at reduced cost. The capital and operating costs of the wet limestone scrubber have been reduced by 20–30% this decade mainly through simplification of the system configuration although the costs of labour and construction materials have increased. Furnace sorbent injection followed by humidification is attractive because of its low capital costs, reasonable SO_2 removal efficiency, and high reliability. Here the main disadvantage is the by-product which usually requires special handling and disposal. By contrast, an FGD plant with a marketable by-product is in a sense a factory producing useful industrial goods such as gypsum or fertiliser. Advanced wet scrubbers designed to produce these products are probably suitable for large power stations burning high sulphur coal in these countries.

The cost of FGD systems is a crucial part of the decision on which system to choose. The capital costs of a wet limestone scrubber installation may amount to about 10% of the total capital costs for a coal-fired power plant assuming that the average capital costs of an FGD system are $150–200/kWe and those of a coal-fired power plant with FGD system $1500–2000/kWe. The effect of installing a wet limestone scrubber on the price of electricity from coal-fired power plants is likely to be less than 10%. Where FGD is retrofitted to an existing power plant, the capital costs of the system are 30% greater, on average, than on a new plant.

The advantages, disadvantages and limitations of an FGD system are determined largely by conditions such as plant size, coal sulphur content, SO_2 emission limit, location, age, annual operating hours, by-product, retrofit difficulty and so on – all of which are unique to each site. An important role of technology transfer to the Asia-Pacific region must be to compare planned installations to existing ones having similar conditions, particularly in Japan, the USA and W Europe, where there is a wide experience of the various systems on both new plants and as retrofits.

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Table 1 National SO_2 emission standards for coal-fired power plants (>50 MWt) (IEA Coal Research, 1993a; Cho, 1991)

	Plant size, MWt	Emission standards, mg/m³*	Notes
Existing plants			
Germany	50-300	2500	must meet new plants standards by 1 April 1993
	>300	400 and 85% S removal	lifetime >30000 h
	>300	2500	lifetime <30000 h
	>300	as licence conditions specify	lifetime <10000 h
USA	>75	1480	by the year 2000 (phase II)
	-	reduction by 10 Mt/y from 1980 levels	by the year 2000, after that a nationwide SO_2 emissions cap of 8.9 Mt/y will be in force
New plants			
Germany	50-100	2000	
	100-300	2000 and 60% S removal	
	>300	400 and 85% S removal	
USA	>73	1480	maximum limits if achievable: >90% S removal: 1480 mg/m³ ceiling - 90% S removal (740-1480 mg/m³) -
Existing and new plants			
Japan		set individually according to nationally-defined formulae, range 170-860	based on stack height and K-values (by region) (Kx10-3xHe, =(m³/h)). K=area constant, He=stack height (m); eg a 1000 MWt utility plant with stack height 260 m in Tokyo (K=1.17) limit is 170 mg/m³ 70-90% S removal 740 mg/m³
Korea	-	3430	local anthracite
	-	2000	coals, excluding local anthracite
	-	1430	coals, excluding local anthracite from 1 January 1995
	-	770	from 1 January 1999
Taiwan	-	2143	from 1 July 1990
	-	1430	from 1 July 1993

* at 6% O2, stp (0°C (273 K), 101.3 kPa) on dry flue gas

Table 2 Typical features of FGD systems (Takeshita and Soud, 1993)

	Wet scrubbers	Spray dry scrubbers	Sorbent injection	Combined SO_2/NO_x, regenerable
SO_2 removal, %	90-95	85-95	50-70	85-95
Capital costs, $/kWe*	160-240	140-170	80-90	190-320
Levelised costs, $/t SO_2 removed (2.6% S coal)*	340-630	300-530	690-720	340-780
Suitability for retrofitting	good	good	excellent	good
Wastewater treatment	required	not required	not required	not required
Markets for by-product	large/gypsum	little	little	moderate
Power consumption, %	1-2	0.5-1.0	<0.5	0.1-3.5
Reheating of scrubbed gas	required	not required	not required	not required
High sulphur coal	suitable	not suitable	not suitable	suitable

This evaluation is not always applicable to every individual process. Capital and levelised costs of combined SO_2/NO_x include those of NO_x control.

* Keeth and others, 1991; Rader and Bakke, 1991; Ashline and Klingensmith, 1990; Emmel and Maibodi, 1991; Aumüller, 1992

Table 3 **FGD systems installed on coal-fired units (to end 1992) (IEA Coal Research, 1993c)**

Process	Wet lime/limestone/ gypsum		Other wet scrubbers		Spray dry scrubbers		Sorbent injection		Regenerable and combined SO_2/NO_x	
	No	MWe	No	MWe	No	MWe	No	MWe	No	MWe
Austria	4	810	-	-	3	792	2	175	-	-
Canada	-	-	-	-	-	-	3	900	-	-
China (mainland)	2	720	-	-	-	-	-	-	-	-
Denmark	3	850	-	-	3	1085	-	-	1	295
Finland	2	250	-	-	5	620	2	280	-	-
France	-	-	-	-	-	-	1	600	-	-
Germany	136	37064	2	99	37	3412	21	1507	12	2075
India	-	-	1	500	-	-	-	-	-	-
Italy	2	1320	-	-	1	77	-	-	1	30
Japan	47	14205	4	272	-	-	-	-	-	-
Netherlands	6	3422	-	-	-	-	-	-	-	-
Norway	-	-	1	30	-	-	-	-	-	-
Poland	-	-	-	-	-	-	2	20	-	-
Sweden	-	-	1	7	10	527	12	532	-	-
Taiwan	4	1700	-	-	2	325	-	-	-	-
Turkey	5	336	-	-	-	-	-	-	-	-
USA	24	10246	180	65088	70	10793	13	1287	21	5227
Total	235	70923	189	65996	131	17631	56	5301	35	7627

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Gravimelt Process

for

Coal Desulfurization and Demineralization

MULTIPLE HIGH VALUE PRODUCTS FROM COAL

by

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Abstract

TRW is developing a technology for chemical extraction of essentially all of the coal sulfur, mineral matter and trace elements from coal, prior to burning, while producing a range of high value coal based commodities. This technology is known as the TRW Gravimelt Process. The process is currently being further developed in a test plant in San Juan Capistrano in California. The coal based commodities produced in the Gravimelt Process are (1) sulfurless fuel for home and industrial heating and electricity generation valued at $70 to $100 per ton, (2) a near sulfurless and ashless as well as relatively low volatile coal for use as coke, breeze or direct injection in steel making valued at $100 to $150 per ton, (3) a combination activated carbon/ion exchange coal product for water purification valued at $250 to $750 per ton - all F.O.B. the plant, and (4) a sulfurless and ashless fuel for future premium applications such as diesel engine or turbine fuel to replace oil and natural gas. A single Gravimelt Process Coal Refinery (GCR) can produce virtually any mix of these products thus upgrading a low value ($15 to $25 per ton) highly polluting fuel to a high value slate of coal products with median value of $100 to $150 per ton. The capital amortized operating cost of the Gravimelt processing on a U. S. basis is $45 to $60 per ton of product coal depending on the product slate. When added to coal costs of $15 to $25 per ton in the U. S., the product cost is $60 to $85 per ton. This results in a very attractive profit potential the magnitude of which increases with the proportion of product sold for steel making and water treatment. Further profit potential exists for plant construction in the Asia Pacific region where labor and coal feed costs may be less than in the U.S.

Available Technologies for Flue Gas Desulfurization in Thermal Power Plants

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Abstract

The methods of control of sulfur dioxide emissions from thermal power plants are reviewed in light of the advances made in developing commercial processes for flue gas desulfurization (FGD) control. This paper begins with a discussion of the most recent developments in conventional wet and dry scrubbing technology and also provides a description of recent full-scale demonstration projects conducted on some of the lower capital cost furnace and duct absorber technologies. The paper also reviews the results of Phase I of the Acid Rain Legislation in the United States (U.S.) with the resultant technology selected by U.S. utilities. The conclusion of the paper discusses the economics of the various processes.

Introduction

Legislative action has been responsible for most industrial SO_2 controls. Major regulations include the Clean Air Act Amendments (CAAA) of 1970, 1977 and 1990 in the U.S., the Stationary Emissions Standards of 1970 in Japan, and the 1983 SO_2 Emissions Regulations of the Federal Republic of Germany.

Since the mid 1980s, SO_2 emissions regulations have been proposed in many other industrialized nations. Most members of the European Economic Community are regulated and Canadian laws are similar to those in the U.S. Utilities primarily use two strategies for control, switching to low sulfur coal and installing scrubbers.

Wet scrubbers have been used by many utilities since 1970 to meet SO_2 emissions regulations. 68,000 MW of FGD capacity were installed in the U.S. between 1970 and 1990. In Japan, 32,000 MW of capacity were added during this period. 48,000 MW of capacity were installed between 1979 and 1990 in Germany. The rest of the world accounts for approximately 4,000 MW.

Wet scrubbers offer the following advantages:

1. As an alternative to fuel switching, the utility can use its normal source of fuel supply.
2. As an alternative to and in contrast to other traditional and emerging FGD methods, wet scrubbers provide high SO_2 removal efficiency, high reagent utilization and high availability.

Of the 180,000 MW of worldwide FGD capacity, 85% are wet scrubbers with the balance being predominantly dry scrubbers.

More than 580 units are currently operating on a total capacity of about 150,000 MW_e. Approximately 70% of the units are based on lime or limestone wet scrubbing. About 20% of the units utilize either sodium-based or lime slurry (spray) dry scrubbing. The remaining 10% of the units use various regenerable processes or sorbent injection technologies of one form or another. Another 180 units, representing about 85,000 MW_e, are planned or under construction, and will employ these technologies in approximately the same proportions.

United States Clean Air Act Amendments

The Acid Rain Provision of the CAAA in the U.S., which was signed into law on November 15, 1990, effectively requires SO_2 emissions compliance in two phases for coal-fired boilers rated at 25 MW_e or more. Phase I, applying to 110 boilers that

are among the largest utility sources, requires emission levels of no greater than 1,075 ng SO_2/J (2.5 lb/10^6 Btu) by January 1, 1995, with provision for a two year extension for implementing 90% removal technologies under most conditions. With the addition of those units currently planned or under construction to meet these requirements, there will be a total of 366 FGD units in the U.S. operating on approximately 125,000 MW_e of capacity. Of these, 63% are either lime or limestone wet scrubbers, 20% dry scrubbers, and 7% other technologies. The remainder are planned units for which the technology has not yet been selected.

Phase II of the CAAA effectively requires boilers 25 MW_e and larger to have their emissions capped at 516 ng SO_2/J (1.2 lb/10^6 Btu) and that these reduced emissions be effective January 1, 2000. There will be a four year extension available for implementing selected clean coal technologies.

The actual selection and application of any FGD technology for a specific site is the result of a careful examination of both technical and economic aspects. While it is generally recognized that high SO_2 removal efficiency has been responsible for the general popularity of wet and (spray) dry scrubbers, recent advances in developing lower capital cost sorbent injection processes have renewed interest in these FGD technologies. Moderate to high levels of removal have been demonstrated, indicating that these technologies can offer attractive alternatives over a broader range of conditions than originally thought.

Conventional technologies

Through its Environmental Equipment and Research & Development Divisions, Babcock & Wilcox (B&W) has been an active participant in the development, demonstration and commercialization of many of these technologies. With wet scrubber sales of 16,859 MW_e and dry scrubber sales of 1,017 MW_e, it is one of the major worldwide suppliers of FGD systems. In addition, B&W has been and is participating in four sorbent injection projects (three ~100 MW_e and one 5 MW_e demonstrations) sponsored by the U.S. Department of Energy (DOE) and the U.S. Environmental Protection Agency (EPA).

Wet scrubbing

As noted earlier, lime and limestone wet FGD systems are the mainstay of SO_2 emissions control throughout the world. In the U.S., passage of the CAA in 1970 promoted trials of various types of systems. It was not long, however, before the utilities and major system suppliers gravitated toward wet scrubbers in which SO_2 removal is accomplished by recirculating an aqueous slurry of lime or limestone in an absorber vessel to effect intimate contact with the flue gas.

The inherent simplicity, the availability of limestone, and the high removal efficiencies required by the law quickly advanced the popularity of this type of system. This occurred in spite of the fact that the early systems often relied on redundancy to overcome difficulties resulting from scale formation in the absorbers. In addition, they tended to incorporate a design that produced a thixotropic, waste sludge that was difficult to dewater to more than about 60% solids. The net effect was that the costs of these first generation systems tended to be higher than they otherwise might have been.

Current state-of-the-art systems offer significantly improved performance compared to the first generation FGD systems. Much of this is attributed to engineering designs developed to conform better with fundamental process chemistry. The largest single improvement has been the development of sulfite oxidation control. Scale formation in the early systems tended to occur as the result of uncontrolled crystallization of the naturally oxidized product calcium sulfate ($CaSO_4 \cdot 2H_2O$ [gypsum]) from the recirculating slurry. For limestone systems, blowing air into the slurry to force oxidation to near 100% provides seed crystals that minimize scaling, while at the same time producing more homogeneous slurries that dewater to concentrations in excess of 90% solids. For these reasons, the limestone forced oxidation (LSFO) system has become the preferred technology worldwide.

The effect of oxidation versus scaling potential is illustrated in Fig. 1. As can be seen from this figure, most of the early systems were designed as natural oxidation in the 30 to 50% oxidation level. This caused severe scaling. Today's technology has units fully oxidized, or in certain selected installations the oxidation is inhibited by additives.

The prime benefits of scale control derived from forced oxidation are greater scrubber reliability and availability. Confidence in the design and operation of these wet systems has risen to the point that a number of utilities in the U.S. and Canada are now specifying and/or buying single absorber systems, with no redundant absorber towers, to satisfy their compliance requirements. Fig. 2 shows the primary components of the absorber towers currently being offered by B&W.

Three B&W scrubber systems are currently operating on high sulfur U.S. coal plants, producing gypsum for wallboard. FGD byproduct gypsum has also been used as an agricultural soil amendment and in cement manufacture. Even if the gypsum is not sold, the enhanced dewatering capability makes the process attractive in congested areas because the gypsum is a stable landfill material that requires less area for waste disposal.

A variation of LSFO FGD systems used by a few utilities is the inhibited oxidation system. In this process, emulsified sulfur or sodium thiosulfate is added to the scrubber liquor to prevent oxidation to calcium sulfate, thus acting as a scale control agent. With low oxidation levels, the growth of larger calcium sulfite crystals produces enhanced dewatering benefits similar to those in the fully oxidized system. The inhibited oxidation system, therefore, enjoys the benefits of lower waste disposal cost and scale control. While it does not produce a usable end product, it does use less power than LSFO with minimal increased chemical cost.

The scrubber configuration is essentially the same as shown in Fig. 2 except there is no oxidation air added at the bottom of the recirculation tank. The oxidation inhibitor is normally added to the slurry feed.

Magnesium enhanced lime (MEL) scrubbers are another variation of state-of-the-art wet FGD technology, though they have not enjoyed the worldwide popularity of the LSFO FGD systems. They have, however, been systems of choice in the Ohio River Valley of the U.S., where over 8,000 MW_e of MEL scrubbers are in operation. The Ohio River Valley MEL scrubbers use a reagent that naturally contains approximately 5% MgO.

MEL scrubber systems have proven capable of routinely performing at over 95% SO_2 removal efficiency even on 3% to 4% sulfur coals, and do so in absorber towers that are significantly smaller than their limestone counterparts (Fig. 3). The reason for this is that the presence of magnesium effectively increases the dissolved alkalinity, and consequently makes removal less dependent on the dissolution of the lime. To achieve the same effect, limestone-based systems require a high liquid-to-gas ratio (and therefore high power consumption), and sometimes the use of additives to approach the same removal efficiencies. The choice between LSFO and MEL systems has often been debated. Utilities have generally based their decisions on site-specific considerations dealing with the higher operating cost of lime, in comparison to the higher capital cost of the larger absorbers and greater pumping costs of LSFO FGD.

Fig. 4 is a listing of the FGD systems purchased during Phase I of the U.S. Clean Air Act Amendments. This definitely indicates the predominance of limestone forced oxidation systems. Of the 16,334 MW listed, 10,594 are limestone forced oxidation systems. The material used in these units was primarily alloy as shown in Fig. 5.

Finally, although the preceding discussion has concentrated on wet scrubbing with lime and limestone slurries, B&W has also supplied wet scrubbers for three 552 MW_e units where the reagent is a waste soda ash (Na_2CO_3) solution. The highly reactive soda ash allows these scrubbers to operate at even lower liquid-to-gas ratios. The application is highly site-specific, however, in that the utility is located close to a soda ash plant in an area where the net evaporation rate permits the product salts to crystallize in the disposal ponds.

Dry scrubbing

Commercial utility installations using dry scrubber technology first appeared in the U.S. in the late 1970s and early 1980s. Derived from spray drying technology, this method of SO_2 emissions control relies on the atomization of a sorbent, most commonly an aqueous lime slurry, in a reaction chamber upstream of a particulate collection device. Typically, the systems are designed to operate at a 15 to 25C (27 to 45F) approach to the adiabatic saturation temperature of the flue gas. The fine droplets absorb SO_2 and form the product calcium sulfite and sulfate as the water evaporates. Atomization is accomplished by two different methods: rotary atomization and dual-fluid atomization. The B&W dry scrubber design shown in Fig. 6 incorporates a patented dual-fluid atomization that has proven to be particularly effective. This design has been in service for approximately 10 years at a 600 MW unit and a 450 MW unit.

A downstream electrostatic precipitator (ESP) or baghouse collects the dry salts along with flyash present in the flue gas. Use of a baghouse enhances the performance of the dry scrubber because additional SO_2 absorption occurs as the flue gas passes through the accumulated cake on the bags. Operation nearer the flue gas saturation temperature further promotes the increased removal efficiency obtained through the intimate contact in this configuration.

In the U.S., dry scrubber technology has primarily been used on units burning low sulfur coals. Required SO_2 removal efficiencies have normally been in the 80% or less range at inlet calcium-to-sulfur (Ca/S) ratios of 1.5 or less. There has been discussion regarding the use of this technology on higher sulfur coals with higher removal efficiency. Such applications have not yet been demonstrated in the U.S., and it is anticipated that the primary commercial application of dry scrubbing in the U.S. will continue to be with the low sulfur fuels.

Advanced technologies

While the wet FGD systems provided the benefits of high removal efficiencies, their relatively high capital cost made them unattractive for those applications where it was desirable to minimize the initial investment. In the late 1970s, interest in developing lower cost technologies heightened when one Eastern U.S. utility determined that a 25% SO_2 removal technology, when combined with coal cleaning, would permit it to meet the regulated emission limit on one of its units. At about the same time, the U.S. EPA was continuing support of bench- and pilot-scale projects to develop low capital cost processes for many of the smaller and older units not regulated by the original Clean Air Act (CAA) of 1970. Initially using limestone injection through staged low NO_x burners, these studies went on to show that moderate levels of SO_2 emissions control were possible by injecting sorbent within certain windows within a boilers time/temperature profile. All this work culminated in a full-scale project, entitled The Limestone Injection Multi-stage Burner (LIMB) Demonstration, which was conducted by B&W on the 105 MW_e Unit 4 boiler at Ohio Edison Company's Edgewater Station in Lorain, Ohio. The success of this project, and of a subsequent LIMB Extension Project sponsored by the DOE, became an incentive for further improvements in the technology. Some of the techniques learned have been employed in related studies that have given rise to other sorbent injection processes, including the following.

Limestone injection dry scrubbing (LIDS) A process in which limestone is first injected into the furnace, and the resulting excess calcined lime (CaO) is used as the reagent for dry scrubbing.

Coolside A process that couples flue gas humidification with hydrated lime [$Ca(OH)_2$] injection into the duct downstream of the air heater.

SO_x-NO_x-Rox-Box (SNRB) A process that combines hydrated lime and ammonia injection upstream of a hot, catalytic baghouse (Box) where the solid products calcium sulfite and sulfate and particulate (Rox) are removed, and the NO_x is reduced to nitrogen and water.

Each of these technologies is described in more detail in the following sections. References to more complete reports on each technology are provided with the title of each section.

Furnace sorbent injection (LIMB)[2,3]

Furnace sorbent injection for SO_2 emissions control was first attempted on a commercial scale in England in the 1930s, and was the subject of several studies in the U.S. just preceding passage of the CAA in the late 1960s. These early efforts, using limestone as the sorbent, typically produced low (20 to 30%) removal efficiencies that were generally regarded as less than adequate for the objectives set at the time. It was only when interest rekindled in the late 1970s and early 1980s that more detailed investigations determined how to overcome some of the chemical and mechanical limitations involved. The LIMB projects at Edgewater went on to demonstrate that furnace sorbent injection represents a low capital cost technology capable of achieving moderate levels of SO_2 control. As such, it is particularly applicable for older, smaller units burning lower sulfur coals.

The first (EPA sponsored) LIMB project at Edgewater had the primary objective of attaining in excess of 50% SO_2 removal at an inlet Ca/S ratio of 2.0 burning 3% sulfur coal. To accomplish this, the project undertook an extensive review of the literature to determine the limiting factors, both chemical and mechanical, thought to be responsible for the lower removals observed previously. Further supporting studies were then conducted.

A system was then developed and installed accordingly designed for calcitic hydrated lime injection in that region of the upper furnace where the sulfation reactions would be maximized.

A humidifier design was developed, based on B&W's dry scrubber experience, that not only overcame the adverse impact of sorbent injection on the electrostatic precipitator (ESP), but also provided a mechanism for enhanced SO_2 removal by being capable of operating at an 11C (20F) approach to the adiabatic saturation temperature of the flue gas.

Fig. 7 shows the LIMB process flow diagram as operated at the Edgewater Station. The hoppers shown under the humidifier were covered by steel plates throughout all testing, so that humidification was effectively carried out as an in-duct process. The humidifier was constructed in a bypass loop over the hoppers of a retired ESP as a precautionary measure. If major ash deposits had formed as the result of humidification, this part of the process could have been isolated and the hoppers used for removal. Fortunately, they were never needed.

Following initial test results indicating SO_2 removal efficiencies in the 55 to 60% range, the project went on to demonstrate removals as high as 72% at a Ca/S ratio of 2.0 with humidification to a close approach to saturation.[4]

The DOE-sponsored LIMB Extension Project sought to demonstrate the generic applicability of the process by characterizing the performance to be expected for a variety of sorbents and coals. Sorbents tested included limestones reflecting three increasingly finer grinds, commercial calcitic and dolomitic hydrated limes, and ligno lime. Tests were conducted while the unit burned coals containing 1.6, 3.0, and 3.8% sulfur. Characteristic curves showing the relative importance of the more important variables are summarized in Figs. 8, 9 and 10. These figures portray a first-order relationship between SO_2 removal efficiency and Ca/S ratio. This is approximately true over the range of conditions tested, as can be seen in Fig. 10. A second order fit with a diminishing increase in removal would describe the dependency more appropriately at higher stoichiometries.

The effects of such variables as injector tilt, coal sulfur content, injection level (temperature) and momentum flux ratio (velocity) were also examined. Factors associated with the time/temperature profile (temperature and velocity) can, however, be system dependent. It is believed that the relative insensitivity of the Edgewater system to these parameters was due to design near the optimal operating conditions.

The LIMB demonstration at Edgewater also provided an opportunity to observe the effects of furnace sorbent injection on boiler and ash collection and handling equipment operation. The increased dust loading associated with the process can cause additional ash accumulation on tubes. Depending on the amount of sorbent to be injected, and the number, capacity, and position of any existing sootblowers in a retrofit situation, it may be necessary to add sootblowers to clean convection pass surfaces. The LIMB ash was found to be as easily removed as normal flyash. It was also observed that the hydrated limes had a much greater tendency to coat the tubes than did the coarsely ground limestone. While the opposite had been anticipated as the result of inertial impaction, it may be that the larger particles were self-scouring. There were no means available to establish any quantitative relationships, however.

The combined effects of a higher particulate loading, an increased concentration of finer material in the case of injection of the hydrated limes, and increased ash resistivity all tended to degrade ESP performance. When operation was first attempted, it was quickly discovered that high ash resistivity gave rise to a back corona condition that was more severe than had originally been anticipated. Provision for the humidifier was already in progress, and once installed, proved to be an effective remedy as stack opacity returned to normal levels of a few percent. Other than this, the other main consideration that must be taken into account is that the ash collection and handling system must be designed or modified to accommodate the ash loading expected for the amount of sorbent injected and reacted. This could be a three-fold increase in ash loading.

The final observation regarding operation relates to the composition of the ash to be disposed. The ash collected downstream of a furnace sorbent injection process has a high quicklime content that must be taken into consideration. Collected as a dry byproduct, it may find any of a number of uses ranging from being an additive for cement manufacture, to soil stabilization, to neutralization of acid mine drainage or other acid wastes.[5,6]

Duct sorbent injection (Coolside)[7]

Similar to the furnace sorbent injection systems, the duct sorbent injection systems utilize the duct between the air heater outlet and the particulate collector inlet to capture SO_2 with either lime- or sodium-based compounds. Limestone sorbents are quite unreactive in the 175 to 60C (347 to 140F) temperature range of interest for this technology. While the sodium-based systems can be effective,[8,9] concern over the solubility of the product salts in the waste effectively limits application to a few

units in the Western U.S. For these reasons, the balance of this discussion will focus on lime-based systems.

This alkali can be injected as a dry powder or as a slurry, but in either case, humidification to a close approach to the adiabatic saturation temperature of the flue gas is required for the process to be effective. The need to effect virtually complete evaporation of the water added makes it necessary either to have a long straight run of duct work, or to modify the flues for the residence time required. The length/size in turn depends on the degree of atomization achieved. Of course, the baghouse or ESP used for particulate collection must be adequately sized for the increased dust loading. The ash collected will contain a mixture of unreacted hydrated lime and flyash, along with the product materials calcium sulfite and calcium sulfate.

Duct sorbent injection systems have undergone extensive testing just within the past few years. The largest of these was performed as the Coolside process demonstration in conjunction with the DOE-sponsored LIMB project discussed above.[7] Initially developed by CONSOL Inc., the process entailed injection of dry calcitic hydrated lime at the inlet of the same humidifier that had been used during the LIMB demonstration. Most of the tests were conducted with the humidifier operating in the range of an 11 to 17C (20 to 30F) approach to the saturation temperature.

Lime utilization and SO_2 removal in the Coolside process are enhanced by the addition of sodium salts. Without the addition of sodium hydroxide, removal efficiencies with a stoichiometric ratio of 2 were in the range of 35% with humidification and a 14C (25F) approach to saturation. Adding sodium hydroxide increased the SO2 removal to approximately 60%.

Because much of the work on duct sorbent injection has been done so recently, no U.S. utility currently has a permanently installed, commercial system operating. There have been a number of inquiries, however, and international interest appears to be growing. Many seem to like to compare furnace sorbent injection with the duct injection. Since the removal efficiencies attainable by the processes are approximately equivalent, the primary considerations for the two technologies are summarized below.

Furnace sorbent injection Significant SO_2 removal does not depend on a close approach to the adiabatic saturation temperature of the flue gas, although some degree of humidification may be necessary in order to keep an ESP operating properly. Installation or upgrading of sootblowers to maintain boiler performance may be needed depending on the sorbent type and feed rate. Provision for safe handling and disposal of ash containing quicklime (CaO) is required if not being used as a byproduct.

Duct sorbent injection Requires a close approach to the adiabatic saturation temperature of the flue gas, which in turn tends to require sufficient power for fine atomization and space for droplet evaporation. Because it is run at close approach temperatures, the process has a greater tendency for forming deposits in the duct if not designed and operated properly. A dry product is produced that does not contain quicklime, but does contain calcium sulfite which can present a chemical oxygen demand upon disposal.

Limestone injection dry scrubbing (LIDS)[12]

Experience with both dry scrubbing and furnace sorbent injection prompted B&W to integrate the two into the LIDS process, as it offered the advantages of combining the use of the lower cost limestone sorbent with higher overall SO_2 removal and sorbent utilization. Fig. 11 shows the flow diagram of the process with particulate collection by either a baghouse or an ESP. In the process, injection of limestone into the furnace effects SO_2 removal as represented in Fig. 9. The unreacted quicklime continues through the system until it is collected in the baghouse or ESP. Depending on the SO_2 removal efficiency desired, a portion of the collected ash is slurried with water through an appropriately sized slaking device. The slurry is then fed to the dry scrubber where the bulk of the SO_2 removal occurs. Significant additional SO_2 removal may also occur during particulate collection, especially if the flue gas must pass through a baghouse at a temperature relatively close to saturation.

B&W's Research and Development Division carried out the LIDS tests at its Alliance Research Center in Alliance, Ohio. A major portion of the facility already existed as a pilot scale combustion furnace called the small boiler simulator (SBS). Rated at 1.8 MJ/s (6.0×10^6 Btu/h), the SBS had much of the auxiliary equipment in place as the result of earlier furnace sorbent injection tests. To this was added a cylindrical, downflow dry scrubber designed for testing with gas residence times in the 5 to 10 second range. Its dimensions were 9.1 m (30 ft) high and 1.5 m (5 ft) in diameter. The baghouse contained 46 Nomex bags 3.0 m (10 ft) long and 12 cm (4.6 in.) in diameter, providing a design air-to-cloth ratio of 51 mph (2.8 ft/min) at 66C (150F).

The cost of achieving continuous operation to achieve true steady-state conditions made simulation of recycle necessary. This was accomplished by operating the pilot in a batch mode, and collecting the ash produced each day for preparation of the following day's slurry in a 7.57 m^3 (2,000 gal) stirred tank. Recycle ratios, defined in terms of mass of recycled ash per mass of fresh sorbent, ranged from 0.4 to 1.9 for the tests conducted.

The LIDS test program characterized the SO_2 removal efficiency over a range of stoichiometries and approaches to the saturation temperature. The test results obtained to date indicate that with a calcium/sulfur molar ratio of approximately 2, removal efficiencies of more than 90% can be obtained.

SO_x-NO_x-Rox-Box (SNRB)[13]

B&W is developing the SNRB process as a combined SO_x, NO_x and particulate (Rox) emissions control technology by which all three pollutants are removed from flue gas in a high temperature baghouse. SNRB incorporates lime-or sodium-based sorbent injection to capture SO_x, selective catalytic reduction (SCR) of NO_x by ammonia (NH_3) and particulate removal in a high temperature, pulse-jet baghouse, as depicted in Fig. 12.

B&W's Research and Development Division conducted early tests in a 1,500 Nm^3/h (2,500 ACFM) pilot at the Alliance Research Center. Encouraging results led to a DOE Clean Coal Technology demonstration project which uses a six compartment unit capable of treating 19,900 Nm^3/h (30,000 ACFM) of flue gas (equivalent to about 5 MW_e). Each compartment contains 42 full-size bags

that are 6.1 m (20 ft) long and 15.9 cm (6.25 in.) in diameter. Because the bags and SCR catalyst assemblies are full size and the unit is operated with a rotating cleaning cycle, scaleup will primarily involve multiplying the number of units required for the intended application. The project, co-sponsored by the Ohio Coal Development Office (OCDO) and the Electric Power Research Institute (EPRI), just completed testing at Ohio Edison's Burger Station.

The tests concentrated on characterizing SO_2 removal with calcitic hydrated lime injected at various temperatures and stoichiometries. Results indicate that inlet Ca/S ratios near 2.0 reduce SO_2 emissions by 80 to 90%, well beyond the original 70% goal. Part of this is ascribed to more complete conversion in the baghouse than anticipated, although the removal appears to be sensitive to the baghouse temperature.

Results on NO_x and particulate emissions control have also been promising. Removal efficiency in excess of 90% has been achieved near an NH_3/NO_x stoichiometry of 0.85. At the same time ammonia slip, a term describing the undesirable bypass of unreacted NH_3, has generally been measured at levels of less than 4 mg/Nm^3 (5 ppmv).

Particulate emissions have averaged 7.7 ng/J (0.018 lb/10^6 Btu), well below the U.S. Clean Air Acts New Source Performance Standard of 12.9 ng/J (0.03 lb/10^6 Btu). This level of control equates to an average removal efficiency of 99.89% for the range of dust loadings and temperatures tested.

As was the case for the LIDS process, the next step toward full commercialization of the SNRB process is a larger scale demonstration of perhaps 50 to 100 MW_e. Again, a new or retrofit application would be suitable at either an industrial or a utility site.

Economics of the processes

A summary of the economics of so many processes, particularly when they represent all stages of development from pilot-scale through commercial full-scale, must naturally be built upon a broad range of assumptions that the reader is reminded to consider in interpreting what follows. The approach taken uses the basis of the capital and operating costs developed for the LIMB and Coolside processes as they relate to the LSFO FGD process. The economic analysis employed was quite thorough and conformed to practices generally accepted by the U.S. utility industry.[13,14] All capital costs are expressed in terms of U.S. dollars per kW, and annual levelized costs in U.S. dollars per ton of SO_2 removed. While this facilitates comparison, the reader is cautioned that not all the analyses start with the same basic assumptions. Rather, the values should be interpreted more properly as representing each technology in a reasonably favorable application of its capabilities.

The capital costs associated with LSFO FGD and with furnace and duct sorbent injection, as represented by LIMB and Coolside as practiced at Edgewater, are shown in Fig.13 for unit sizes in the range of 100 to 500 MW_e. The costs represent units burning a bituminous coal with a heating value of 27.7 MJ/kg (11,872 Btu/lb), and containing 2.50% sulfur and 10.77% ash (all as-fired values). Capital costs are similar for 1.5 and 3.5% sulfur coals, since basic equipment sizes are not that much different.

In contrast to the relative insensitivity of capital costs to coal sulfur, annual levelized costs which reflect operation over the life of the plant vary considerably with coal sulfur, as can be seen in Figs. 14, 15 and 16. Examination of these figures also reveals that, while the cost per ton of SO_2 removed decreases with increasing coal sulfur, the decrease for LSFO FGD is much more dramatic than for the sorbent injection technologies. The main reason for this is the greater sorbent utilization in the wet technologies. For the same reason, the analysis shows why the lower capital cost sorbent injection technologies tend to be favored for the older, smaller plants where moderate levels of SO_2 are needed. As described earlier, the cost of MEL wet scrubbers are equivalent to those for the limestone systems in general. However, site-specific factors can be very influential in decisions between the two.

The other notable feature that appears within Figs. 13 through 16 is the higher cost of the Coolside process in comparison to that of LIMB. Much of this is attributed to the cost associated with the purchase and operation of the fairly large compressor required for fine droplet atomization to achieve a close approach to the flue gas saturation temperature. For the same reason, the costs of duct injection of a slurry, while not specifically studied, would be expected to be comparable.

The economics of lime-based dry scrubbing is fairly well established since the process is commercial. However, there has been no recent study that provides as much detail as just provided on LSFO FGD and the sorbent injection technologies. Nevertheless, the industry tends to think in terms of the costs of dry scrubbing being approximately 80 to 90% of LSFO FGD. This is reflected in a recent independent study[15] that showed an estimated $170/kW capital cost and $490/t of SO_2 removed annual levelized cost for a 300 MW_e unit burning 2.6% sulfur coal. This same study estimated the comparable LSFO FGD capital cost at $210/kW and the annual levelized cost at $550/t of SO_2 removed, approximately equivalent to the figures determined in the B&W study.

The economics of the LIDS and SNRB processes are not as well established as those just described, since their development is ongoing. At this point in time, the capital cost of the LIDS process is estimated to be approximately equivalent to that of conventional dry scrubbing under the rough assumption that the cost of the limestone preparation and feed system is about equal to the pebble lime (commercial quicklime) slaking and pumping system. The lower cost of limestone, as compared to lime, is expected to generate savings in the annual levelized cost, however. Using a $40/t cost differential in an economic model similar to that used in the study referred to above, one might expect an annual levelized cost savings of about $70/t of SO_2 removed.

SNRB economics are the least refined of all the processes discussed due to the fact that many of the costs have yet to be truly established for a large, commercial, industrial or utility application. The removal efficiencies are higher than expected and are currently being realized in the 5 MW_e demonstration which are improving previous economic projections. Moreover, it is virtually impossible to break out the costs according to the individual pollutants. As a result, it is a bit premature to say more than to suggest that the capital and operating costs of the SNRB process are expected to be competitive with the combined cost of a system incorporating separate SCR, wet FGD, and particulate removal components.

Summary

The control of SO_2 emissions from fossil fuel-fired boilers has progressed dramatically over the past 25 years. Wet scrubbers, and especially those employing the LSFO and MEL technologies, have become the state-of-the-art methods for achieving removal efficiencies in the 90 to 98% range. Spray or dry scrubbing with lime slurries for lower removal efficiency is seen as a technology more useful for lower sulfur coals. However, it may prove to be economically viable for some higher sulfur coal applications as well, especially when combined with sorbent injection as is done in LIDS. Interest in the sorbent injection technologies alone, for moderate levels of removal at relatively low capital cost, at first grew out of anticipation of the CAAA in the U.S., only to become technologies that may be of even more value worldwide. Finally, development of the advanced SNRB process, based on elements learned from the previous projects, continues to push the technologies into new areas that are expected to provide overall increased emissions control economically.

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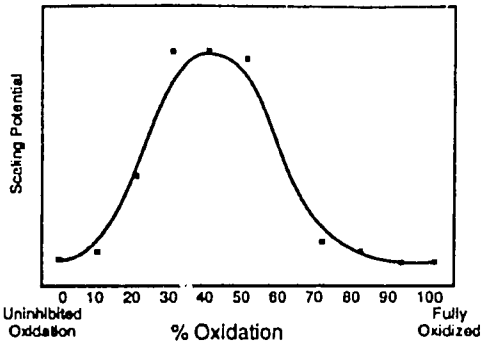

Fig. 1 Improved process control

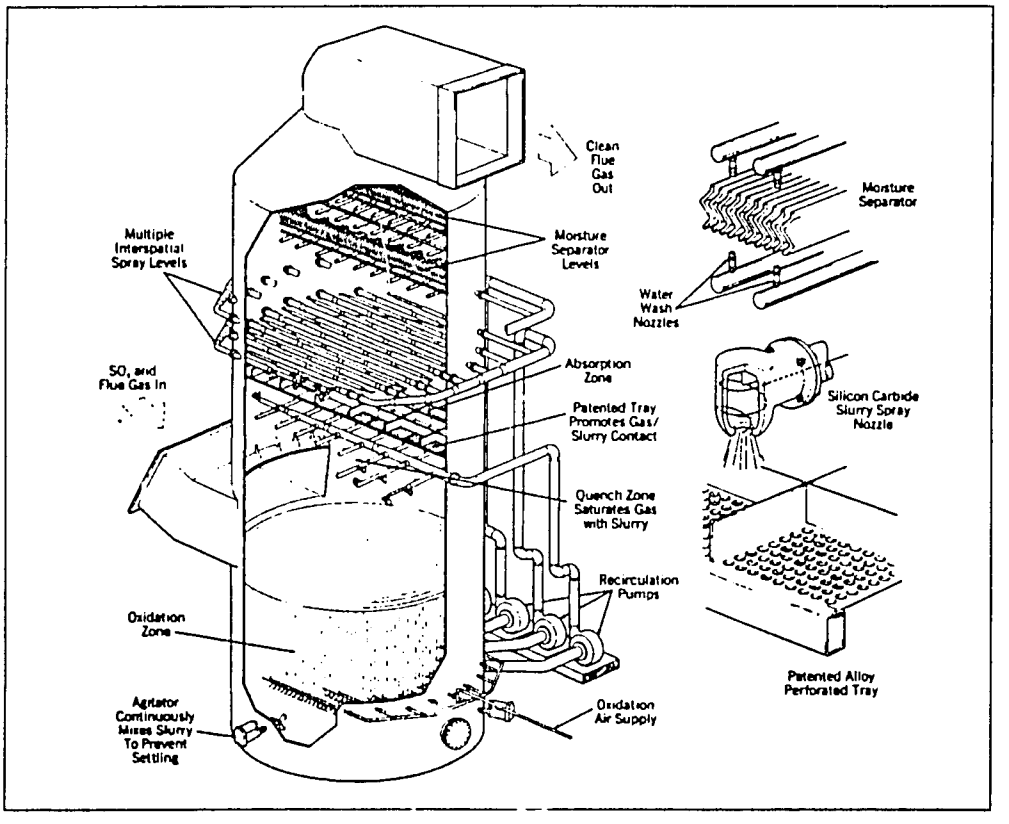

Fig. 2 B&W wet FGD absorber tower.

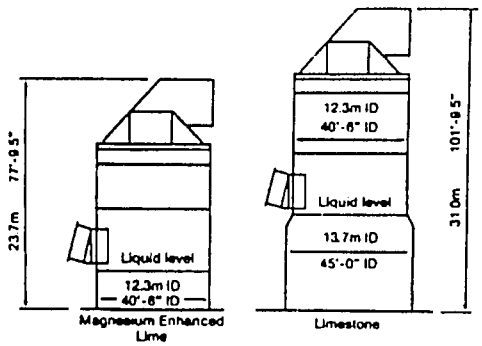

Fig. 3 Sizes of MEL and LSFO absorber towers for a 250 MW$_e$ unit.

Utility	Station	Unit	MW	Total Process
PSI Energy	Gibson	4	660	Limestone Inhibited Oxidation
Allegheny Power	Harrison	1-3	2040	Magnesium Enhanced Lime
Kentucky Utilities	Ghent	1	550	Limestone Forced Oxidation
Owensboro	Elmer Smith	1,2	415	Limestone Forced Oxidation
TVA	Cumberland	1,2	2600	Limestone Forced Oxidation
AEP	Gavin	1,2	2700	Magnesium Enhanced Lime
IP&L	Petersburg	1,2	724	Limestone Forced Oxidation
Virginia Power	Mount Storm	3	550	Limestone Forced Oxidation
Atlantic Electric	BL England	2	170	Limestone Forced Oxidation
Illinois Power	Baldwin*	1,2	1160	Limestone Forced Oxidation
Penelec	Conemaugh	1,2	1800	Limestone Forced Oxidation
Sigeco	Cully	2,3	370	Limestone Forced Oxidation
NYSE&G	Milliken	---	300	Limestone Forced Oxidation
City of Henderson	Station 2	1,2	340	Magnesium Enhanced Lime
NIPSCO	Bailly	7,8	615	Limestone Forced Oxidation
Niagara Mohawk	Huntley*	67,68	400	Limestone Forced Oxidation
Centerior	Eastlake*	4,5	940	Limestone Forced Oxidation
			16,334 (13,834)	

* Delayed

Fig. 4 Phase 1 Scrubber Activity

Utility	Station	Material
PSI Energy	Gibson	Alloy A255
Allegheny Power	Harrison	Alloy 317 LMN
Kentucky Utilities	Ghent	Alloy Solid C-276
Owensboro	Elmer Smith	Alloy 317 LMN
TVA	Cumberland	Steel Rubber lined
AEP	Gavin	Alloy 317 L
IP&L	Petersburg	Alloy Clad C-276
Virginia Power	Mt. Storm	Alloy WP C-276
Atlantic Electric	BL England	Alloy Clad C-22
Illinois Power	Baldwin	Alloy 317 LMN
Penelec	Conemough	Steel Rubber Lined
Sigeco	Culley	Steel Rubber Lined
NYSE&G	Milliken	Tile
City of Henderson	Station 2	Alloy 317 LMN
NIPSCO	Bailly	Alloy C-276 Steel Lined
Niagara Mohawk	Huntley	Steel Rubber Lined
Centerior	Eastlake	Alloy 317 LMN

Fig. 5 Phase 1 Absorber Material Selection

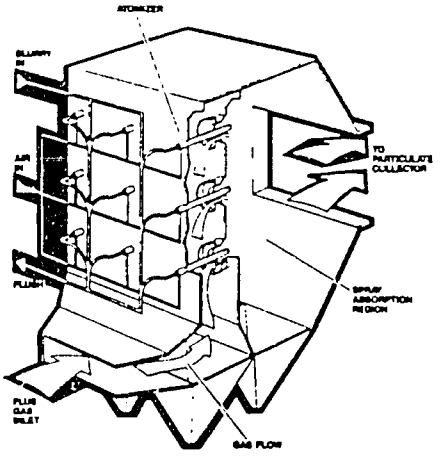

Fig. 6 B&W dry scrubber module.

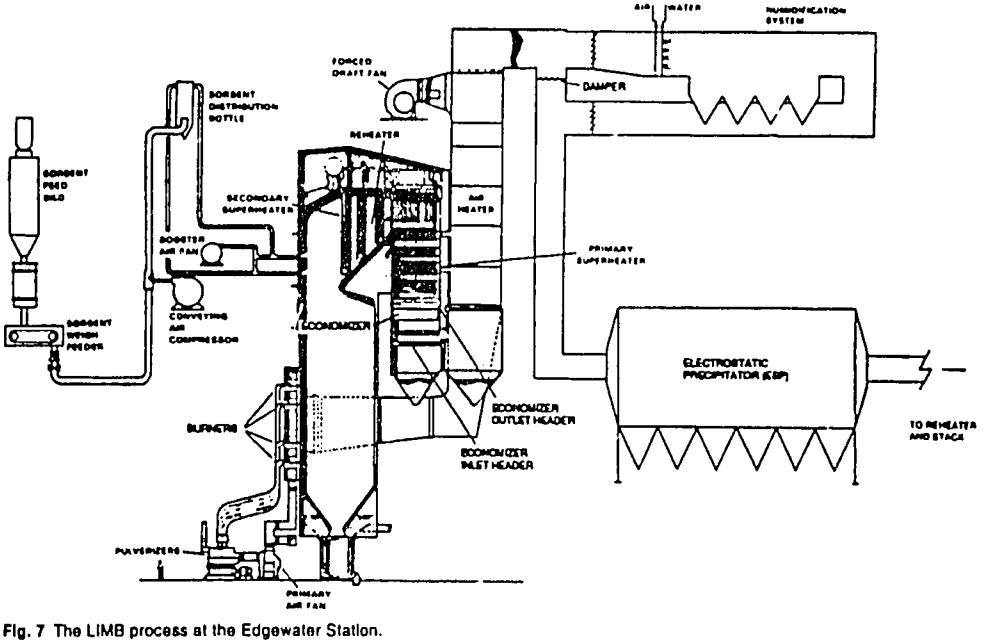

Fig. 7 The LIMB process at the Edgewater Station.

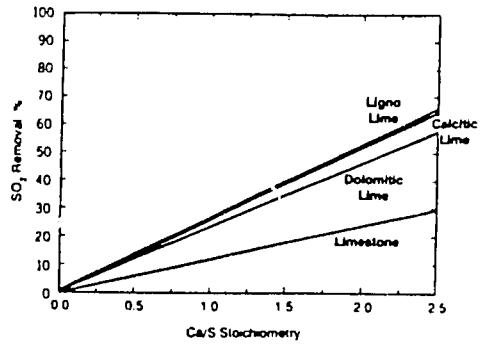

Fig. 8 Effect of different sorbents on SO_2 removal while burning 1.6% sulfur coal and injecting at elevation 56.2 m (181 ft).

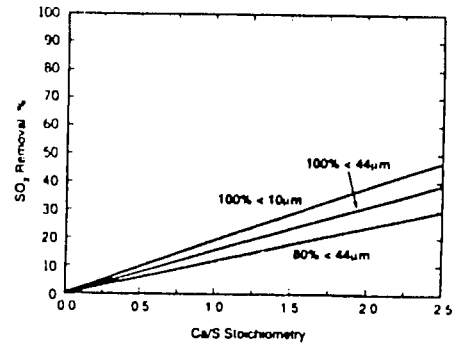

Fig. 9 Effect of limestone grind on SO_2 removal while burning 1.6% sulfur coal and injecting at elevation 55.2 m (181 ft).

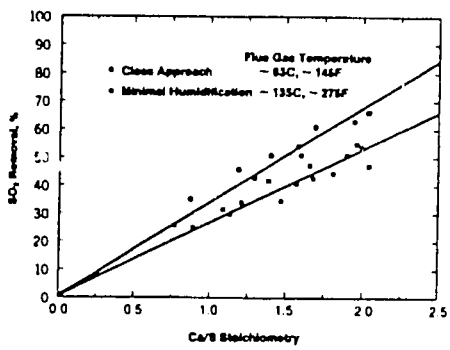

Fig. 10 Effect of humudification on SO_2 removal.

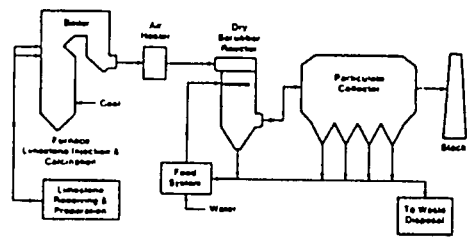

Fig. 11 LIDS process flow diagram.

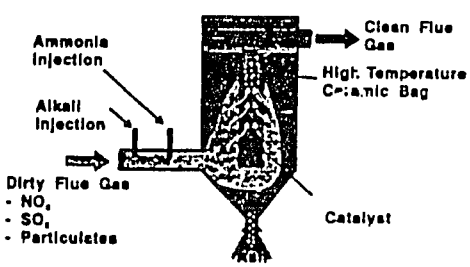

Fig. 12 The SO_x-NO_x-Rox-Box (SNRB) process.

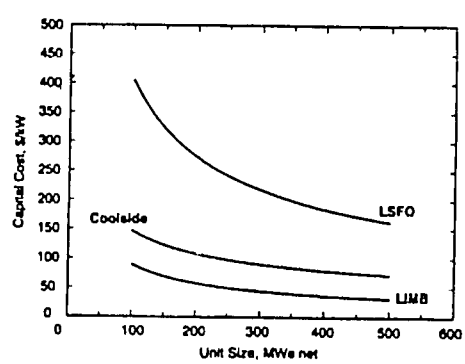

Fig. 13 Capital cost sensitivity of LIMB, Coolside and LSFO to unit size for 2.5% sulfur coal.

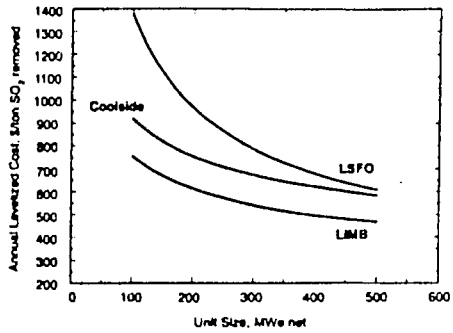

Fig. 14 Annual levelized cost sensitivity of LIMB, Coolside and LSFO to unit size for 1.5% sulfur coal.

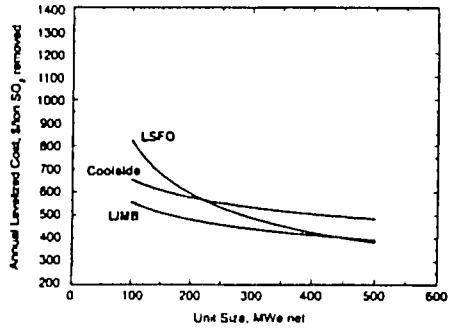

Fig. 15 Annual levelized cost sensitivity of LIMB, Coolside and LSFO to unit size for 2.5% sulfur coal.

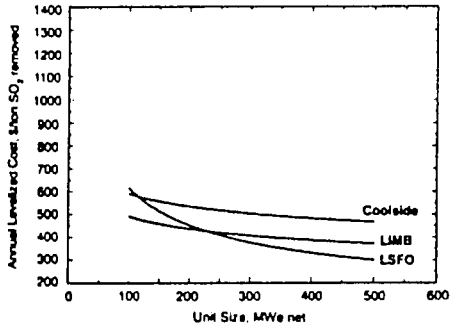

Fig. 16 Annual levelized cost sensitivity of LIMB, Coolside and LSFO to unit size for 3.5% sulfur coal.

TECHNO ECONOMIC FEASIBILITY ASSESSMENT OF INTEGRATED GASIFICATION COMBINED CYCLE (IGCC) POWER GENERATION TECHNOLOGY WITH HIGH ASH INDIAN COALS.

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INTRODUCTION

India is endowed with abundant reserves of coal likely to last 200 years at the present rate of consumption. The estimated reserves as on 1st January, 1993 (in billion tonnes) are,

Coking Coal	29.4
Non -coking coal	164.4

Unfortunately nearly 71% of our non-coking coal reserves are of inferior grade. The ash content in the coals meant for power generation is at present 40-45% which is likely to increase in future.

Coal plays a very important role for power generation in India. More than 65% of Power is generated from the pulverised coal fired thermal power plants. The thermal power plants have problems, constraints and limitations. It is therefore necessary to look for alternate technologies for power generation with high ash coals which are more efficient, environmentally beningn and also improve the performance of existing thermal power plants. The coal gasification based power generation i.e.Integrated Gasification Combined Cycle (IGCC) has been identified as one of the alternatives.

Advantages of IGCC

IGCC plants are known to have the following advantages over the pulverised coal fired thermal power plants (PC Plants)

- Higher efficiency
- Lower water consumption
- Lower emissions of particulates, NOX, SOX and CO2
- Flexibilities of modular and phased construction.
- The IGCC plant efficiency can be further improved with the development of advanced materials for the gas turbine to operate at a higher efficiency.

Status of coal gasification/IGCC in India

Complete gasification of coal has been of considerable interest in the Indian context and R&D work is being pursued in quite a few national laboratories, academic institutions and industrial establishments. The details in brief are:

- Pilot plants of capacity 19 tpd and 24 tpd, based on moving bed pressure gasification have been established at two of the laboratories belonging to Council of Scientific and Industrial Research located in Dhanbad and Hyderabad. Extensive experimental trials have been carried out with various coals.

- A 6.2 MW capacity Integrated Gasification Combined Cycle (IGCC) process demonstration unit based on moving bed pressure gasification has been set up by the Bharat Heavy Electricals Ltd., (BHEL), a public sector undertaking, at Trichy. Extensive trials have been carried out with various types of coals.

- BHEL has also set up a 18 tpd fluidised bed coal gasification plant at Hyderabad and carried out several experiments.

- In addition to above, the Fertiliser Corporation of India had set up two coal based fertiliser plants on commercial scale at Ramagundam and Talcher, which are entrained flow reactors. These plants are in operation since 1978.

FEASIBILITY STUDY FOR A 600 MW PLANT

With a view to introduce IGCC technology in the country, a feasibility study' was carried out for establishing the relative techno-economic merits of various coal gasification processes with high ash coals for combined cycle power generation. The objectives of the study were:

- To evaluate and rank the gasification processes suitable for high ash coals.

- Compare their economics with the PC plant

- To establish an overall commercialisation programme for the IGCC technology in the country.

Technology selection criteria

The selection of coal gasification technology was based on the following criteria.

- The demonstration of technology on a commercial scale or large pilot plant scale.
- Willingness to provide process package for the study by process licensors.
- Experience with Indian coals
- Willingness to participate in the demonstration plant in India.

An appropriate gas turbine was selected based on the following criteria.

- Frequency of electrical system should be 50 cycles/second to suit Indian System
- Commercial availability
- Advanced gas turbine (1260 degrees centigrade firing temperature, with higher efficiency

Based on the above criteria the following four gasification processes were chosen for study.

- Dry entrained bed process (DEB)
- Slurry entrained bed process (SEB)
- Fluidised bed process FB)
- Moving bed process (MB)

IGCC plant

A conceptual design was prepared for a mine mouth IGCC plant located at the North Karanpura coal field of Bihar State. A generalized block flow diagram of coal gasification integrated with combined cycle electric power generation is enclosed. The fuel gas production is sized to fully load two gas turbines. The total net power produced from this IGCC plant is approximately 600 MW. The design coal is non-coking unwashed, run-of-mine coal from the Dakra seam. The coal, on as-received

basis, has 38.8% mineral matter, 10% moisture, a higher heating value of 3332 Kcal/Kg, and an ash fusion temperature (fluid, under reducing atmosphere) of more than 1500 C. It represents the typical coal feedstocks which would be available for future power generation in India.

The process licensers of DEB,SEB and FB provided the necessary gasification process packages and cost data. The data on MB was derived from experiments carried out in the pilot plant of 24 tpd and the process demonstration unit of 150 tpd with the same candidate coal considered for the study. The combined cycle plant has two trains. Each train consists of one gas turbine, one HRSG (heat recovery steam generator), and one steam turbine. An advanced gas turbine having a firing temperature of 1260 C,heat rate of 2500 Kcal/Kwh and an output of 200 MW is selected to take advantage of the recent turbine efficiency improvement and to demonstrate the full potential of IGCC plant. The steam turbine is a reheat turbine operated under 103 kg/cm2 a/538 C/538 C steam condition.

PC plant

The PC plant consists of one unit and has a design capacity of 600 MW so as to be consistent with that of the IGCC plant . Data for the pulverised coal fired thermal power plant were extrapolated from the data given in the feasibility report of Power Project (2x500 MW). The coal used in the PC plant is same as that of the IGCC plant. The IGCC and PC plants are located in the same place.

Performance comparison of IGCC and PC plants

The plant resource requirements, power outputs, heat rate, and efficiency for the four IGCC plants in comparison with PC plant both with and without FGD (Flue Gas Desulfurization) are given in Table 1

The SEB case consumes substantially more coal and has a higher heat rate than other three IGCC cases. This is because the slurry feed system of the gasifier suffers severe thermal penalty when a high ash coal is used. Only with washed coal , it can be competitive with other processes.

The moving bed case has a better heat rate than the SEB case. But this heat rate is higher than those of the DEB and FB cases. This is because the moving bed case requires a large quantity of steam injected to the gasifier to avoid ash clinkering.

The FB case has the best heat rate among all cases. The major reasons are:

- The gasifier is operated at low temperature and thus has a relatively high cold gas efficiency.
- The gasifier uses in-situ sulfur capture.
- The gasifier uses hot gas cleanup for particulates removal.
- There is air integration between the gasifier and gas turbine.

All the IGCC technologies except the SEB case have better heat rates than the PC plant. The difference between the FB case and PC plant is quite substantial. All the IGCC plants use less water than the PC plant.

Cost comparison of IGCC and PC plants

The capital requirements and costs of generation for the four IGCC cases in comparison with a PC plant both with and without FGD are given in table 2.

The DEB case has a very high capital requirement. This is because it has a very high operating temperature and requires very large and expensive waste heat boilers. The SEB case has about the same capital requirement as the DEB case because its lower plant efficiency requires substantially more coal to be processed.

The moving bed case has a lower capital requirement than the DEB and SEB cases because(i) it is air blown without the requirement of an expensive air separation plant and (2) the low product gas temperature from the gasifier minimizes the waste heat recovery requirement. The FB case has the lowest capital requirement because it operates at low temperature, uses in-bed sulfur capture and hot gas cleanup, and has no air separation plant.

All the IGCC cases are more capital intensive and have higher costs of generation than the PC plant without FGD. The FB and moving bed cases ,however, are cost competitive with the PC plant with FGD.

As IGCC plant usually consists of multiple trains it is expected to have a higher plant availability than the PC plant. A

preliminary availability analysis conducted in this study indicates that the present IGCC plant design can have 85% availability or about 7400 h/y plant operation. At this operating level the cost of generation in the FB case is actually lower than that of the PC plant without FGD.

Environmental aspects

One of the compelling reasons for seriously considering coal gasification for electric power generation is the capability of the gasification system to operate in an environmentally acceptable manner. Emissions from the IGCC and PC Plants are given in Table 3. When compared with the current air emission standards in India , the emissions from the IGCC plants are well below the standards. Compared to emissions from the PC plant the IGCC is far superior in environmental performance.

Overall ranking of IGCC technologies

In addition to the plant performance and economics, an overall ranking of the four IGCC technologies is done based on fifteen criteria grouped under three major categories, process, performance and cost. The ranking is indicated in table 4. The rating is based on a weight factor from 1 to 10 for each criterion and weighted average. A higher number means a better rating. The ranking obtained is in the order of fluidised bed, moving bed, dry entrained bed and slurry entrained bed.

RECOMMENDATIONS/CONCLUSIONS

This study had shown that IGCC is a viable power generation option for the high ash and high ash fusion temperature coals. In comparison with PC plant, it has superior heat rate at comparable cost of generation. In addition to the better heat rate, IGCC also offers lower emissions, less water consumption , higher plant availability, and flexibilities for modular construction and phased construction.

Among the four IGCC technologies, the FB gasifier is more attractive to use for the high ash Indian coal. The FB gasifier, however, has several technical uncertainties. This gasifier has been proven only on a pilot scale. The inbed sulfur capture and hot gas particulates removal are yet to be demonstrated at the confidence level. The ability to achieve a high carbon conversion in the ash sulfation has not been demonstrated.

The moving bed gasifier, is commercially proven and has been tested for Indian coal. Even though it is less efficient and more costly than the fluidized bed technology, it is considered equally attractive to use for the high ash Indian coal.

The DEB technology has an attractive heat rate. But it has a very high capital requirement.

One of the recommendations emanating from the study is to setup demonstration plant at an appropriate location, as a first step in the commercialisation plan of IGCC in the country. It is proposed to setup the plant in an existing thermal power plant so as to utilise the available infrasructure to the extent possible and thus reduce the capital cost of the demonstration plant.

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Table: 1

PLANT PERFORMANCE COMPARISON

	IGCC				PC	
	DEB	SEB	FB	MB	Without FGD	With FGD
Plant Resources Requirements Coal (as received),tpd	9,964	12,576	8,890	10,768	10,886	10,886
Limestone, tpd	618	0	280	0		
Raw Water, m3/h	1,324	2,224	1,019	1,698	2,754	3,000
Plant Output, MW Gross Power Generated						
Gas Turbine	392.20	396.50	350.40	368.30	0.00	0.00
Steam Turbine	308.40	258.00	280.20	271.80	600.00	600.00
Total	700.60	654.50	630.60	640.10	600.00	600.00
In Plant Power Consumption	136.20	158.30	53.40	54.40	42	51
Net Power to Grid	564.40	496.20	577.20	585.70	558.00	549.00
Heat Rate, Kcal/kwh	2,451	3,519	2,138	2,514	2,708	2,753
Overall Thermal Efficiency	35.10	24.40	40.20	34.20	31.80	31.20
Sulfur Byproduct, tpd	24	37	0	32	0	0

Table: 2

COST COMPARISON BETWEEN IGCC AND PC PLANTS

(4th Q, 1989 Pricing)

	IGCC Plant			PC Plant		
	DEB	SEB	FB	MB	Without FGD	With FGD
Net Power Output, MW	564.40	496.20	577.20	585.70	558.00	549.00
Total Capital Required, Rs. Crores	2,055	2,059	1,460	1,529	1,065	1,278
Unit Capital, Rs/kw net	36,418	41,500	25,292	26,103	19,084	23,276
Relative Unit Capital	1.56	1.78	1.09	1.12	0.82	Base
Cost of Generation, Paise/kwh						
@ 5500 h/y operation	146.00	170.20	103.80	115.50	86.70	102.20
@ 6000 h/y operation	135.40	158.10	96.50	107.60	81.40	95.60
@ 7000 h/y operation	118.80	139.20	85.00	95.30	73.00	85.40
@ 7400 h/y operation	113.40	133.00	81.30	91.30	70.30	82.10
Relative Cost of Generation (based on 5500 h/y operation)	1.43	1.67	1.02	1.13	0.85	Base

Table:3

PLANT EMISSIONS
IGCC Plant

	DEB	SEB	FB	MB	PC Plant
1. Nox emission kg/hr	419	435	411	410	2110
ug/Nm3	83	81	83	84	674
2. Sox emission kg/hr	40	337	480	218	2970
ug/Nm3	8	63	97	45	948
3. Particulates emission kg/hr	24	24	24	24	412
ug/Nm3	5	4.5	5	5	132
4. Treated process waste water - m^3/hr	41	82	-	-	200

CURRENT AIR EMISSION STANDARDS IN INDIA

(in micrograms/Nm3 ambient air at a distance of 20 times the stack height)

	Industrial area	Resd. & rural area	Sensitive area
SO_2	120	80	30
NOx	120	80	30
Particulates	500	200	100

Table:4

OVERALL RANKING OF IGCC TECNOLOGIES

Weight Factor		DEB	SEB	FB	MB
	Process				
10	1. Maturity	7	10	4	10
7	2. Scale-up Risk	10	10	5	10
5	3. Capacity per Gasifier	10	6	8	2
10	4. Suitability for High Ash Coal.	5	1	10	8
7	5. Cope with High Ash Fusion Temp.	5	3	8	10
5	6. Cope with High Coal Moisture	6	10	8	10
7	7. Coal Size Requirement	10	10	10	2
5	8. Need for Special Equipment.	6	7	3	6
10	9. Auxiliary Power Consumption	5	3	10	10
7	10. Load Following Capability	10	10	8	5
	Weighted Average.	7.2	6.7	7.6	7.7
	Performance				
10	11. Heat Rate	7	2	10	5
5	12. Raw Water Consumption	7	2	10	7
5	13. Quantity of Solid Waste	8	7	4	3
	Weighted Average	7.3	3.3	8.5	5
	Cost				
10	14. Capital	3	2	10	8
10	15. Cost of Generation	5	3	10	8
	Weighted Average	4	2.5	10	8
	Summary				
7	Process	7.2	6.7	7.6	7.7
10	Performance	7.3	3.3	8.5	5
7	Cost	4	2.5	10	8
	Weighted Average	6.3	4	8.7	6.7

Indirect Coal Liquefaction Via Fischer-Tropsch Technology For The Baseload IGCC Plant

by
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IEA Second International Conference on The Clean and Efficient Use of Coal & Lignite: Its Role in Energy, Environment and Life
Nov. 30 - Dec. 3, 1993
Hong Kong

Introduction

Integrated Gasification Combined Cycle (IGCC) is an emerging technology for electric power generation from coal with minimum impact on the environment. Power is generated efficiently by a combination of syngas-driven gas turbines and steam turbines. Studies have shown that the capital cost of an IGCC plant is relatively high when compared to a natural-gas-fired combined cycle plant while its variable operating costs are comparatively low because coal is a lower priced feed stock.

Results from various IGCC coproduction studies conducted by Bechtel [1,2] and others [3,4,11] have indicated that the economical feasibility of an IGCC plant can be enhanced with the coproduction of methanol, liquid hydrogen, ammonia, and urea. Favorable IGCC economics are achieved through the use of a spare gasifier to improve reliability and coproduction to increase utilization of the coal gasification facility.

In a study sponsored by FPL and EPRI, Bechtel investigated the addition of an operating spare gasification train with methanol coproduction from the syngas in order to improve the reliability of a baseload electric power plant [1]. This spare train will be used to produce methanol and fully load the CC plant when other gasifier trains are in operation. As shown in Figure 1, the plant equivalent availability is improved from 86% to 90% through the use of a spare gasification train. With the coproduct(s) as backup fuel, the power block can stay on-stream when one or more gasifiers are out of service. The resulting plant equivalent availability will be similar to that in a natural gas-based combined cycle plant (93%).

The results of this 1992 study also indicate that the cost of the spare gasifier is offset by the improved plant availability and the methanol by-product credit. Coproduction of hydrocarbons via Fischer-Tropsch (F-T) technology is a logical alternative to methanol coproduction because it can offer synergistic effects similar to those in the methanol coproduction scheme. Bechtel is currently carrying out a Baseline Design/Economics Study for the DOE/PETC on indirect coal liquefaction using advanced F-T technology [2].

In a separate study sponsored by Dakota Gasification Company (DGC) as part of their Clean Coal Technology V proposal, Bechtel also investigated a once-through F-T design. Due to the restriction of the existing gas contract, the F-T products (liquid transportation fuels) and the substitute natural gas (SNG) are the coproducts of the DGC proposed demonstration plant.

Some of the results from the above studies are presented in this paper in order to illustrate how the employment of the advanced F-T technology may benefit a baseload IGCC plant.

High-Wax-Yield Fischer-Tropsch Synthesis

Since 1980, the U.S. DOE has sponsored a series of tests and engineering studies on high-wax-yield, slurry-reactor F-T processing (plus wax hydrocracking) as an efficient and cost

effective means of producing high quality distillate hydrocarbon fuels from coal. It now appears that by fluid catalytic cracking of the wax, high yields of the chemical intermediates for reformulated gasoline components such as alkylate and MTBE (methyl tertiary butyl ether) can be produced as well.

Because F-T synthesis generally follows the Schulz-Flory-Anderson molecular weight distribution, operation at high wax yield maximizes liquid yield and minimizes gas yield. The liquid product can be hydrotreated and reformed to produce a satisfactory gasoline. The product wax has a wide carbon number range and the average carbon number of the wax produced in a 50% wax yield operation was shown by Mobil to be well over 60. This wax is readily converted to lighter materials by thermal cracking, hydrocracking or fluid-bed catalytic cracking. Hydrocracker operation has been demonstrated by Universal Oil Products [5], Mobil [6], and Pittsburgh Applied Research Corporation [7], and leads to high yields of a low pour point distillate having an excellent cetane number. Fluid-Bed Catalytic Cracking has been demonstrated by Mobil [6] and Amoco [8], and can be directed at maximizing C_4 production. These C_4s can then be used to supplement refinery butane/butylenes in the production of alkylate and MTBE.

Another alternative is a two-step operation, as demonstrated by Mobil [9], in which the vapors containing most of the C_{20} minus materials are passed to a ZSM-5 reactor where they are converted to a high quality gasoline. The wax is handled in the same manner as above.

The slurry reactor is essentially a bubble column reactor where the liquid phase is a mixture of liquid wax and catalyst. The gas provides the necessary agitation for good mixing and mass transfer of reactants to, and products from, the liquid phase. A diagram showing one possible configuration of the internal cooling tubes is shown in Figure 2. While Shell Oil has elected to use a fixed-bed reactor in its new distillate plant in Malaysia, due to start up in 1993, studies have shown that the slurry reactor is potentially more attractive provided high catalyst concentration and high superficial velocities can be demonstrated [11].

The slurry reactor is a good selection for once-through processing because of its excellent heat transfer characteristics, but the need to design for high conversion (over 95% without co-production) puts a premium on the accurate prediction of axial dispersion effects (i.e. backmixing) on scale-up. Such effects were very important, for example, in the scale-up of the fluid-bed catalytic cracking process. So far the DOE has tested the slurry F-T reactor in the two-inch diameter Mobil pilot plant [9] and in the two-foot diameter LaPorte reactor [12]. Some earlier runs were also made by Rheinprüssen [13] in a four-foot diameter reactor but these were on another catalyst and are difficult to interpret. The design of a once-through, F-T slurry reactor at over 80% conversion is difficult with present knowledge. This is not a problem, however, when power is coproduced and conversions less than 80% are practical.

The slurry reactor is also the best choice for operation on the low H_2/CO ratio syngas produced in modern coal gasifiers such as those of Destec, Shell and Texaco. The rationale is as follows:

1. Low H_2/CO ratio can lead to carbon formation via the Boudouard reaction:

$$2CO \rightarrow CO_2 + C \downarrow$$

   A slurry reactor, however, raises the H_2/CO ratio that the catalyst actually sees owing to the preferential mass transfer coefficient into the liquid phase.
2. Even if some carbon formation does occur, the slurry reactor may still be viable.

3. Catalyst deactivation can be handled by means of periodic catalyst withdrawal and addition, whereas replacement of fixed-bed catalyst requires a shutdown.
4. High wax production requires low reaction temperatures. Because of uniform temperatures and catalyst replacement, a slurry reactor can be run continuously at the end of run temperature for the fixed-bed reactor and give equivalent yield distribution. This gives both high reactor productivity and the potential for higher pressure steam generation.

The IGCC/Fischer-Tropsch Coproduction Facility

The block flow diagrams of a stand-alone F-T plant for the production of liquid transportation fuels and an IGCC/once-through F-T coproduction plant are shown in Figures 3 and 4, respectively. As shown in these plant configurations, the costly recycle compressors and steps such as CO_2 removal, deep cryogenic recovery of light ends and autothermal reforming are not needed in the once-through F-T coproduction plant. Additional saving is achieved through the use of 95% purity oxygen rather than 99.5%.

The analysis of the design coal is shown in Table 1. Any modern gasifier, such as Shell, Destec, or Texaco could be considered for this design because they are proven, highly efficient gasifiers, producing inert slags which have uses as an aggregate or for road building.

Coal, oxygen, and steam are fed to the coal gasifiers and converted into a raw syngas that is a mixture of hydrogen, carbon monoxide, carbon dioxide, methane, and other trace gases, plus contaminants such as hydrogen sulfide, heavy hydrocarbons, and ammonia. The raw gas passes to a series of units where heat is recovered by steam generation and the contaminants are removed. The clean syngas then passes to the F-T synthesis section, where liquid products are formed by a catalytic reaction between CO and H_2. The operation is once-through, without recycle. Additional intermediate pressure steam is generated in the cooling coils of the F-T reactor. Since the catalyst is very sensitive to trace contaminants, especially sulfur, the gas must be highly purified, down to 1 ppm sulfur, before it enters the F-T synthesis section.

F-T reactor liquid (i.e. the wax fraction) is separated from the catalyst slurry, which is returned to the reactor, and sent to the wax hydrocracker. F-T reactor effluent vapor is combined with the wax hydrocracker vapor and sent to the gas plant where it is cooled to -80 °F to separate out the unconverted syngas, and the liquids are sent to the fractionator, where distillates, naphtha, LPG and fuel gas are produced. The naphtha and LPG are stored and primarily used internally as gas turbine fuel to supplement syngas when a coal gasifier is shutdown. The distillates are marketed commercially along with any excess naphtha and LPG.

A slip stream of the unconverted syngas from the gas plant is cooled in cryogenic exchangers, hydrogen is recovered for use in the wax hydrocracker, and the remaining gas is sent to the gas turbines where a little over 40% of the total power is generated. The remainder comes from steam turbines using steam generated and superheated in the heat recovery steam generator (HRSG) downstream of the gas turbine. By-product steam from the gasifier outlet coolers and from the F-T reactors is also superheated in the HRSG and any excess, above that required internally, is used for power generation.

The design basis of the coproduction plant is for ten operating coal gasifiers with four 24-foot diameter F-T reactors, two gas turbines, two steam turbines and two HRSG's. The feed rate of as-received coal and the output capacity of the plant are as follows:

Coal Feed Rate, STPD (basis: as received)	19,000	
Products	45 °F Ambient	95 °F Ambient
Net Power, MW	882	911
LPG, BPD	4,244	4,375
Naphtha, BPD	14,091	14,526
Diesel, BPD	17,527	18,067
Total F-T Liquid, BPD	35,862	36,968
Sulfur, STPD	426	

The gas turbines will have a higher capacity in the winter time (ambient 45 °F) than in the summer time (ambient 95 °F). The gasifiers are sized for the highest gas turbine capacity (45 °F ambient). The excess synthesis gas at 95 °F ambient is consumed by raising the synthesis gas conversion in the F-T reactors from 77% to 79%. This requires only an additional 3 foot of reactor height, but the gas turbines are kept fully loaded year round. (Alternatively, it would have been possible to lower liquid production and keep the syngas to the gas turbines constant by lowering conversion in the F-T reactors. This is less desirable because of the effect on the gas plant which would have to be oversized.)

The gasifiers typically have an on-stream factor of 86%. Stored naphtha and LPG are available as supplemental fuels when one gasifier or more is off line. Thus the overall plant availability is raised to 93%.

High Quality Distillate Fuels from Coal

The F-T process incorporating a hydrocracker will produce storable and transportable distillate fuels from coal which are of superior quality. Acceptable gasoline can be produced from the lighter products but only after extensive processing. In a co-production facility, the naphtha and LPG cuts are used as environmentally superior, storable liquid fuels to improve the reliability and availability of the base load IGCC power plant.

The economic production of large quantities of high quality F-T distillates should prove attractive to refiners who will purchase these distillates in order to blend off lower quality streams and increase production. There will also be a market for the LPG in refineries where it can be used to supplement refinery C_3/C_4 streams for alkylate and MTBE production. The naphtha also has refinery feedstock value as feed to the hydrotreater/catalytic reformer.

Bechtel's linear programming modeling tool, PIMS (Process Industry Modeling Systems) was used to determine the values for the F-T products when they are blended wih petroleum-derived stocks to produce specification gasoline and diesel duels. The PIMS model was developed to represent a generic Midwest (PADD II) petroleum refinery in the year 2000 (the earliest a F-T liquefaction plant could possibly be constructed and operated). Provisions were provided to allow the refinery to expand the capacity of numerous upgrading operations such as hydrotreating and oxygenate production, in order to meet the stringent fuel specifications dictated by the Clean Air Act Amendments (CAAA) of 1990.

Economic Analysis

The benefits of methanol coproduction to a baseload IGCC plant is illustrated in Figure 5. The capital cost of an IGCC/methanol plant is higher than that of the IGCC-only plant because of the spare gasifier and the methanol plant. However, the cost of electricity (COE) is slightly lower with the IGCC/methanol coproduction plant due to higher plant availability and methanol byproduct credit.

Similar incremental benefits of the coproduction concept can also been illustrated with a once-through F-T plant sharing the common coal gasification with a baseload IGCC plant. The plant costs of the IGCC/F-T co-production facility and for the stand-alone IGCC power plant have been developed and compared in the following manner:

(1) The process design (except the plant sizes) of the coal gasification and combined cycle unit for these two plants are similar.
(2) The cost of electricity (COE) for the IGCC-only plant is first determined under standard financial assumptions as given in Table 2 and at the estimated 86% plant availability.
(3) The economic viability of the IGCC/F-T facility is evaluated by determining the required liquid product prices so that the COE from the IGCC/F-T case is the same as that from the IGCC-only case.
(4) The estimated plant availability of the IGCC/F-T plant is 93% which is equivalent to that of a natural gas-based combined cycle plant.
(5) The required F-T liquid price is compared under different assumptions with the base case price given in Table 2.

The base case prices for the products are based on the current market prices for petroleum products with crude oil at $20 per barrel. The diesel price of $32.34 per barrel is a mean value when a premium is assigned for the near zero sulfur content and high cetane value of the F-T product. A separate premium for the low aromatic content is not included. The range of values used in deriving this average was obtained from several preliminary linear program model analyses and varied from $30 to $39 per barrel.

With the financial assumptions and bases described above, the COE from the IGCC-only case is estimated at 41.8 mills per kWh. The effects of the market price of F-T derived diesel on the COE from the IGCC/F-T facility are shown in Figure 6. As shown, the co-production case can produce electric power at 41.8 mills per kWh if the market value of the F-T derived diesel is at $36.70 per barrel (87 cents per gallon). The preliminary results of the linear program analysis indicate that the value of the F-T diesel may range from $30 to $39 per barrel. The diesel value is a function of the premium it may capture for its superior qualities (no sulfur, low aromatic, and high cetane).

Discussion

Results presented in this paper indicate that IGCC/methanol coproduction concept helps to justify the spare gasifier which enhances the reliability and availability of the combined cycle plant. Additonal data further illustrate that the once-through F-T process with a slurry reactor design is an attractive alternative to the methanol synthesis process for an IGCC co-production plant. However, the following issues should be investigated in order to verify this conclusion and further quantify the economical viability of the once-through F-T concept and the related production cost of the F-T liquid products:

(1) Maximum single F-T slurry reactor size;
(2) F-T product property data for the determination of their premium values;
(3) F-T liquid product prices on a site-specific basis;
(4) Off-site plant cost;
(5) Optimum F-T product upgrading scheme; and
(6) Coproduction of higher-value byproducts, such as C_3, C_4, and C_5 olefins.

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Table 1 Design Coal Analysis

Proximate Analysis, wt%	As Rec'd
Moisture	5.5
Volatile Matter	37.0
Fixed Carbon	50.5
Ash	7.0
Total	100.0
Ultimate Analysis, wt%	
Carbon	72.35
Hydrogen	4.97
Sulfur	3.20
Oxygen	5.56
Nitrogen	1.36
Ash	7.00
Chloride	0.06
Water	5.50
Total	100.00
Higher Heating Value, Btu/lb	13,250

Table 2 Financial Assumptions

Source of Capital		Rate of Return
Common Equity	45%	13.4%
Preferred Stock	10%	10.0%
Debt	45%	10.0%
Federal and State Income Taxes	38%	
Book Life, yrs	30	
Tax Life, yrs	20	
Initial Year of Construction	1992	
Beginning of Commercial Operation	1996	
Allocation of PFI over Construction Period	15, 25, 35, 25	
	Unit Cost	Escalation
PFI Escalation		5.25%
General Inflation		5.25%
Feed/Product Cost & Escalation		
Coal Feed	$37/ton	5.25%
LNG	$21/Bbl	5.50%
Naphtha	$24/Bbl	5.50%
Distillate (Diesel)	$32.34/Bbl	5.50%
Sulfur	$90/ton	5.25%

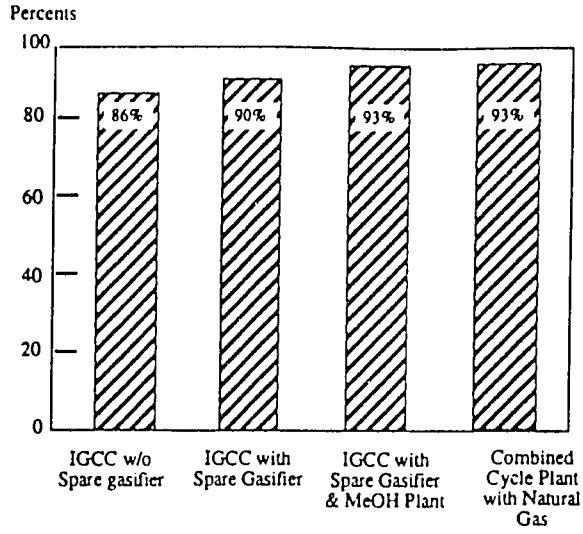

Figure 1 Plant Equivalent Availability

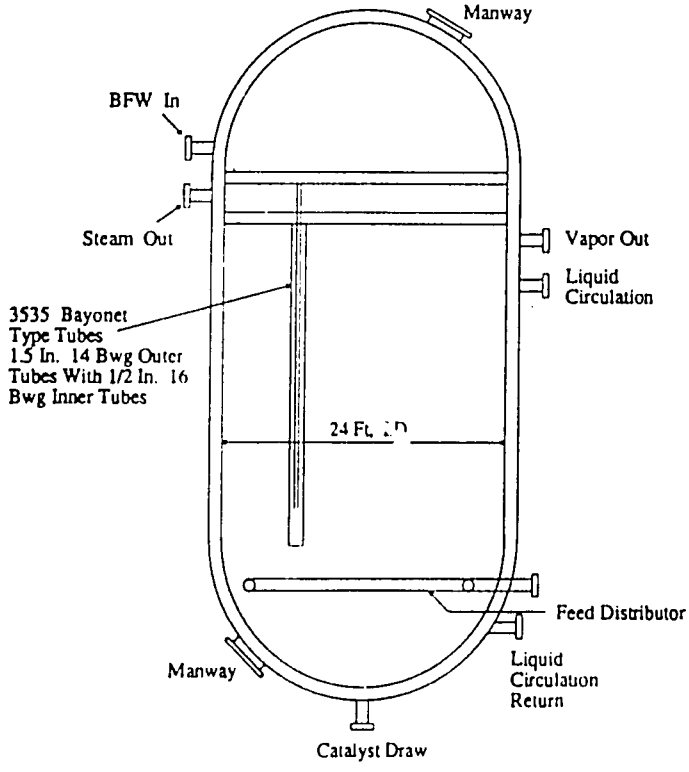

Figure 2 Slurry Fischer-Tropsch Reactor

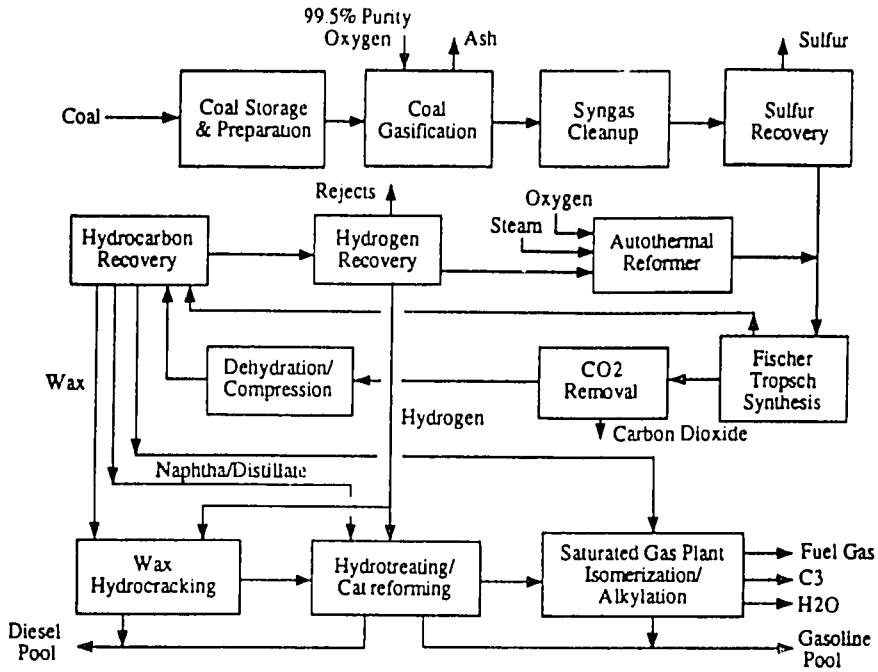

Figure 3 Block Flow Diagram Showing Typical Indirect Coal Liquefaction Process Via F-T Technology

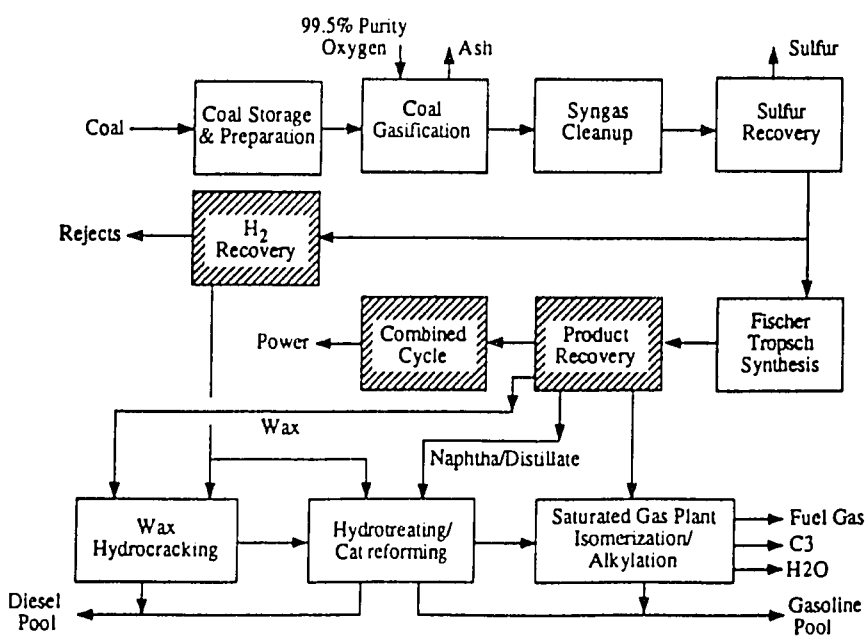

Figure 4 Block Flow Diagram Showing Typical IGCC/Once-Through F-T Coproduction Plant

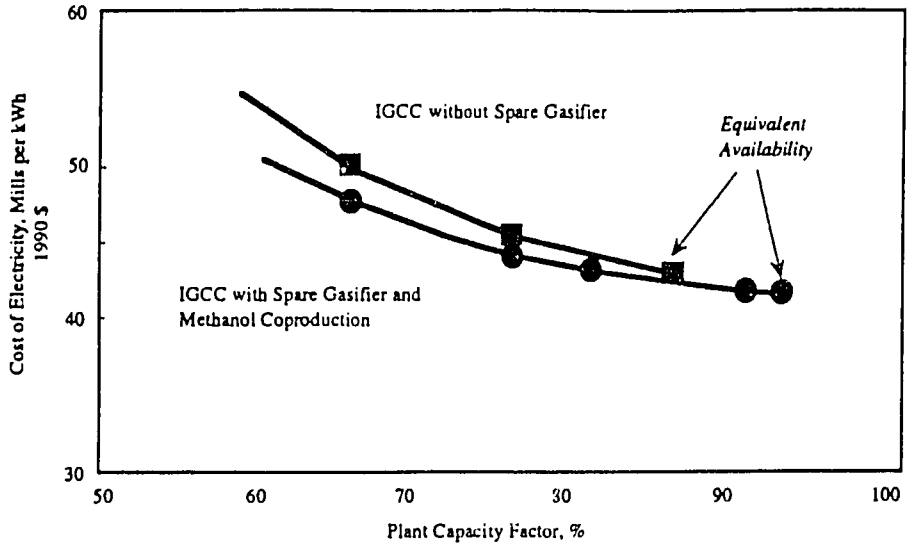

Figure 5 Cost of Electricity

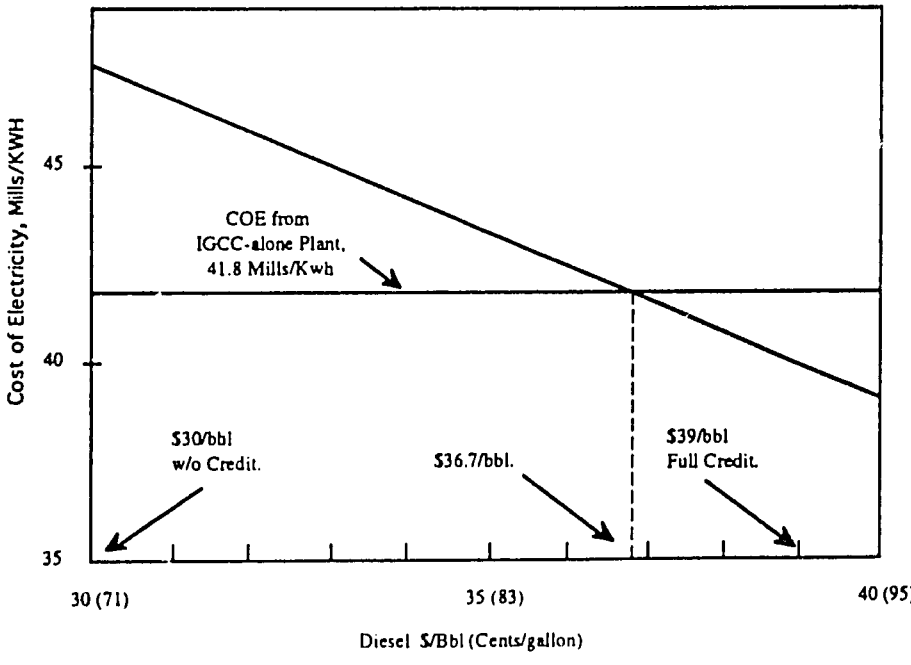

Figure 6 Effect of Diesel Price on COE from IGCC/F-T Plant

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CONTROL OF SO2 AND NOx EMISSIONS FROM FOSSIL POWER PLANTS:

RESEARCH AND PRACTICE OF TPRI

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ABSTRACT

It is presented in the paper, the current status and the future prediction, to the end of this century, of SO2 and NOx emissions from fossil power plants in China. The research work carried out by TPRI in the development of CFBC, LDI and PAFP for SO2 removal, and two practical examples of low NOx combustion are briefly introduced.

1. The Current Status and The Future Prediction of SO2 Emission

The composition of electric power in China has been dominated by coal for many years. By the end of 1990, total installed generating capacity reached 135.0 GW, of which fossil-feul-fired power plants accounted for 74 percent; the total electricity generated reached 615 TWh, with fossil feuls accounting for 80.5 percent ; and about 276 million tons of raw coal was consumed in the year in these fossil-fuel-burning units, accounting for some 25 percent of the total output of the country. According to the state planning , by the year of 2000, the total installed capacity of Chinese power systems should be at least 240 GW, of which the fossil part will account for about 77 percent ; and the coal required for power generation will increase to about 530 million tons per year, accounting for about 38 percent of the total output. So, it is obvious that coal consumed in fossil-fuel-fired power plants occupies a very important place in the national fuel balance, and the distribution of sulfur contents in the coal burned and thus the SO2 emissions from these power plants will also influence the SO2 air pollusion of the whole country in a decisive manner.

Figure 1 shows a statistical classification of the sulfur contents of the coal burned in the main fossil power plants in China at present and the variation trends in the future. As shown in the figure, in 1990, coals having sulfur content less than 1

percent accounted for about 45 percent of the total for power generation; sulsur content of 1 to 2 percent -- about 40 percent; and sulfur content greater than 2 percent -- about 15 percent. However, these some 15 percent high sulfur content coal is mainly distributed over the provinces of Guangxi, Gueizhou, Shaanxi, Shichuan and Jiangxi etc. The average sulfur contents of the coals burned for power generation in these provinces are 4.18 percent in Guangxi, 2.94 percent in Gueizhou, 2.44 percent in Shaanxi, 2.39 percent in Shichuan, and 1.95 percent in Jiangxi. For statistics over the whole country, the average sulfur content of the coal fired for power generation was 1.23 percent in 1990. Based on this figue, the total amount of SO2 formed from fossil power plants in China was about 5.5 million tons per year.

Due to the practical limitation of Chinese economy, most of the fossiled power plants have not yet been equipped with effective SO2 removal devices. As a result, large areas of the country have been polluted seriously by SO2, and some of them even by acid rain. In the south-western part of China, the provinces of Guangxi, Gueizhou and Shichuan, where high sulfur coal is used, is considered now as the third biggest area of acid rain in the world. It is estimated that the economic loss caused by that amounts some 16 billion Yuan (USD 2.77 billions) every year.

According to a prediction, the coal which will be used by the new units constructed during the Eighth and Ninth Five-year plans has relatively lower sulfur content, resulting in a slightly decrease of the average sulfur content of coal burned for power generation over the whole country, as 1.21 percent for 1995 and 1.19 percent for 2000. Nevertherless, due to the rapid increace of the installed capacity of coal fired units, the total amount of SO2 formed in these power plants in the year of 2000 will still increase to about 10.5 million tons. If there are no effective measures to be taken immediately, the result will be unmanageable.

For this reason, a control target has been set by the Chinese State Bureau of Environmental Protection in which the total amount of SO2 emission from all the fossil power plants in the year of 2000 should remain at a constant level of 1990. This entails that SO2 removal equipment with a total reduction capacity of about 5 million tons of SO2 per year must be installed for power generation by the year of 2000. In order to speed up fund raising, the Environmental Protection Committee of the State Council has recently passed in principle a plan for imposing duties on SO2 emissions, which will be tried out in some provinces and cities first. This is not only a very important and heavy task to the Chinese environment protection workers , but also provides a broad and attractive market for the environmental protection industry of China, and that of the world as well.

On the other hand, it is obvious that to meet planned emission standards, different degrees of SO2 removal will be required for coals with different sulfur contents. Considering the practical situation of China and the general control target by the year of 2000, it is expected that the Chinese power plant SO2 emission standards will be getting more strict as time goes on , but will not reach the advanced level of industrialized countries in a short time. If a doubled SO2 emission threshold in Germany (400 mg/m3) was adopted in China (800 mg/m3), and calculations were based on the total installed capacity of coal fired units in 1990, then about 36 percent of the coal-fired units would require SO2 removal efficiencies of less than 60 percent, and 47 percent units would require efficiencies of 60 to 80 percent, while only 17 percent would require SO2 removal greater than 80 percent. The corresponding

efficiencies for the new units constructed during the 1990 to 2000 period would be 33 percent, 56 percent and 11 percent respectively. So, it will be of great economic significance to develop and disseminate different types of SO2 removal technologies, especially the technologies of SO2 capture within furnaces which are featured by relatively lower capital investment, so as to meet the different SO2 removal required.

2. SO2 Removal within Furnaces -- CFBC & LDI

Though flue gas desulfurization technology with limestone scrrubing is quite mature in abroad, for the tremendous capital investment required (about 20 to 30 percent of the total for the power plant), it would be difficult to be disseminated in China over the whole country in a short time. Thus, besides conditional applications of the technology in areas where high sulfur content coal is burned, great emphysis should be given to the development of in-furnace SO2 removal technologies, such as Circulating Fluidized Bed Combustion (CFBC) and Limestone Direct Injection into furnace for SO2 capture (LDI).

2.1 CFBC

CFBC is a newly developed clean and efficient combustion technology. Due to its high efficiency competitive with pulverized coal combustion, lower emissions of SO2 and NOx, higher adaptability to coal type, easiness for multi-purpuse use of ash, etc., this technology has recieved great attention from countries all over the world, and thus developed quite fast.

Because of a later starting, the present technical development of CFBC boiler in China is some lagging behind compared with the advanced level in the world. By the end of the Seventh Five-year Plan, a number of CFBC boilers with steam capacities of 35-65 t/h had been manufactured with the joint efforts of universities, research institutes and boiler workses and put into operation already. The capacity rank, operation reliability, and performance indices reached or approximated the levels in advanced countries 5-10 years ago; however, most of them were not equipped with SO2 removal systems.

In order to speed up the application and dissemination of the technology in utility power plants and to shorten the technical distance between China and the advanced countries in the area, TPRI suggested several years ago to the former Department of Energy and the State Committee of Planning to import a CFBC boiler with a capacity around 100 MWe for demonstration. Now, a project with joint responsibilities of the Electric Bureau of Shichuan Province and the TPRI, which aimes to purchase a set of Pyroflow boiler of 410 t/h and to install that in the Neijiang Power Plant, is undergoing smoothly.

To get a better understanding of the combustion characteristics of the coals and the SO2 capture capability of the limestone to be used, a series of combustion / SO2 removal tests were carried out at a small CFBC test rig in TPRI for two coals (design coal : Nanchuan, check coal : Furong) and three limestones.

Figure 2 shows a schematic diagram of the test rig. Figure 3 and Figue 4 show the influences of bed temperature on the combustion efficiency and the SO2 capture

respectively; while Figure 5, Figure 6 and Figure 7 -- the influences of Ca/S mole ratio on the efficiency of SO2 removal, the free CaO content in fly ash, and the resistibility of that, too.

The main conclusions obtained from the test are as follows:

1) The project coals, Nanchuan coal and Furong coal, both belong to the difficult burning, low reactivity coal. To ensure a high combustion efficiency of the demonstration unit, it is necessary to increase the furnace height and to raise the bed temperature to a certain extent.

2) Limestone-A has relatively high SO2 capture capability. When burning Nanchuan coal with Ca/S ratio of 2.2, the SO2 removal efficiency reached 94 percent, and the concentration of SO2 emitted was about 460 mg/m3 .

3) After desulfurization with lomestone, the resistibility of fly ash increases greatly. When the Ca/S ratio equals 2.2, the resistibility at 150 oC reaches 10^14 ohm.cm , which exceeds greatly the working limit of normal temperature ESP. So, it is probable that the Neijiang Project has to use some sort of high temperature ESP.

Additionally, a newly built 1 MW CFBC Test Facility with a net furnace height of 23 m has been put into operation recently at TPRI, and further testing of the coals / limestones of Neijiang Project has been carried out in the facility. The detailed experimental results are being compiled now.

2.2 LDI

The injection of limestone powder directly into a furnace for SO2 capture is a long standing idea. In the 1960s, a number of experiments were carried out in laboratories and at utility boilers as well by the United States, Japan, and some European countries, while the SO2 removal efficiency was only about 20 percent. In the mid-70s, due to large amount of experimental work carried in pilot scale test facilities, the efficiency reached 50 percent, then the technology received wide attention from people again. After that, several LDI processes with moisturized activation reactors were developed, such as LIFAC, in which the SO2 removal efficiency reached 55 to 85 percent with a Ca/S mole ratio of 2.0 . Thus, LDI becomes gradualy a commercially applicable technology for SO2 removal.

In order to solve the problem of low temperature corrosion of oil fired boilers when high sulfur oils were used, a TPRI research project was carried out in the mid-60s in China, in which dolomite powders were injected directly into a furnace to reduce flue-gas SO3 concentrations. The process was tested in a 65 t/h oil fired utility boiler in Shanghai, and expected results were obtained. Then in late-80s, to coordinate with a feasibility study of SO2 removal retrofit for high sulfur coal burning in the Chongqing Power Plant, a simulation test of LDI was carried out at the institute.

Figure 8 shows a schematic diagram of the simulation test system. Figure 9 gives the main results of the simulation test. In the figure, @ denotes the result for the case of 1150 oC at injection point without moisturization. As shown in the figure, the SO2 removal efficiency increases from 21 to 48 percent with the Ca/S ratio increasing from 1.0 to 3.0 . In the same figure, O gives the result with moisture adding for used CaO activation. In the case where Ca/S equals 1.5, relative humidity is 24.4 percent,

and residance time is 7.5 s, SO2 removal efficiency reaches 42 percent, which is obviously higher than that of the case without moisturization.

For further development of the complete technology of LDI, the 1 MW Pulverized Coal Combustion Test Facility of TPRI has been modified for LDI test, including adding an activative reaction duct, etc. As cooperating organizations of the project, the Tsinghua University and the Nanjing Environmental Protection Institute will be responsible for the cold model test of the activation reactor and the selection of sorbents, respectively. All the experimental work is expected to be finished by the end of this year.

3. Flue Gas Desulfurization -- PAFP

SO2 removal in coal fired power plants is an additional money consuming project. The way to reduce the additional investment is to either develop the technology with low capital cost, such as CFBC and LDI, or to raise the utilization values of byproducts from the processes to compensate partly the cost for SO2 removal by the sales gain of these byproducts.

The Phosphate Ammonium Fertilizer Process (PAFP) is a noval flue gas desulfurization process developed by TPRI with the aim of byproduct selling. The research project was listed as a National Key Science and Technology Project of the Seventh Five-year Plan of the country in 1986, of which the objective assigned was to fulfil a pilot plant test with a flue gas treatment capacity of 5000 m3/h.

The pilot scale test plant was built at a by-pass gas duct of a wet bottom boiler of 410 t/h in the Douba Power Plant, Shichuan. A local anthracite of Furong with a sulfur content of 3.7 percent was used.

The schematic diagram of the pilot plant system is shown in Figure 10 with the upper half for flue gas desulfurization and the lower half for fertilizer production. The main technological processes are as the follows.

After dedusting to ash concentration of below 200 mg/m3, the SO2 containing flue gas is presuerised to about 7 kPa, then enters a Venturi for temperature and humidity adjustment. Thereafter, the flue gas is delivered to a SO2 absorbtion tower group consisting of 4 parallel activated carbon sorbors, of which one is used periodically for regeneration to ensure over 70 percent of primary SO2 reduction rate maintained. From this process, sulfuric acid of some 30 percent concentration is obtained. The SO2 remainder in the gas is then captured once more in a phosphate ammonium scrruber. By means of continuous ammonia-adding adjustment, the final SO2 removal efficiency will be kept at over 95 percent.

The dilute acid from carbon beds is used to extract ground phosphate rock to make phosphoric acid, to which ammonia is added to form liquid phosphate ammonium as the secondary SO2 removal agent. Then, the reactant is oxidized, concentrated and finally dried into solid fertilizer as the terminal byproduct.

The technical basis of PAFP is sulfuric acid production through the catalytic desulfurization of activated carbon. Therefore, high efficiency and low cost activated

carbon will be the key material for the successful application of this process. Through detailed screening tests, a corncab-based carbon was finally selected and used in the process, of which the performance of SO2 reduction excels some iodated anthracite-based carbons while the cost is lowered by 30 to 40 percent of the latter.

During the time of 2000 hrs appraisal operation, the assigned technical indicies of over 95 percent sulfur reduction rate, over 90 percent decomposition rate of ground phosphate rock, and over 35 percent (N+P2O5) furtilizer grade were achieved. Till now, the pilot plant has accumulatively run more than 10000 hours, producing several dozens tons of qualified phosphate ammonium fertilizers. This opens a new economically feasible way of desulfurization for power plants burning high sulfur content coal of St > 2.5 percent in China.

Based on the results obtained from the appraisal operation, a budgetary estimation for a PAFP installation with a gas treatment rate of 450000 m3/h, an SO2 concentration of 7150 mg/m3, and an annual operation time of 6500 hrs was conducted. In addition to about 20 thousand tons of SO2 reduction, the plant can provide agriculture with over 27 thousand tons of phosphate ammonium fertilizer valued some 23 million Yuan (USD 3.98 millions) every year. After deducting the turn back cost of the initial PAFP investment, a net profit of over 7 million Yuan (USD 1.21 millions) will be obtained.

4. NOx Emission and Its Control

4.1 Present status of NOx emission from utility boilers

In order to comprehend the present status of NOx emission from utility boilers in China and to provide a scientific basis for relevant standard formulation, a survey of the levels of NOx emissions from utility boilers using different burning systems in China was conducted by TPRI in the mid-80s. Emphysis of the survey was on the coal fired utility boilers with capacities over 100 MWe; nevertherless, NOx emissions from some small coal fired units in densely populated areas and a few oil fired boilers were also investigated. Detailed measurements were conducted at total 59 boilers, including 44 from domestic boiler works and 15 imported from abroad.

Figure 11 shows the NOx emission data from the survey, which is scattered to some extent, but is mostly in the range of 600 to 1200 mg/m3 with the most dense area of 700 to 900 mg/m3.

Figures 12, 13 and 14 reflect the influences of coal type, volumatric furnace load, and burner type on NOx emissions respsctively.

The prelimilary conclusions from the survey are as follows:

1) Generally speaking, NOx emissions from the units burning anthracite and lignite are lower than those of burning lean and buituminenous coal. This is probably related with the lower peak temperature of anthracite flame due to its lower reactivity, and the lower furnace temperature when burning lignite due to its relatively high moisture content.

2) NOx emission increases with increase in volumatric furnace load. Obviously, this is because that higher furnace load leads to higher furnace temperature.

3) NOx emissions from corner firing furnaces are generally lower than those from wall firing ones. This is mainly due to the reducing atmosphere formed after ignition which is caused by the lower mixing rate in corner jet burners, and the lower peak temperature of flame in corner firing furnaces.

Based on these measurement data, the total amount of NOx emitted from utility boilers in China in 1988 is estimated at about 1.5 million tons; and will increase at a rate of about 34 thousands tons of NOx per 10 TWh of electricity generated. If there are no measures taken immidiately, the yearly NOx emission would possibly exceed 3 million tons by the end of this century. Therefore, the task of NOx control is also very heavy and urgent.

4.2 Practical examples of low NOx combustion

Air staging is one of the low NOx measures easest to apply. In abroad, it is not seldom to see that deviated secondary air and over firing air are used in tangentially fired utility boilers for low NOx combustion through creating a reduing atmosphere unfavourable to NOx formation in the firing ball.

For experience gathering in this field, TPRI conducted a low NOx combustion retrofit to a 220 t/h boiler in Xigu Power Plant in 1989. The schematic diagram of the burner structure after retrofit and its arrangement in the horizontal cross section of the furnace are shown in Figure 15. As can be seen in the figure, the middle and upper nozzles of secondary air are modified to horizontally deviated ones with turning vanes of 15 degrees in maximum, while the lower one remains unchanged to avoid segregation of coal particles from air streams. Also, a set of over firing air nozzles are added at a distance of 2250 mm over the central lines of the upper primary air nozzles.

The retrofit proved to be very effective, that a 25 percent NOx reduction was reached without a noticeable increase in carbon loss. Presently, the NOx emission level of this boiler holds around 600 mg/m3, and the slagging problem is also alleviated when coals with lower ash fusing temperatures are used.

The two boilers of 1025 t/h made by Shanghai Boiler Works, which are installed in the Wujing Power Plant, Shanghai, are other examples of applying this technology. TPRI was involved in the regulation test and the appraisal test of these two boilers. The combustion systems of the boilers are featured by: i) application of 'lean - rich' burners with coal segregation by elbows; ii) reversely tangentialed primary and secondary air supplied; and iii) the over firing air. The schematic diagram of 'reversely tangential firing' is shown in Figure 16.

The test resuls of NOx emission from these boilers are ranged from 400 to 500 mg/m3, showing high effectiveness of the measures taken.

ACKNOLEDGMENTS

The author wishes to thank Yuan Ying, Zhou Yuwei, Zhang Ming, Hei Hongguang, Xu Zhenzhong, Chen Jilu, Bi Yuseng, Liou Zhenqi, Wu senglai at TPRI for permission of using their unpublished reseach documents.

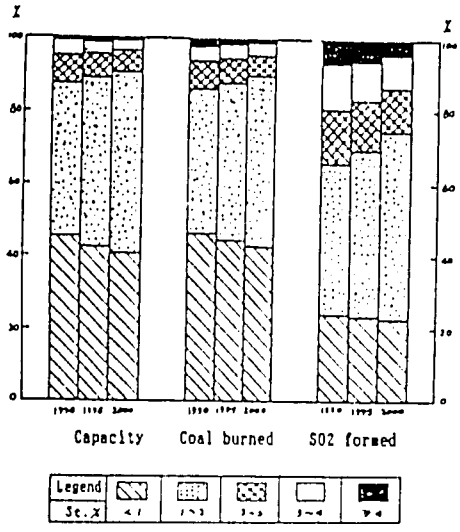
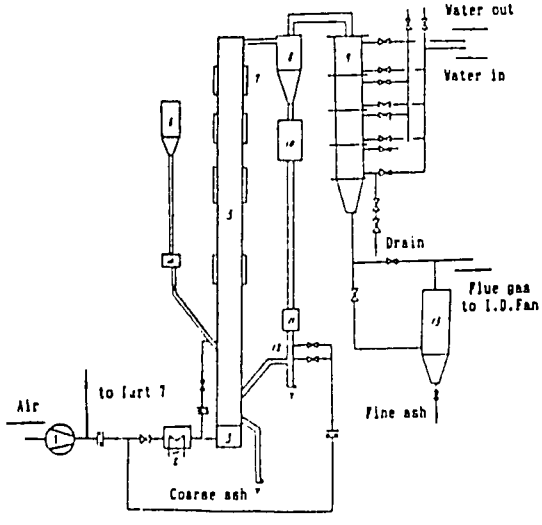


Fig.1 Statistical classification of sulfur contents of coals fired in main fossil power plants in China.



1.F.D.Fan 2.Electric Heater 3.Air Chamber 4.Coal Feeder 5.Combustion Chamber 6.Coal Bunker 7.Cooling Jacket 8.Cyclone 9.Gas Cooler 10.Ash Bunker 11.Observation Port 12.Control Valve for Ash Turning back 13.Baghouse

Fig.2 Schematic diagram of a CFBC test rig in TPRI.

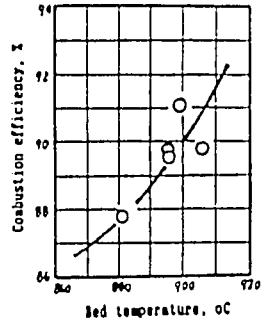


Fig.3 Influence of bed temperature on combustion efficiency.

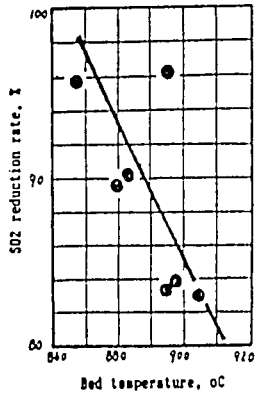


Fig.4 Influence of bed temperature on SO2 reduction rate.

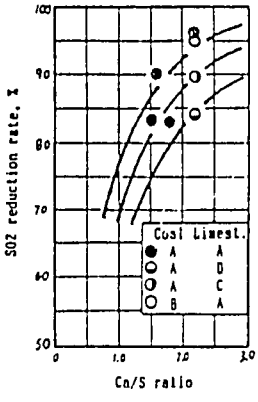


Fig.5 Influence of Ca/S ratio on SO2 reduction rate.

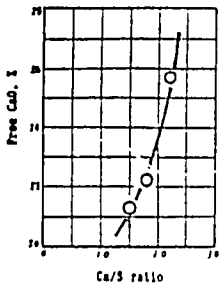
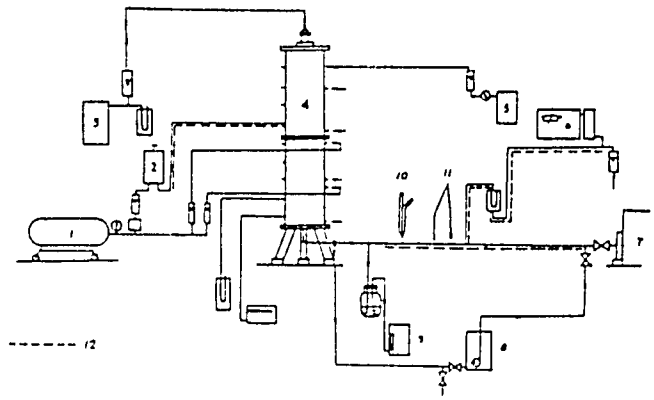


Fig.6 Influence of Ca/S ratio on free CaO in fly ash.



1.Compressor 2.Limestone Feeder 3.Bottled LPG 4.Combustion Chamber 5.Cylindered SO2 6.SO2 Analyzer 7.I.D.Fan 8.Water Tank and Pump for Washing 9.O2 Analyzer 10.Pitot Tube 11.Dry-wet Bubble Thermometer 12.Electr. Heating Ribbon

Fig.8 Schematic diagram of LDI simulation test rig in TPRI.

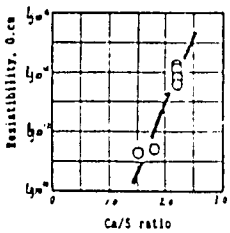


Fig.7 Influence of Ca/s ratio on resistibility of fly ash at 150 oC.

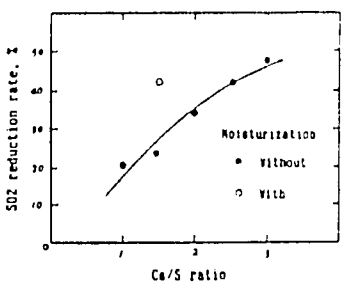


Fig.9 Sulfur reduction rate as a function of Ca/S ratio.

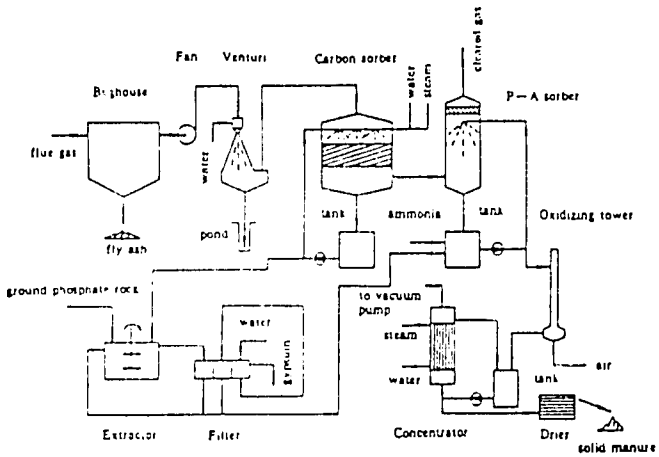


Fig.10 Flow diagram of the PAFP pilot test system.

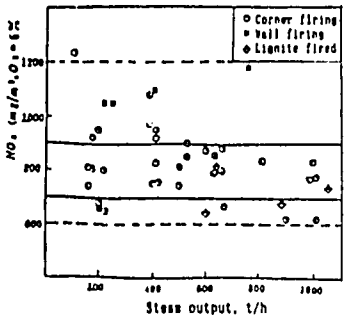


Fig.11 NOx emission from coal fired utility boilers.

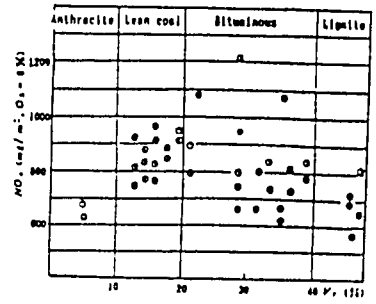


Fig.12 Comparison of NOx emission from different coals.

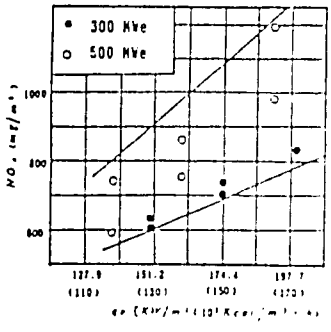


Fig.13 Influence of volumatric furnace load on NOx emission.

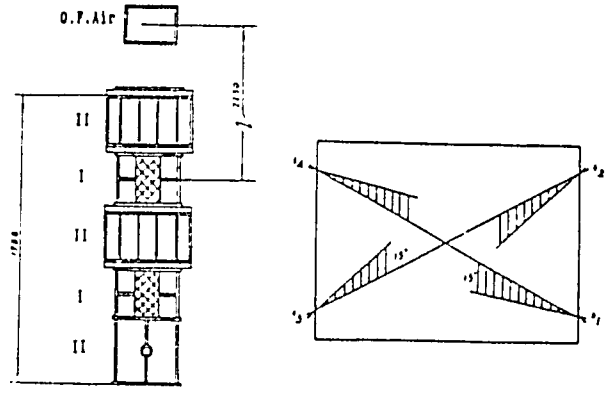


Fig.15 Burner retrofit schem of a 220 t/h boiler.

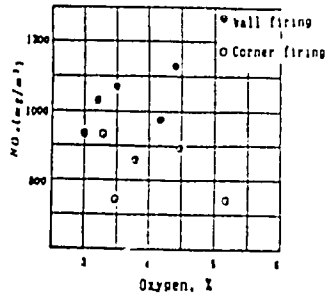


Fig.14 Comparison of NOx emissions from different burners.

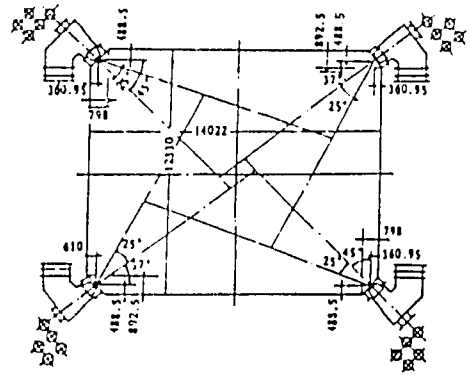


Fig.16 Burner arrangement of a 1025 t/h boiler.

WORKSHOP B3

TECHNOLOGY OPTIONS: PYROLYSIS AND FLUID-BED COMBUSTION

COAL COMPLEX CENTERING ON COAL PYROLYSIS

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1. INTRODUCTION

With its abundant reserves and stable supplies , coal will remain an important basic resource as a primary energy for Japan. Estimated consumption of coal by the year 2000 in Japan will increase to nearly 142 million tons per year from the current consumption of 114 million tons per year(1). Efficient utilization of coal will assume growing importance in the future when we consider the increase in energy consumption , supply limits of fossil resources including oil and natural gas , and the effects of energy use on the global environment. Nobel use should be made of such easy-to-use fossil fuels as oil and natural gas as a precious asset for mankind , and earth-friendly coal utilization technology must be developed in this country of vast energy consumption.

Technology development has been carried out for the complete gasification , hydrogasification , and liquefaction of coal as fuel for electric power generation (IGCC) , substitute natural gas (SNG) , and liquid fuel , respectively. These coal conversion technologies have been energetically researched into since the 1970s , but still need a time to be used widely for commercial application because of great development difficulties , high investiment costs and low economics involved.

Coal can be used not only as a source of energy but also as a high-value-added raw material for chemicals and carbon-based materials. Effective utilization of coal best suited to its characteristics requires the development of a rational conversion technology for specific purposes. The pyrolysis of coal yields multiple products such as gas , liquid , and char by simply applying heat to coal. Since coal pyrolysis has lower deve-

lopment hurdles and incurs less equipment costs than coal gasification and liquefaction technologies , it has come to be highlignted as a mild gasification technology.

The gas , liquid and char produced from coal can be used respectively as a fuel and chemical feedstock , as a chemical feedstock and fuel oil , and as a boiler fuel and ironmaking fuel (including reductant). The feasibility of converting these products into commercial products to meet market needs in both quantity and quality is a precondition for the commercialization of the coal pyrolysis process. A comprehensive system must be built whereby these products can be utilized in an effective and balanced way. Of particular improtance is the application of coal flash pyrolysis technology from which an increase in the yield of high-value-added gas and liquid components can be expected. A steel industry is expected to provide one of the most advantageous fields for developing a comprehensive utilization system for flash pyrolysis products of coal.

This paper outlines the coal flash pyrolysis process under research as one of the next generation coal utilization research and development projects to be undertaken by the New Energy and Industrial Technology Development Organization (NEDO) of Japan.

2. COMPREHENSIVE COAL UTILIZATION SYSTEM BY FLASH PYROLYSIS

In order to construct the comprehensive and efficient utilization system of pyrolysis products , we must broarden the fields of application not only to one industry but also to the other industries including public sector. Figure 1 shows an exapmle of coal flash pyrolysis product utilization system as a complex centering on a steelworks and embracing peripheral indusries.

Conventional iron and steel-making processes utilized coal mostly in the form of coke charged into blast furnaces and by-products produced from coke manufacture . In recent years , coal utilization has diversified , as typically seen in the spread of pulverized coal injection (PCI) into blast furnaces , addition of coal into basic oxygen furnaces in the scrap steel melting process , and the development of the direct smelting reduction process as a new ironmaking process.

Technology of injecting large amounts of pulverized coal into blast furnaces (from the present rate of 100 kg/t-pig to the future rate of 200 kg/t-pig) and that of melting large amounts of scrap , both under

development , will have the effect of lowering the coke rate in the blast furnace operation , reducing the supply of coke-oven gas (COG) to downstream processes , and tightening the supply of tar as a chemical feed-stock. The direct smelting reduction process will eliminate the manufacture of coke-oven by-products. A COG-equivalent gas from the coal flash pyrolysis process (4000 to 5000 kcal/Nm³) is supplied as a gaseous fuel for the hot and cold rolling processes and for the nearby gas energy consuming industries . Benzene-toluene-xylene (BTX) and tar liquid components are utilized as chemical feedstocks at the chemical company. Char , a solid product ,may be utilized as a substitute for PCI in blast furnaces , as a carbonaceous material in the direct smelting reduction process and scrap melting process and as a fuel for private electric power generation boilers at the steelworks. It may be also used as a fuel for the thermal power plant operated by the local electric power company. In addition , the flash pyrolysis char has the potential to be used as an adsorbent char.

3. CONVENTIONAL COAL PYROLYSIS PROCESSES AND REQUIREMENT OF NEXT GENERATION PYROLYSIS PROCESS

Several technical points must be considered when commercializing a pyrolysis process for large-volume production of high-value-added gas and liquid from coal. They are how to avoid the agglomeration of coal of high caking property in the pyrolysis process and how to supply the heat required to accomplish the rapid heating of coal.

Representative coal pyrolysis processes developed to date are summarized in Table 1 They are the moving-bed (mixing bed) Lurgi Ruhrgas process(2) , rotary kiln Toscoal Process(3) , fluidized-bed COED(4) and CSIRO(5) processes , entrained-bed ORC process(6) , rotary-grate Encoal process(7) ,fluidized/entrained bed IGT process(8). Heat is supplied by heated ceramic balls in the Toscoal process and by combustion heated char in the Lurgi-Ruhrgas , COED , CSIRO and ORC processes and by combustion of product gas in the Encoal and IGT processes. The combustion heated char used to supply heat and avoid agglomeration , and can be recycled to a great extent. None of these processes has been commercialized yet , except for the Lurgi-Ruhrgas process that has its aim in improving the lignite quality. IGT and Encoal , all in the United States , have been developing in the pilot plant level. Some processes were developed with the aim of improving coals of low rank , but their development work was suspended for reasons of low gas and liquid yields , great scale-up difficulty , or low applicability (economy) of products obtained .

A next-generation coal pyrolysis process required especially in Japan must:

* Produce high-value-added liquid as chemical feedstocks and gas products with high yields. (The yield of volatile matter can be increased by rapidly heating of coal.)
* Produce gas with properties befitting the intended application.
* Be high in thermal efficiency.
* Be able to treat a large amount of coals (or easy to scale up).
* Be able to use many types of coal.
* Be low in equipment cost.
* Be free from high development hurdles.
* Be flexible enough to meet the trend of product demand.
* Be environment-friendly (low in impact on environment).

4. CONCEPT OF NEXT-GENERATION FLASH PYROLYSIS PROCESS

The entrained-bed coal flash pyrolysis technology has a high possibility of growing into a process that will offer a high yield of volatile matter , be easy to scale up , and be able to handle a wide variety of coals. In considering the pyrolysis process applicable at a steelworks , we paid attention that the process is capable of producing the gas with heating value similar to the COG and liquid with high added value as much as possible while reducing the amount of char products.

An example of simplified process flow diagram of the flash pyrolysis we have proposed is presented in Figure 2.

Coal , which is dried and pulverized to a 80 percent minus 200 mesh size , is pneumatically conveyed in a dense phase from the feeder into the pyrolysis reactor with nitrogen or product gas of this process. Injected coal into the pyrolysis reactor is heated very rapidly by the upstream of hot gas generated by the partial oxidation of char and devolatilized to produce gas , liquid and char at the reactor conditions such as temperature of 600 ℃ to 900 ℃ , gas residence time of a few seconds. The gaseous and solid products flow concurrently upwards . The formed char is separated in a hot cyclone and its heat is recovered via a char heat recovery unit. Some of the char is partially oxidized by oxygen and steam to supply heat for the pyrolysis reaction involved . The rest of char is utilized as a fuel for electric power generation or iron production. Heat is recovered by oil flushing , for example , from the gas stream from the hot cyclone , containing gas and liquid products. Liquid products are recovered from the gas stream by water flushing , for instance. Heavy liquid products that condense in the heat recovery step can be recycled to the pyrolysis reactor

and treated again there. The gas is removed of BTX , sulfur , ammonia , and other components in the gas treatment system before it is used as a fuel.

Among possible development themes are the efficient gasification of char , injection of coal into the pyrolysis reactor without agglomeration , seperation of hot char and recovery of heat from the product stream. Conventional technologies can be best utilized in these developments.

5. DESCRIPTION OF THE 2.4-TON/D PROCESS RESEARCH UNIT

Following the encouraging results from the earlier exploratory laboratory-scale experiments with a coal input of 5 kg/hr(9) , a process research unit apparatus (PRU) , which has a coal feeding capacity of 2.4 tons per day , has been built to evaluate the process concept mentioned above and to develop its key technologies. The schematic flow of the PRU is shown in Figure 3. The PRU consists mainly of pulverized coal and char feeding systems , a 28-cm-I.D.,400-cm-long entrained coal pyrolyzer set up just above a 50-cm-I.D. , 60-cm-long char gasifier , a solid char seperation section , and a tar recovery section.

A pulverized and dried coal/char (-200 mesh 80 % in size) stored in the char feeder is constantly fed at about 50 kg/hr by a rotary valve and conveyed pneumatically with nitrogen to be injected into the char gasifier through a pair of char-oxygen burners. Injected coal/char is gasified by oxygen to generate the hot gases such as CO,CO_2 ,H_2 and H_2O at the temperature of 1400 ℃ to 1700 ℃. The sensitive heat of hot gases from the gasifier provides the heat necessary for subsequent pyrolysis reaction. At the coal flash pyrolyzer connected to the gasifier, a pulverized coal is put into the hot gas stream through a pair of coal injectors at the rate of 50 kg/hr to 150 kg/hr , which depends on pyrolysis temperature selected , and devolatilized at the heating rate of about 10^4 ℃/sec. The operating conditions of the pyrolyzer are temperature of 600 ℃ to 900 ℃, gas residence time of about 2 seconds and atmospheric pressure. The product stream containing gas , tar ,and char from the pyrolyzer goes to the hot cyclones and the char is separated to be stored in the char vessels. The hot gas leaving the cyclones is quenched with water spray scrubber and the tar is condensed in the hold vessel. After tar mist is eliminated , the gas produced is burned at the flare stack. Part of the tar produced is collected by freezing with liquefied nitrogen to be analyzed. The gases produced such as H_2 , CO , CO_2 , light hydrocarbon gases are analyzed by using both on-line gas chromatography and sample bags.

6. TEST RESULTS OF THE PRU AND MASS AND HEAT BALANCES OF A FULL SCALE UNIT

Taiheiyo coal (a domestic subbituminous coal) was used for the PRU experiments. Analyses of the coal and its chars obtained from the PRU experiments are given in Table 2.

Taiheiyo coal was gasified by oxygen instead of its char to evaluate the performance of char gasifier as a hot gas generator. Figure 4 shows the effect of oxygen to coal mass ratio on cold gas efficiency. As is shown, cold gas efficiency of the PRU gasifier results in 40 to 60% , which is relatively low considering that a full-scale gasifier is expected to reach more than 70% efficiency. This is because 30 to 35% of total heat input in the PRU gasifier turn out to be heat loss to the gasifier wall due to its size.

The performance of coal flash pyrolyzer is shown in Figure 5. Figure 5 illustrates the relation between the product yields and reactor temperature Data from the laboratory-scale experiments with a downflow entrained bed of having a 5 kg/hr coal input are also shown for comparison. In the PRU data , char yield becomes quite lower to less than 45 wt% of dry-ash-free(daf) coal beyond 700 ℃ . This means that the PRU is favorable to obtain high yield of total volatiles such as gas and liquid. Gas yield becomes 2 to 3 times higher than that of laboratory experiments , on the other hand , tar yield becomes lower. The reasons for the difference between the PRU and laboratory scale data are assumed as follows.

* The PRU gives a very high heating rate (10^5 ℃/sec) of coal particles compared with that (10^4 ℃/sec) of laboratory scale and the residence time of coal particles within the PRU pyrolyzer is found to be about 10 times longer than that of laboratory scale downflow entrained reactor due to inner circulation of coals injected. This causes the decrease of char yield.
* The decrease of tar yield in the PRU is due to secondary reaction of tar on the activated char surface . Secondary reaction of tar is easy to occur in the PRU pyrolyzer because of high concentration of char particles.

The operating data are being accumulated using several other kinds of coals such as subbituminous and high volatile bituminous coals.

Based on the test results from the PRU , an attempt has been made to take mass and heat balances of a full-scale plant. The calculated results based on a 1000 tons per day plant scale are illustrated in

Figure 6. Product yields for a full scale pyrolyzer are taken from the PRU data. As for the performance calculation of a full scale char gasifier, the following assumptions are made.

* Carbon conversion is 98%.
* Gas components such as CO, CO_2, H_2, H_2O are partly at equilibrium of water gas shift reaction at the outlet of gasifier.
* Heat loss within the gasifier is dominated by the radiative heat transfer to the reactor wall.
* Char is conveyed pneumatically with nitrogen at the condition of char to gas mass ratio of 30 .

An example of pyrolysis process data per unit coal is given in Table 3. Process data show that gas , liquid(BTX+tar) and char product yield are 60–70 wt%,10–15 wt%,and 20–30 wt%of coal , respectively. The product yields of this process are compared with those of other processes in Figure 7.

7. CONCLUSIONS

According to the test results from the PRU , the coal flash pyrolysis process we have proposed has a possibility of producing high gas and liquid yields and becoming a feasible process which can meet the requirements. At present , operating data are being accumulated from the PRU and research is proceeding toward feasibility study of the process before construction of a pilot plant.

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Table 1 Development of coal pyrolysis processes

Process	Reactor type	Development scale and period	Main products	Heat supply method
Toscoal	Rotary kiln	25t/d (1970)	Char	Heated ceramic ball by product gas combustion
Lurgi -Ruhrgas	Moving bed (Mixing bed)	Commercialized (1963)	Char	Char combustion
Encoal	Rotary grate	900t/d (1992-)	Char	Product gas combustion
COED	Fluidized bed	36t/d (1970)	Liquid/Gas	Partial combustion of char
CSIRO	Fluidized bed	0.5t/d (1984)	Liquid	Char combustion
IGT	Fluidized bed /entrained bed	24t/d (1991-)	Char/Liquid	Product gas combustion
ORC (Garrett)	Entrained bed	3t/d (1976)	Gas/Liquid	Char combustion

Table 2 Analyses of Taiheiyo coal and its chars

dry-wt%

		Proximate Analysis			Ultimate Analysis				
		VM	FC	ASH	C	H	O	N	S
Taiheiyo coal		44.61	61.31	14.08	67.58	5.49	11.35	0.89	0.11
Taiheiyo char	650 °C	12.46	51.24	36.30	58.19	1.69	3.11	0.71	0.01
	740 °C	7.26	57.22	35.52	59.50	1.33	2.95	0.70	0.01
	850 °C	5.26	51.60	43.14	53.67	0.86	1.78	0.55	0.01

Table 3 An example of pyrolysis process data (Taiheiyo coal)

Pyrolysis reactor condition	•Temperature	: 700	°C
	•Pressure	: 1	atm
	•Gas residence time	: 2	sec.
Char gasification condition	•Char required	: 348	kg /t-coal
	•Oxygen required	: 199	Nm^3 /t-coal
	•Steam required	: 182	Nm^3 /t-coal
Process products	•Gas	: 926 (3930	Nm^3 /t-coal kcal/Nm^3)
	•Tar	: 84	kg /t-coal
	•BTX	: 32	kg /t-coal
	•Char	: 233	kg /t-coal
Process efficiency	•Thermal efficiency	: 95 %	

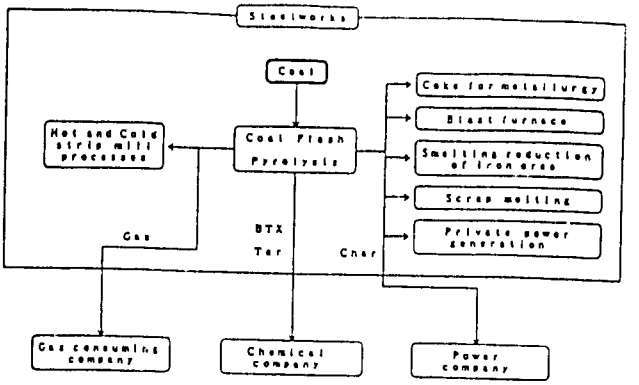


Figure 1 Coal flash pyrolysis utilization system

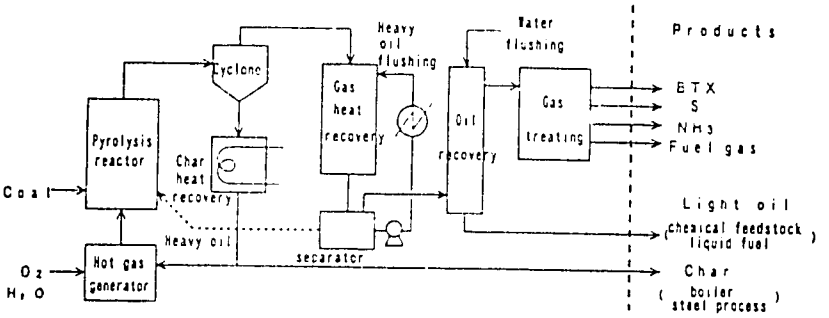


Figure 2 Process flow diagram of coal flash pyrolysis

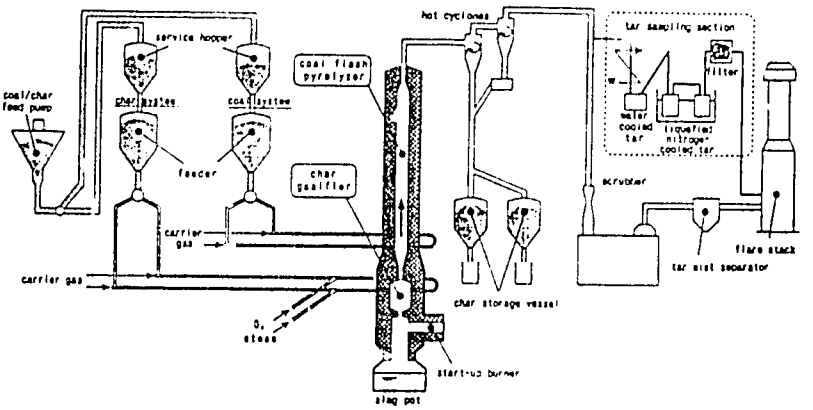


Figure 3 2.4t/d Process Research Unit

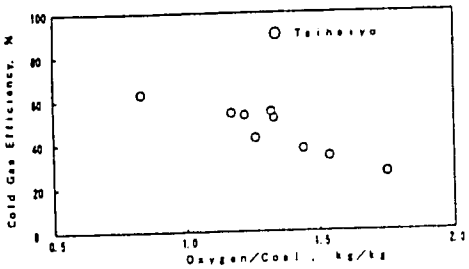


Figure 4 Fffect of oxygen to coal mass ratio on cold gas efficiency

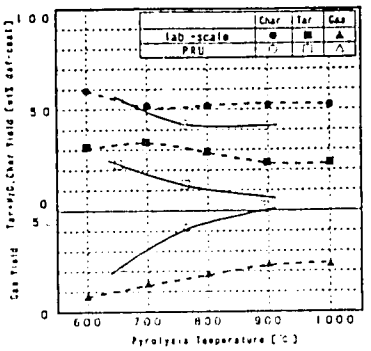


Figure 5 Effect of pyrolysis temperature on product yields (Taiheiyo coal)

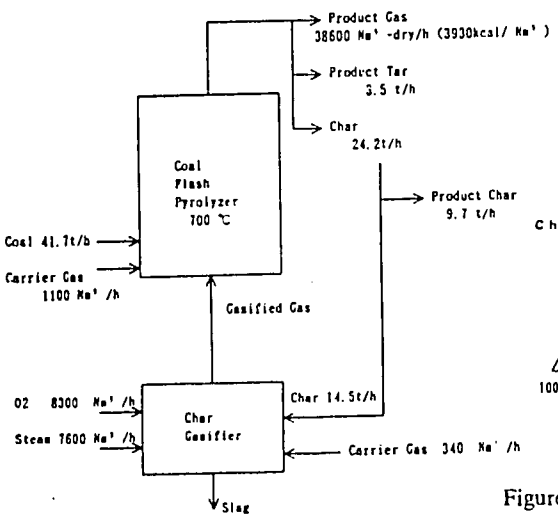


Figure 6 Mass and heat balances of a 1000t/d scale plant

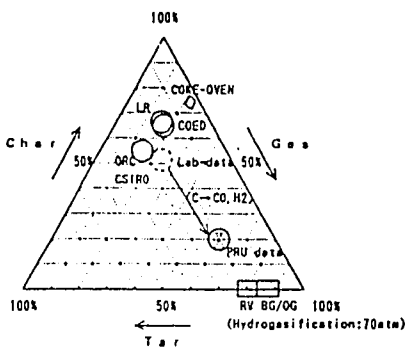


Figure 7 Comparison of process products

Advanced Solid Waste Treatment with
Product Control Indirect Flash Pyrolysis
"The Best Available Control Technology".

Product Control System™
"PCS"

PCS is an innovative resource recovery pollution control industry system, which opens new markets and business opportunities based on the **decentralised** and **complete** solid waste management **concept.**

- . -

Process Description: "...that which was recently technically and economically unavailable, is now viable and available reality, even beyond the year 2000..."

Keywords:

- ^ **Indirect Thermal Treatment**
- ^ **Reductive Environment**
- ^ **Continuous Processing**
- ^ **Cost-Effective Alternative**
- ^ **Flash Pyrolysis**
- ^ **Low Vacuum**
- ^ **Continuous Monitoring**
- ^ **Energy Recovery**

The PCS indirect thermal treatment process uses flash pyrolysis to thermally decompose organic and inorganic solid waste. The main component of the process is its use of a specially designed, indirectly fired rotary reactor in which waste in a reductive environment is partially vaporised and/or gas-out in low vacuum between the temperature ranges of 450 °C - 1,000 °C (850 °F - 1,850 °F) .

Gas phase from the reductive decomposing process is directly combusted at a minimum 1,250 °C (2,300 °F) 2 sec residence time and heat from its flue gas is recovered. The remaining gas is cleansed in a high capture efficient, indirectly cooled, wet gas scrubber prior to discharge. Scrubber process water is cleansed prior to discharge and the

precipitate from the water treatment is reintroduced for attenuation into the system.

Solid phase is indirectly cooled and discharged for utilisation. If the basic material is of organic origin, the solid end product is an activated carbon powder which is utilised as a filtration material or as energy. If the basic material is of inorganic and/or mixed origin and/or contains a high content of heavy metals and/or halogens the solid end product is conditioned into an unleachable water resistant form of low volume for final disposal.

Proven advantages over other pyrolysis systems include:

> The indirect heated process provides a true pyrolysis reductive environment avoiding dioxin formation;
> The ability to treat unsorted organic and inorganic contaminants that are thermally decomposable under 1,000 °C (1,850 °F);
> Totally closed and totally safe system;
> Modular system design;
> Extended range of alternative applications;
> Complete, automated and monitored technology;
> Recovery of saleable products such as: Waste-to-Energy, Pure Activated Carbon, Clean Coal - not to mention savings on landfill fees resulting from decreased amounts of neutralised ash residue after treatment.
> Low investment, operation and maintenance costs.

A process schematic is shown in Figure 1.

Process Application: "...the PCS converts trash into cash..."

Keywords:

^ Pure Chemical
^ Pure Activated Carbon
^ Pure Nuclear

^ Mixed Thermoplastics
^ Impregnated Wood
^ Wood and Straw Waste
^ Lignite and Coal
^ Household Waste
^ Used Activated Carbon Recovery
^ Halogens

^ Solid Waste
^ Hazardous Waste
^ Unsorted

^ Packaging Material
^ Agricultural Waste
^ Pharmaceutical Waste
^ Contaminated Soils
^ Hg Luminescent Light
^ Pesticides
^ Heavy Metals

The process has been developed for the treatment of different mixed and/or unsorted solid organic and/or inorganic industrial, municipal and/or post-consumer waste stream with toxic pollutant hazardous substances that can be flash pyrolysed and/or carbonised at temperatures under any range of 1,000 °C (1,850 °F). The technology development of Product Control comprises three main areas. The various basic materials require different modular constructions and the purpose of the treatment and the quality of the end products depends on the quality of the input materials.

1. Pure Chemical: waste amenable to treatment includes; - industrial, municipal and/or post-consumer waste; soils and sludges; waste contaminated with heavy metals, halogens, pesticides and/or organic contaminants such as: household waste, thermoplastics, rubber; tire; organic and oil sludge; impregnated and contaminated wood; agricultural waste; desulphurisation of lignite and coal; contaminated soils; contaminated packaging material resulting from the food, chemical and agricultural industries; mercury-based luminescent light, contaminated activated carbon, etc.

End products: Waste-to-Energy conversion resulting in Pure Carbon and/or Clean Coal; the destruction and/or neutralisation at low cost resulting in low volumes of processed neutralised ash residue.

2. Pure Activated Carbon: a second version of the process is applicable for the manufacture of Pure Activated Carbon from wood chips, straw, coconut shells, rice hulls, peats and nuts and/or other agro-forest waste products.

End products: high quality Pure Activated Carbon and/or inexpensive waste-to-energy. An annual 15,000 tons of wood waste input provides approximately 2,500 tons per year of a high quality end product and energy surplus.

3. Pure Nuclear: a third version of the process provides for the treatment of low level organic radioactive nuclear waste for the purpose of volume reduction.

End product: volume reduction at a low cost.

On-site or off-site stationary unit facilities for the Pure Chemical and Pure Activated Carbon standard systems are available with a throughput of 2 tons per hour, (15,000 tons per year), of permanent processing. A mobile unit - as a special version - is also available with a capacity of 0.5 - 1 ton per hour (3,000 - 6,000 tons per year input).

Process Operation: "...simply said: it works..."

Keywords:

^ PCS Rotary Reactor
^ Fully Automated
^ Process Surveillance System
^ Closed Technology
^ End User Friendly
^ Simple Maintenance

The waste is first reduced by a homogenizer mill to less than 5 mm (< 0.2 inches) prior to entering the dryer. Operating at 450 °C (850 °F), the directly fired closed dryer lowers the moisture content of the waste to less than 15 percent. The dried waste is conveyed into the rotary reactor where it is indirectly flash pyrolysed at 450 °C - 1,000 °C (850 °F - 1,850 °F) into gas-vapours and solids perspectively. Generally, most heavy metals and high boiling point organic compounds will remain in the solid phase while volatile organic compounds and some volatile metals will be concentrated into the gas phase.

The gas-vapour phase is directly combusted for the recovery of energy from the flue gases.

The solid material is indirectly cooled and utilised. If the basic material is purely organic in origin, it is utilised by being processed into Pure Activated Carbon.

After energy recovery is completed, in the form of process heating - drying, steam and/or hot water (electric power production is available as option), the flue gases are treated in an indirect cooled gas scrubber connected to a water treatment system. Clean flue gas and clean water are discharged from the system. The system operates continually and is fully automated and monitored by Honeywell-Product Control electronic process-control and quality assurance-quality control instrumentation. A summary of operating parameters is provided in the exhibit.

A process flow schematic is shown in Figure 2.

Vendor Information: "... our industrial competence is vital to the success of your business..."

Keywords:

^ Swedish-British
^ For Licensing
^ PCT Patented
^ Complete System

Founded in 1987, Product Control Ltd. is a British - Swedish joint venture company that specialises in research, technical development and engineering of waste management and pollution control technologies. Development of its flash pyrolysis technology was initiated by George Edward Someus, a Swedish inventor, during the 1970's.

After laboratory and bench scale testing a mobile pilot experimental plant using the technology became operational to demonstrate the principle of the developed innovative technology. The first commercial Product Control flash pyrolysis design was presented in the "US. EPA Fourth Forum on Innovative Hazardous Waste Treatment Technologies, Domestic and International" conference and exhibition in November of 1992. This presentation was met with great success. The technology is patented in the United States (US 5194069) and Europe, with additional patents pending elsewhere world-wide.

Further information: Product Control Ltd.
La Plaiderie, St. Peter Port, Guernsey, Channel Islands, United Kingdom. Att: Mr. G. Edward Someus, Director.
Tel: 44-481-726 426, Fax: 44-481-726 526.

Typical Standard Operating Parameters of the Commercial Plant Design

Applied industry standards	EN/DIN	US
Process building	600 m2	6060 sq.ft.
Storage building	300 m2	3030 sq.ft.
Total weight of apparatus	175 tons	196 sh.tons
Throughput per hour	2 tons	2.25 sh.tons
Throughput per year	15,000 tons	16,800 sh.tons
Particle size	< 5 mm	< 0.2 inch
Moisture content	< 45 %	< 45 %
Dryer:		
Temperature	450 °C	850 °F
Solid residence time	one hour	one hour
PCS rotary reactor:		
Temperature	450-1,000 °C	850-1,850 °F
Solid residence time	one hour	one hour
Pyrolysis gas combustor:		
Temperature min.	1,250 °C	2,300 °F
Gas residence time min.	2 sec	2 sec
Indirect cooler for solids:		
Temperature in	1,000 °C	1,850 °F

Temperature out	60 °C	140 °F
Indirect cooled gas scrubber:		
Capacity per hour	14,000 m3	495,000 cu.ft.
Scrubber resistance	2,500 Pa	2,500 Pa
Required for operation:		
Electricity per hour	170 kW	170 kW
Fuel per hour, approx.	50 kg	12 US gal
Water per hour	1 m3	35 cu.ft.
Required personnel per shift	3	3
Automatization/monitoring	yes	yes
Tropical version	available	available
Mobile version	available	available
Product Liability Insurance	yes	yes
Turn key delivery time approx.	12 months	12 months

"... better & safer solid waste management technology at lower price & cost..."

...

FIGURE 1: PROCESS SCHEMATIC

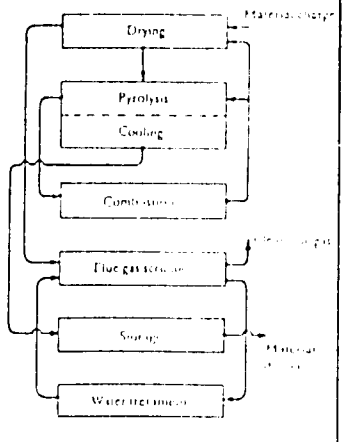
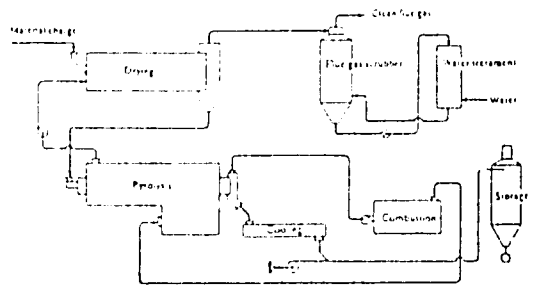


FIGURE 2: PROCESS FLOW SHEET



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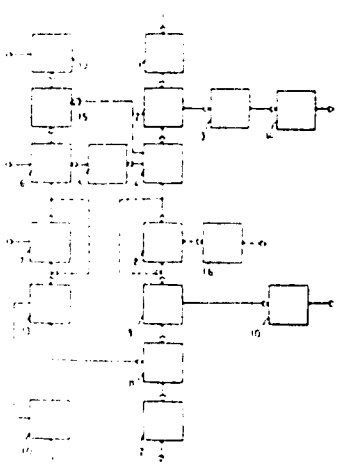
(81) Designated States: AU, CA, CH, JP, US, European patent (AT, BE, CH, DE, DK, ES, FR, GB, GR, IT, LU, MC, NL, SE)

Published
With international search report

(54) Title: METHOD AND APPARATUS FOR TREATMENT OF WASTE MATERIALS AND/OR NUCLEAR CONTAMINATED MATERIALS

(57) Abstract

According to the method of the invention the base material is ground until the grain size will be max. [illegible] mm, dried to a relative humidity content below 3/5 [illegible] at a core temperature of 400-1200 °C on a pressure of 200 [illegible] m³ in oxygen-free reducing indirect heated environment and vapours arising at drying will be condensed, solid material remained from distillation will be burnt or utilised, vapours arising will be either directly burnt or cooled below 60 °C and/or washed and/or precipitated and remaining combustible gases will be burnt, the ash left will be pelletized or granulated on a pressure of 50 000-300 000 [illegible] m³. Grinding equipment (1) is connected with drying equipment (2), this is connected with the distillery (4) and the condenser (3), distillery (4) is also connected to the gas treating unit (5) or gas combustor (15) and the solid material combustor or mineralisator and/or vitrificator (9). The gas treating unit (5) is connected with the gas cooler (6), gas cooler (6) is connected with liquid combustor (13) and/or gas combustor [illegible] combustor (15) is connected to gas filter (10), condenser [illegible] connected to the condensed liquid treating device (14), the equipments of the scheme are connected through gas filter (10), liquid treating unit (7), solid material treating unit (16 and 12) and condensed-liquid treating unit (14) to the open environment.



US005194069A

United States Patent [19]

Soméus

[11] Patent Number: 5,194,069

[45] Date of Patent: Mar. 16, 1993

[54] METHOD AND APPARATUS FOR REFINEMENT OF ORGANIC MATERIAL

[75] Inventor: George E. Someus, Guernsey, Channel Islands

[73] Assignee: Productcontrol Limited, Guernsey, Channel Islands

[21] Appl. No.: 576,456

[22] PCT Filed: Apr. 14, 1989

[86] PCT No.: PCT/SE89/00206

§ 371 Date: Oct. 3, 1990

§ 102(e) Date: Oct. 3, 1990

[87] PCT Pub. No.: WO89/09809

PCT Pub. Date: Oct. 19, 1989

[30] Foreign Application Priority Data

Apr. 14, 1988 [SE] Sweden 8801357

[51] Int. Cl.[5] ..... C 10B 39/02

[52] U.S. Cl. 44/500; 202/8; 201/33; 201/35; 201/34; 202/226; 202/136; 202/131; 202/63

[58] Field of Search 44/500; 201/8; 35/33; 201/34; 202/227; 131; 136; 63

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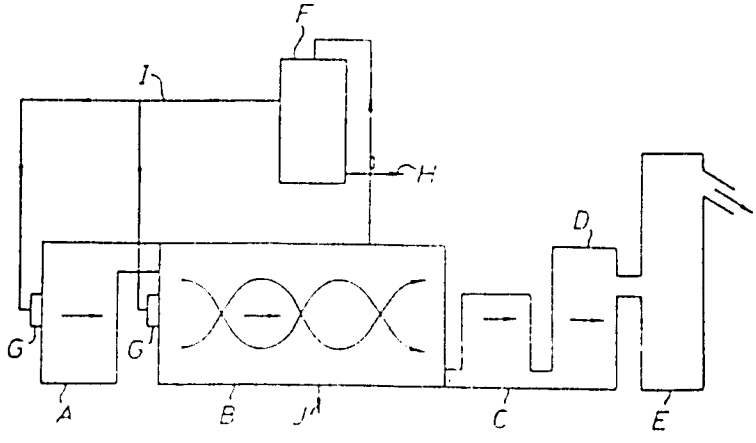
Primary Examiner: [illegible]
Assistant Examiner: [illegible]
Attorney, Agent, or Firm: Lucas & Parry

[57] ABSTRACT

A method and an apparatus for the refinement of organic material is disclosed. Converting and processing organic material is achieved with or without organic and inorganic additives. The base material uses waste material, i.e. forest industry waste and slaughter-house waste. The method and apparatus produce a packeted end product specially also carbon powder granulate as fuel and charcoal for grilling, smelting, as well as active coal and additives for steel production.

9 Claims, 6 Drawing Sheets



Cleaning of Sulphur Contaminated Coal with
Product Control Indirect Flash Pyrolysis Technology

Soméus, G. Edward; Product Control Limited,
La Plaiderie, St. Peter Port, Guernsey, Channel Islands, United Kingdom

Content

1./ Introduction of the Company
2./ Terminology and general overview of the thermal treatment technologies.
3./ The PCS innovative technology
3.1./ Overview of the complete PCS technology
3.2./ The PCS Reactor and its operation
3.3./ The auxiliary equipment
3.4./ What are the advantages?
3.5./ Alternative applications
3.6./ Market and economy
3.7./ Development history of PCS technology and its present status
4./ Patent position
5./ The perspective of the PCS technology

1./ Product Control Ltd is a British - Swedish joint venture company that specialises in research, technical development and engineering of solid hazardous waste management and pollution control technologies. The development of flash pyrolysis technology was initiated by myself in 1979. I have a Swedish background from the University of Lund in Sweden, I am a environmental scientist and geochemist.

2./ Unfortunately the term pyrolysis has often been used to identify other thermal treatment technologies, other than pyrolysis, such as for gasification and combustion in a low oxygen content, reductive environment.

The term pyrolysis refers to reductive thermal treatment, indirect heat up, dry distillation, carbonisation and the gas-out process of the organic and or inorganic material.

The term flash pyrolysis refers to a very fast process of gas-out. The time factor is of great technical importance concerning this process.

Slide 1. Compares the position of different technologies. Everything from actual incineration with high oxygen content to the gasification processes and finally true pyrolysis with the theoretical total absence of oxygen. Of course, in practice, some very low content oxygen will always remain in the reactor. If nothing else then in chemical bounded oxygen.

The term "Product Control Systems PCS" refers to the indirect thermal treatment family with main components of the indirect heated rotary reactor which is the heart of the technology, indirect cooled solid material cooler and the indirect cooled scrubber. The PCS technology is complete in the sense that the technology starts with raw material input and provides a complete solution treatment process including, material transportation systems, drying, flash pyrolysis reactor, gas-vapour combustion chamber, water treatment, Honeywell process control and other auxiliary equipment.

PCS technology is not a modification taken over from other industrial production methods, but is specially designed and developed for the solid hazardous waste management industry. This is why it took 14 years to reach the well developed technical position enjoyed today.

3 / The PCS innovative technology specifically addresses the need for a clean-up tool for one of the most difficult problems today, that of solid hazardous waste management and precombustion cleaning of organic sulphur that is chemically bound to the coal. In many cases, new generation environmental requirements do not allow for a direct thermal treatment process e.g. incineration, because of the mixed chemical complexity of the basic material, which increases the problems associated with heavy gas treatment. As a result, it is necessary to apply complicated gas treatment technologies at great cost. 25 years ago the gas treatment assembly was only an approximate 20 % of the total cost of the complete technology with the other 80 % consisting of the main technology itself. Today, just gas treatment can put out as much as 80 % of the total cost of systems installation.

Recent U.S. and European environmental legislation moves to a clear guide line concerning norms of pollution control. Because of the world pollution problems, we can expect future environmental norms to be even more stringent than today. The new generation is being developed with a new environmental attitude. This will result in new market demands, new products and new attitudes of waste management technology which will fulfil these demands resulting from these changes. PCS technology incorporates this new generation attitude of thermal treatment of waste materials. It is principally based on preventive, multi step treatment of waste rather than on direct treatment which results in complicated after effects.

3.1 / Overview of the complete PCS technology

Slide 2 The coal is first physically cleaned to remove part of the pyritic sulphur and the ash forming minerals, and reduced by a homogenizer mill to less than 5 mm (~0.2 inches) prior to entering the dryer. Operating at 400 °C (752 °F), the directly fired closed dryer lowers the moisture content of the coal to less than 15 percent. (If no drying required than the coal, after the physical cleaning, can directly be charged into the reactor.) The dried material is conveyed into the rotary reactor where it is indirectly flash pyrolysed at 450 °C - 1,000 °C (850 °F - 1,850 °F) into gas-vapours and solids respectively. The residence time is approximately one hour. Generally, the Clean Coal, the high boiling point organic compounds and the rest of the ash forming minerals will remain in the solid phase, while volatile organic compounds and sulphurs phosphorus will be concentrated into the pyrolysis gas-vapour phase.

The solid end product, Clean Coal, is indirectly cooled and utilised.

The pyrolysis gas-vapour phase is directly combusted for the recovery of energy from the flue gases. The combustion temperature is over 1,250 °C (2,300 °F) with a minimum residence time of 2 seconds. After energy recovery is completed, in the form of process heating - drying, the flue gases are treated in an indirectly cooled gas scrubber connected to a water treatment system and the sulphur phosphorus is collected from the scrubber water and neutralised with limestone.

Clean flue gas and clean water are discharged from the system The system is continually operated, fully automated and monitored by Honeywell-Product Control electronic process-control and quality assurance-quality control instrumentation

3.2 / The PCS Reactor and its operation

Slide 3-4: After the physical cleaning, the ground and dried coal material is to be charged into a small sized compensating bunker of approximately 1 m3 which is connected to a speed controlled rotary cell drain, which discharges the material to the feeding screw in a closed operating mode The feeding screw permanently charges material into the reactor.

The reactor rotates around its symmetric axle, is horizontally arranged and cylindrical formed with no refractory line installed inside The high quality steel mantel is heated from outside through the lined combustion chamber Inside the reactor body, blades promote the transportation of the material The reactor is a permanently working vessel, the basic material enters in at the input-end while the out-gassed solid material and the pyrolysis gas-vapour phase are discharged at the output end, separately from each other

The main features of the pyrolysis reactor

1. Indirect heat transfer through the mantel to the ground material with extended surface area
2. Permanent operation and homogenised material throughput
3. Special sealings to provide guaranteed closed operation
4. Process control of the operation
5. Low vacuum provides for a high security factor during the operation
6. Practical and not complicated end user friendly construction, low cost
7. Synchronised auxiliary installations

Our main purpose is the gas out of coal, collect the impurities using as low amount of air as possible through indirect heat transfer For this reason, flash pyrolysis must take place at a certain temperature

The required amount of energy input is basically supplied from hot flue gases These are produced in the combustion chamber for direct incineration of the pyrolysis gas vapours and heats the reactor body from outside the mantel Heat transfer happens indirectly through the mantel to the material The heating is nothing more than the transfer of the energy content of a hot medium to a cooler medium

The heat transfer contains three phases

Primarily Energy transfer from heat under the material in the rotary kiln. The material, which is ground down to a maximum dimension of 5 mm, (0 25 inches) to have extended surface area, is permanently mixed, which mixing process is promoted by the blades inside the reactor body The heated material is to be permanently replaced by cooler materials again and again Therefore the thermal conductivity of the coal is of less importance and can be within a wider range This is a very important and vital technical factor, particularly in relation to the coal which is usually bad thermal conductor

Secondarily Radiation heat transfer from the inner top surface of the reactor body

Tertiary Over the temperature of 275 C° (530 F°) an exothermic reaction starts during the decomposition of the material

It is to be noted, that the basic pyrolysis process is of endothermic character, which means that heat must be transferred. Especially high water content wastes require a high input of energy during the drying and heating up process. Therefore, a low input moisture content is preferable. Reactions at temperatures of 275 C° (530 F°), and over, become exothermic. Sometimes heat has to be taken away to control the process, otherwise, overheating cannot be controlled. The thermal engineering design of the reactor is related to the throughput capacity of the reactor and the extremely qualitative variations of the input material.

The flash pyrolysis process.

The main technical concept of the reactor is a flash pyrolysis process, in a low vacuum, to separate the material during the decomposition process into pyrolysis gas-vapour phase and solid phase. The separated phases will concentrate the different hazardous substances, depending on the different boiling points of the different substances. The separated after treatment of the material will technically be greatly simplified and much cheaper, especially the treatment of the process gases which is a key factor. Therefore, PCS technology stands for a complex system of Clean Coal management. Its basic idea being the supply of a complete new technology which solves all relevant technical problems without creating new ones.

No matter if the basic material is of organic, inorganic and/or mixed character, the chemical components will be separated at a certain treatment temperature if the boiling point of the components are under 1,000 C°, (1,850 F°). The pyrolysis reactions are not only a sequenced series of reactions, but a parallel series of reactions as well, with different activities of energy. This conclusion is the basis of this technology. That by the control of heating and residence time, a very wide range of input products can be treated with mixed chemical composition. This is the most important factor concerning solid waste management.

To provide a successful flash pyrolysis process, three different factors are needed:

A. High enough temperatures, that the coal pass the complicated decomposition phases,
B. Opportunity for the gas-out process to transfer the volatile organic and/or inorganic compounds into gas-vapour phase,
C. That the chemical bounds of the hazardous substances be broken up.

During the heating up process the volatile compounds are broken down into smaller molecules. The pyrolysis products are generally not similar to the chemical composition of the basic material, but rather, are new chemical components. The steps of the pyrolysis process are thermal inductions of the material. Depending on the chemical composition of the coal, different quality and quantity pyrolysis gas-vapours and solid rest material is to be produced. The size and form of the reactor is such that the gas-out process in different sections of the reactor interior is different, with thermal decomposition running parallel at different sections.

The exothermic process is a slow process. Therefore the extended pyrolysis gas-vapour production will not result in an explosive production of gas vapours. Even if such theoretically explosive production of pyrolysis gas-vapours happens, the size of the reactor's inner space, the reductive environment and the adjustable permanent vacuum control compensate the action.

During the thermal decomposition primary and secondary products are produced.

The primary products are the out-gassed pyrolysis gas-vapours, directed to combustion, and solid end products.

The secondary products are the rest of the tarry materials and/or the not perfectly gas-out inorganic components. These remain in the capillaries and pores blocking the open channels in the solid end products.

To avoid the production, and/or minimisation of secondary products the flash pyrolysis is processed in a low vacuum, approximately at a negative pressure of 50 Pa, to let the pyrolysis gas-vapours leave the reaction space as soon as possible. This action promotes the diffusion of the pyrolysis gas-vapours from the core of the material up to the surface. The low partial pressure of the volatile compounds gives the reaction balance a permanent tendency in the direction of the production of primary products.

Because the flash pyrolysis thermal decomposition process is not only dependant on the level of heating, but the length of treatment time as well, the most important factor is a very effective and fast warm up of the basic material in the core. Therefore the production of the pyrolysis gas-vapours will fast be increased and the amount of the rest of the solid materials decreased. Thus, the out-gassing process is perfected.

Processes inside the Reactor

The length of the reactor ensures the heating process during the throughput of the material. Another words, time is an important factor. The volatile compounds will only perfectly gas-out if the temperature of the thermal treatment through the waste material is higher than the limit temperature of the transformation point. The avoidance of production of the secondary products is only possible if the thermal decomposition is done in vacuum. The required heat up time is approximately one hour, which can be adjusted + or - 20 % by controlling the rotation speed of the reactor. Of course the diameter of the reactor is large enough to ensure enough space during the creation of the pyrolysis gas-vapours.

There are five well distinguished phases concerning the dry distillation process inside the reactor:

I. Warm up phase: up to 150-160 C° (300-320 F°). Characterised by the evacuation of the free and most of the bounded water from the coal.
II. Heating up phase: up to 270-280 C° (518-536 F°). Characterised by the evacuation of the remaining chemically bounded water, with simultaneous development of gasification.
III. Thermal decomposition phase: up to 380-400 C° (716-752 F°). This is characterised by self carbonisation with exothermic chemical reactions and a heavy gasification process.
IV. Gas-out phase: up to 500 C° (932 F°). Characterised by the escape of volatile compounds, including the heavy tars, from the material.
V. Stabilisation phase: over 500 C° (932 F°). The solid rest phase of the flash pyrolysis process is Clean Coal and/or inorganics including ash.

The conversion and decomposition of waste materials covers different thermal transformations, such as structural changes and decomposition, cracking, condensation and polymerisation of the molecules. We have opportunity to receive technical information concerning those transformations and changes through temperature control.

3.3./ The out-gassed solid rest material at the approximate temperature of 650 C° (1,200 F°) is to be discharged through the discharge spiral blades at the end of the reactor at a speed related to the speed of the reactor.

The hot solid Clean Coal products are further transported by a worm feeder into the indirect cooled cooler, in which it is to be cooled in a reductive environment. The solid material cooler is designed to be able to cool powder and/or fine granulated materials from up to 1,000 C° (1,850 F°) down to 40 C° (104 F°) and is totally closed. The discharged end product is further utilised for clean combustion power generation resulting very low rates of generated SO2 and NOx.

The pyrolysis gas-vapours at the approximate temperature of 600 C° (1,112 F°) are also to be discharged at the same end through a suction pipe specially designed for this purpose. The hot pyrolysis gas-vapours remain in their respective complex phases as they are formed. Once the pyrolysis gas-vapours are condensed, the reaction will be irreversible. This is a harmful and heavy environmental pollutant complex substance including most part of the sulphurs/phosphorus and the volatile compounds from the coal input material Therefore, pyrolysis gas-vapours have to be neutralised and/or destroyed. This is achieved in an after combustion chamber which is operated under high temperature conditions and long residence time.

Thus the solid end products and the pyrolysis gas-vapours are separated for separate after treatment.

After the flues gases passed the reactor zone, they are additionally energy recovered in the dryer. The directly heated closed dryer has been developed for the special purpose of drying waste materials. Already, during the drying phase, hazardous substances can be volatized. They are, together with the dying medium flue gases, purified in the scrubber. The inflow temperature of the hot flue gas is approximately 400 C° (752 F°) and the outflow temperature of the mixed utilized flue gas, with high content of moisture, is approx. 110 C° (230 F°).

The drying process makes it possible to dry waste materials with maximum 45 % moisture content to 15 %. The low dimension of the input material in the dryer and the extended contact area between waste heat carrier gas makes an effective flash drying effect.

After drying, the material is to be fed in through a transport screw in the reactor. Meanwhile, the utilised flue gas flows in to the scrubber, first passing a dry dust collector system. The scrubber tower is designed to separate the cooling from the scrubbing phase. The indirect cooling medium is air or water, circulating around the scrubbing channels. This solution is especially important during the summertime operations and in hot zones to avoid the boiling up of the scrubber. The impurities are trapped in the scrubber water by different purification effects; multi stage spraying from nozzles in the counter stream, bubbling, drop-out, centrifugal separation and condensation/diffusion.

The scrubber water is to be purified The water treatment system serves the purpose of neutralising the soluble impurities taken from the carrier gas and through treatment of additive materials, such as limestone, chemically bound and precipitated to an insoluble neutralised

chemical form. Meanwhile, the cleansed process gases are discharged The high moisture content precipitate is filtered from the water and separately introduced to the system, where it will pass the pyrolysis reactor again to be burned out and are neutralised.

The discharged process gases are permanently analysed to prove to the authorities that the emission rates are well under the normative Because the U.S. Clean Air Act and the German TA Luft legislation are expected to be stricter than today, the PCS system is already technologically prepared to meet the possible new norms after the year 2000.

3.4./ Among currently available technologies for Clean Coal the PCS process is unique in several critical aspects concerning the criteria and concept Product Control Ltd. used in developing the Product Control System "PCS" process included:

A. Good destruction efficiency,
B. No possibility of dioxin or furan formation,
C. Continuos monitoring and process control suitability;
D. Suitability for different waste materials,
E. Decentralized location of industrial investment based on 2 tons/hour unit standard capacity for solid hazardous waste management, meanwhile for Clean Coal production the standard capacity is 6 tons/hour input.
F. Cost efficiency, low O & M cost;
G. Modular design for alternate application, simple and practical construction,

The patented PCS method and apparatus addresses all of these criteria.

A. A benchmark of good treatment technology is high removal and destruction efficiency. Pilot-scale testing demonstrated that the PCS process was more than capable of this.

B. The second criteria for process design was elimination of the possibility of dioxin and furan emissions in case if it is operated to process solid hazardous waste. The PCS is not an incineration technology.

The PCS process decomposes the input material in a special indirectly heated vessel to produce a reductive atmosphere devoid of free oxygen, and thus eliminates the possibility of hazardous gas formation

C. The special patented feature of the PCS indirect heated rotary reactor and other vital apparatus components makes viable the process of continuos process control and monitoring of the destruction efficiency This is satisfied in the criterion of the method and apparatus design.

D. The proof of the viability of a removal and destruction technology is its ability to process different solid organic and/or non organic hazardous substances. The PCS process is suitable for many types of waste, sorted and unsorted as well, all those that are economically decomposable by dry distillation under any range of 1,000 C° (1,850 F°).

E. The size, the removal and destruction efficiency and capacity of the technology, furthermore, the low cost makes it viable and available to make a decentralized installation with the advantage of the safer and lower cost of transportation for the input waste stream.

F. The small reactor size and the capability to recirculate process gas-vapours from the decomposition process makes the process equipment, especially the flue gas treatment unit, small, technically simple and safer and economically viable. As well, the smaller size and the simple construction reduces the capital and the O & M cost, with special concern to the corrosion process. There are alternative recovery of the saleable products, such as Clean Coal and/or Waste-to-Energy or Pure Activated Carbon.

G. The modular design makes the wide range of alternative applications viable and available. The simple and practical design is end user and maintenance friendly with an unconditional technical solution.

3.5./ Applications: The technology development of Product Control comprises three main areas. The various basic materials require different modular constructions and the purpose of the treatment and the quality of the end products depends on the quality of the input materials.

3.5.1. Pure Chemical: waste amenable to treatment includes, - industrial, municipal and/or post-consumer waste; soils and sludges; waste contaminated with heavy metals, halogens, pesticides and/or organic contaminants such as: cleaning of coal, household waste, thermoplastics, rubber; tire; organic and oil sludge; impregnated and contaminated wood; agricultural waste; contaminated soils; contaminated packaging material resulting from the food, chemical and agricultural industries; mercury-based luminescent light, contaminated activated carbon, etc.
End products: Waste-to-Energy conversion resulting in Pure Carbon and/or Clean Coal.

3.5.2. Pure Activated Carbon: a second version of the process is applicable for the manufacture of Pure Activated Carbon from coal, wood chips, straw, coconut shells, rice hulls, peats and nuts and/or other agro-forest waste products.
End products: high quality Pure Activated Carbon and/or inexpensive waste-to-energy. An annual 15,000 tons of wood waste input provides approximately 2,500 tons per year of a high quality end product and energy surplus.

3.5.3. Pure Nuclear: a third version of the process provides for the treatment of low level organic radioactive nuclear waste for the purpose of volume reduction.
End product: volume reduction at a low cost. (Designed input capacity of 100 kg/hour.)

3.6./ Market and economy: There are already many different technical solutions on the international environmental industry market, a market with increasing demand. However, only a few of them are successful. Those will be successful which have the most efficient technical solution at the most reasonable cost and price. The PCS technology is one of those few technologies, which principally concentrates on the following idea:

That which was recently technically and economically unavailable, is now viable and available reality, even beyond the year 2000.

3.7./ History of the development and present status:

The main idea was to develop a new and complete pyrolysis system, which is not any modification and/or alternative application of the previously known technique. The direction of the development concept, from the beginning, was related to a rotary kiln system, which at that time was the main orientation in the treatment of organic materials.

After laboratory tests were completed, a small scale unit was constructed in 1985. The success of the scale model resulted in the construction of a new larger - third generation - mobile pilot plant which has been considered for use as the test, demonstration of the innovative main components of the PCS technology. Those are: indirect heated rotary reactor, indirect cooled cooler, indirect cooled scrubber. At this stage the financial situation required that I set up the pilot plant in Hungary, where operational costs are lower than those of Sweden.

The pilot plant has been working in Hungary since September of 1990 and has been tested for more than two thousand hours. The pilot plant was designed to be based on the condensation principle to hard test the indirect cooled scrubber. This test period ended at the beginning of 93', with the result of the concept of the technologies being successfully proven. The practical experience from the previous years has made viable the new, fourth generation construction which have been designed in the last four years for a standard capacity of 2 tons/hour, 15,000 tons/year for solid hazardous waste management, meanwhile the standard input capacity for production of Clean Coal is 6 tons/hour, 50,000 tons/year

4./ I have invented several patents, furthermore developed know how, complete technology and engineering design related to the patented inventions, which are as follows:

4.1./ Method and Apparatus for Refinement of Organic Material, Swedish PCT application no.: 00206/1988 (approved in the USA, EPO and elsewhere)

4.2./ Gas Treating Apparatus, Canadian PCT application no 00607/1989 (under approval in the USA, EPO, Japan and elsewhere)

4.3./ Method and Apparatus for Treatment of Waste Materials and/or Nuclear Contaminated Materials; PCT application no : /HU92/00029(pending in the USA, EPO, Japan and elsewhere)

5./ The PCS technology is not only a new technical and economical concept, but it is also a new concept of attitude concerning the management of human and natural environment, man made resources; based on practical, end user and environmentally friendly techniques and good, sound economics

To close this session I would like to emphasise in a few words the focus of this project: a more advanced and safer solid waste management technology with great economic advantages.

FIGURE 1: THERMAL TREATMENT SYSTEMS

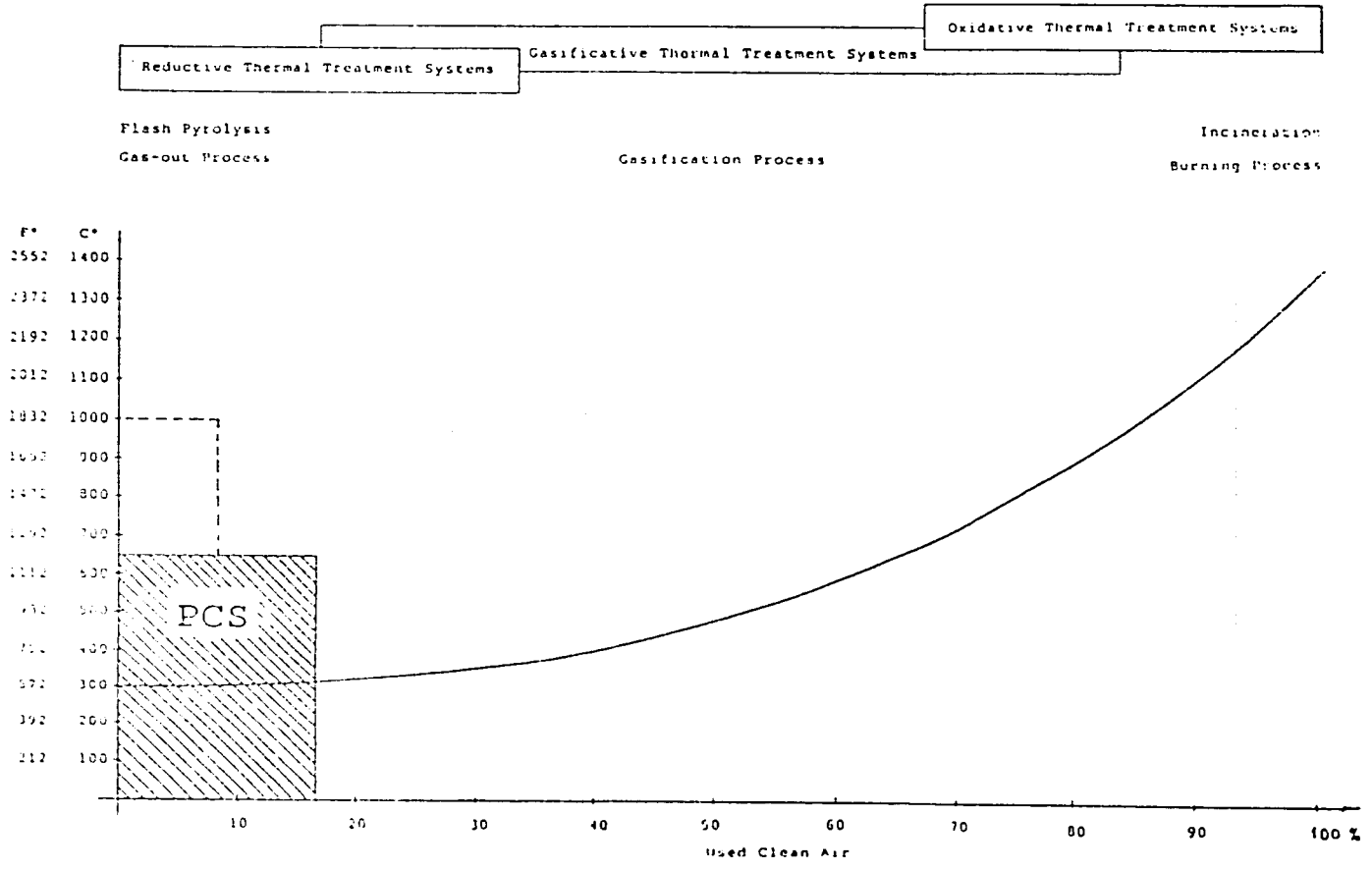


FIGURE 2: PROCESS FLOW SHEET

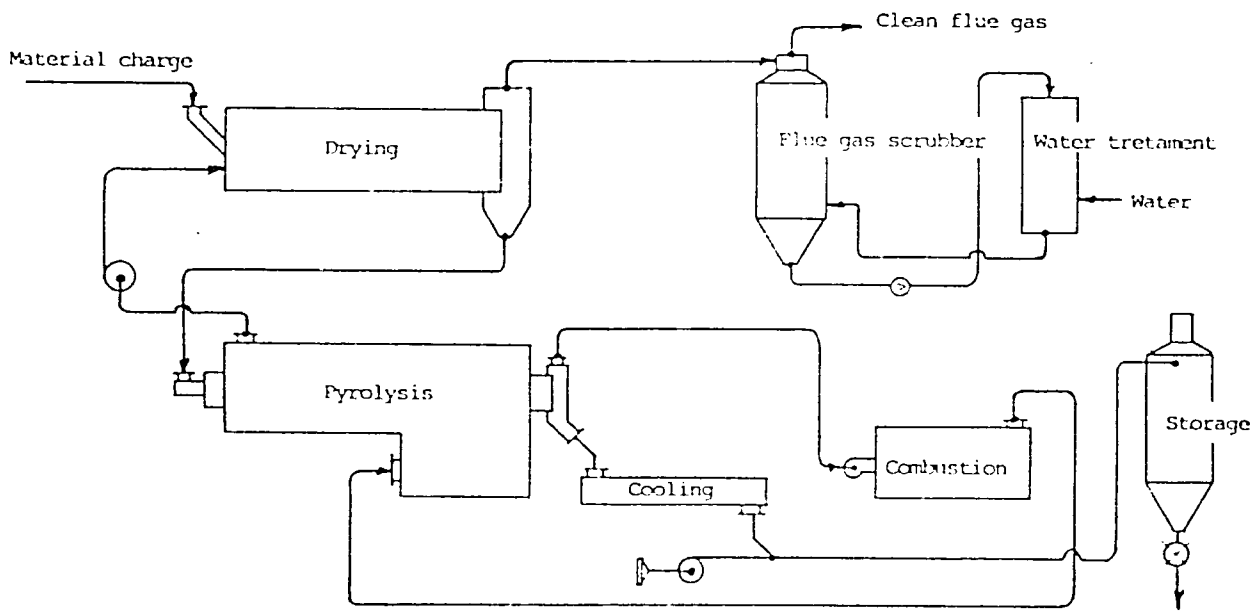
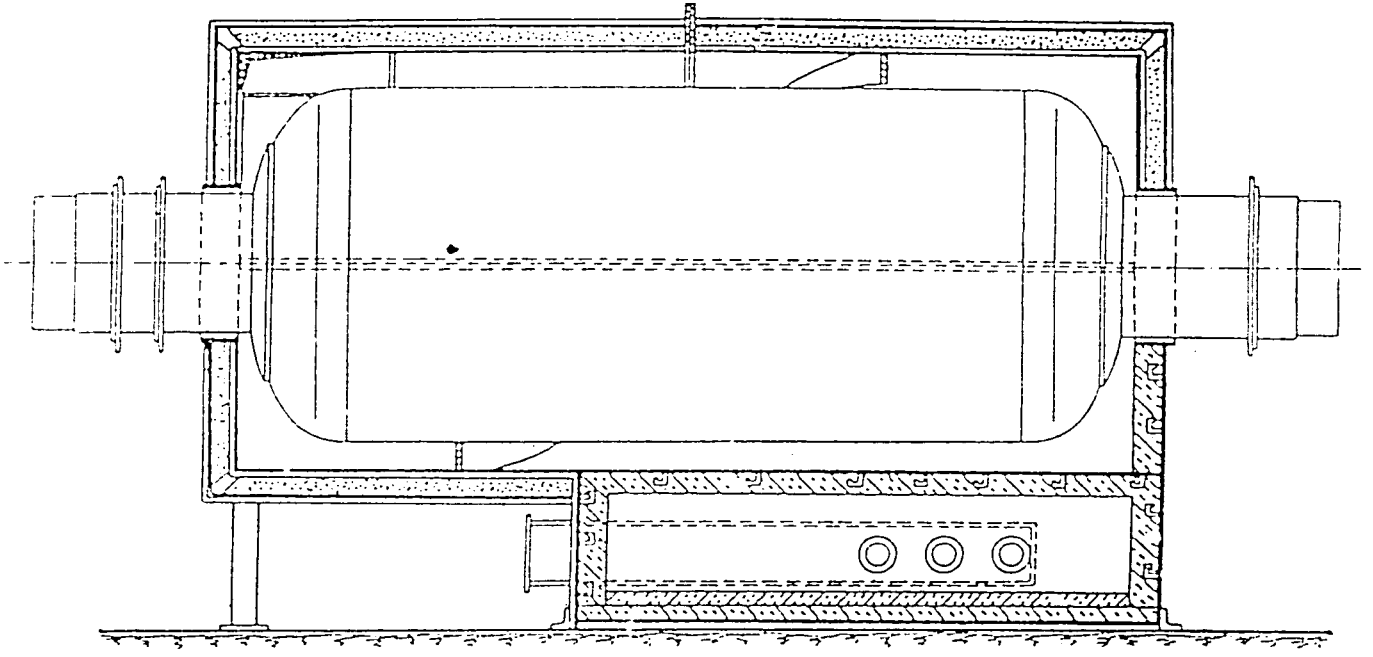
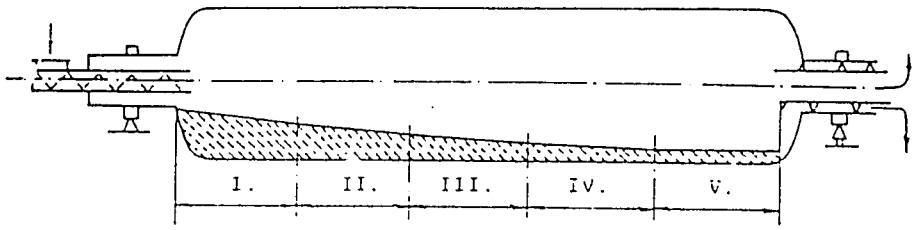
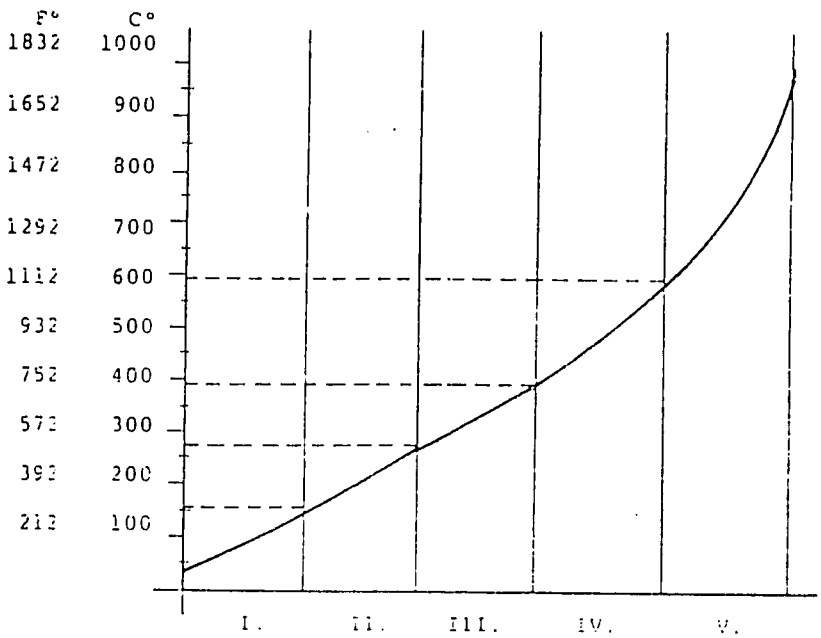


FIGURE 3: FLASH PYROLYSIS REACTOR



PCS REACTOR





The main features of the pyrolysis reactor:

1. Indirect heat transfer through the mantel to the ground material with extended surface area.
2. Permanent operation and homogenised material throughput.
3. Special sealings to provide guaranteed closed operation.
4. Process control of the operation.
5. Low vacuum provides for a high security factor during the operation.
6. Practical and not complicated and user friendly construction.
7. Synchronised [illegible]

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Technology Options/Pyrolysis and Fluid Bed Combustion

Circulating Fluidized Bed Gas-Steam Cogeneration and Its Environmental Assessments

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3 December, 1993

Abstract

A new circulating fluidized bed(CFB) cogeneration process for gas and steam with bright prospects in urban energy-environmental improvement is presently under development in China.

Based on existing CFB experience and expertise, the basic principle of the cogeneration technology exploits high temperature circulating solid material(i.e., ash) as a thermal carrier to meet the need for the coal pyrolysis (or thermal decomposition) process and thereafter for fixed-carbon gasification with steam under multi-component gases in a connected fluidized bed gasifier. The remaining char in the gasifier is then discharged to the CFB combustor(or boiler) to be burnt up to produce steam as in conventional CFB boilers. Generated steam can be used both for power generation and for industrial process heating (or residential space heating). Therefore, coal gas, steam and electric power can be tri-generated continuously in an integrated plant.

Another CFB coking and combustion combined-cycle power generation technology (CFBCC/CC), evolved from the cogeneration process, is introduced briefly here.

A techno-economics analysis based on a small hot experiment and modelling predictions, comparisons between the tri-generation option and some popular solutions for coal-gas/steam separate generation are presented in the paper. The effect on energy saving and the potentials in improving urban environmental quality are also analyzed in this paper.

Keywords: CFB gas/steam cogeneration, techno-economics analysis, environment coordinated performance

Introduction

It is well known that coal resources are the pillar main energy supply in China. The proportion of coal consumption has increased to 76% or so in 1990. It is predicted that coal production by the year 2000 will reach 1.4 billion or even more Coal will remain as the main primary source in China for the foreseeable future. On the other hand, the gas popularization rate for energy of urban areas is very low, and many small coal fired stoves are still used for residential cooking and heating, which contribute to the poor ecological environmental conditions.

At the same time, many industrial enterprises (e.g., ceramic plants or paper mills)urgently need high quality gas to meet their various process heating requirements. Considering that oil and

natural gas resources are comparatively low compared with some Western developed countries, coal-based gas is therefore a necessary option for gas popularization both in urban areas and in certain industrial plants.

In view of energy saving effects and environmental protection, the utilization of coal-gas is beneficial when compared with other alternative options for energy supply.

The principle of gas supply for existing coal-based gasification processes for Chinese urban areas includes: producer coal gas; coke oven gas; continuous vertical carbonizer gas; water gas, Lurgi pressurized gasifier gas etc. For various reasons, however, the above coal gasification processes are obstructed to some extent in China. For instance, coke oven gas is usually considered as the best city gas due to its carbon monoxide(CO) content of 5~6% and heat content of 16~18 MJ/Nm^3. But its popularization is restricted by limited coking coal resources and coke market outlets. For a medium or small town, the option is restricted also by the small plant scale and large capital investment requirements. Generally, for a small and medium town or city, there are few available options to residential coal gas supply. Therefore, it is an urgent task to research and develop a new gasification technology or process which is suitable for most types of Chinese coal, also for coal gas supply both for towns and some industrial enterprises.

The New CFB Gas and Steam Cogeneration Process

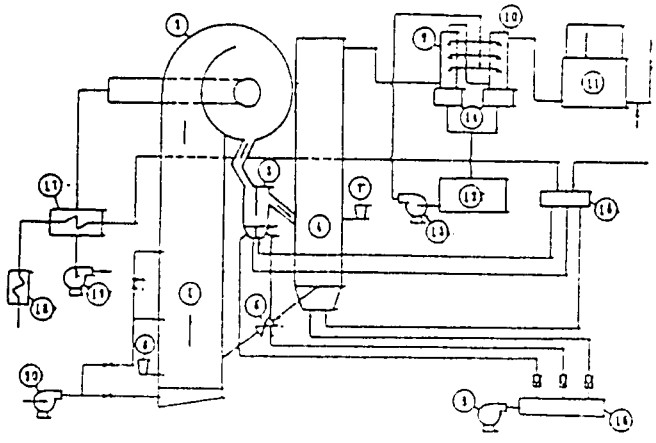
At present, fluidization technology is receiving more and more attention due to its eminent heat and mass transfer performance. Circulating fluidized bed boiler(CFBB) is one particular utilization in the field of power generation. Fluidized bed coal gasification is the earliest successful utilization (e.g., the Winkler gasifier). However, the gasifier needs extra heat for coal gasification under fluidization.

CFB gas/steam cogeneration is an ingenious combination of the above two types. It uses sufficient circulating solid materials from a CFB combustor to carry heat for fed coal thermal decomposition(or devolatilization) and for the partial gasification of fixed carbon into a CFB gasifier. Then the remaining semi-coke is diverted to the fluidized bed combustor which is connected in close proximity to the gasifier where it is burnt up to produce steam. Steam generated from the combustor can either be used to drive a steam turbine for electric power generation or supply heat sources for space heating, and/or even for both. So three thermal products of coal-gas, steam and electric power can be generated in the same compact unit simultaneously with the CFB gas/steam cogeneration process being the key technical nucleus.

Aimed at verifying its feasibility as well as studying its related component performance, a small equipment for hot experiment was built at Tsinghua University[3]. A series of cold and hot experiments have been done, the experiments showed that the CFB gas/steam cogeneration process was technically feasible with its creative conceptual advancement and good engineering enlarging performance. The experimental unit can be seen in Figure 1. A verified mathematical model was built to imitate its main technical behaviors.[1, 5]

The experiment showed that: the unique process is suitable for most types of coal resources with a high thermal efficiency. When bituminous coal of 20% volatile content is used, the specific output of coal gas from the gasifier is around 250 $Nm^3/t\cdot coal$ with a gas caloric content of some 15 MJ/Nm^3 and carbon monoxide(CO) content of less than 15%. This high grade coal gas can be used as town residential gas without further preparation[3].

A pilot experimental unit with rated steam output of 35t/h from the combustor is now being built in China. Its conceptual design is illustrated in Figure 2, and its main technical data is listed in Table 1[2].



1. combustor
2. separator
3. feeder valve
4. gasifier
5. refeeder valve
6. coal feeder for combustor
7. coal feeder for gasifier
8. air-fed fan
9. primary cooler
10. second cooler
11. gas tank
12. water cooling tank
13. water cooling pump
14. water sealing channel
15. steam tank
16. air tank
17. superheater
18. starting boiler
19. fan inducer
20. fan blower

Figure 1: Small hot experimental equipment for CFB gas/steam cogeneration

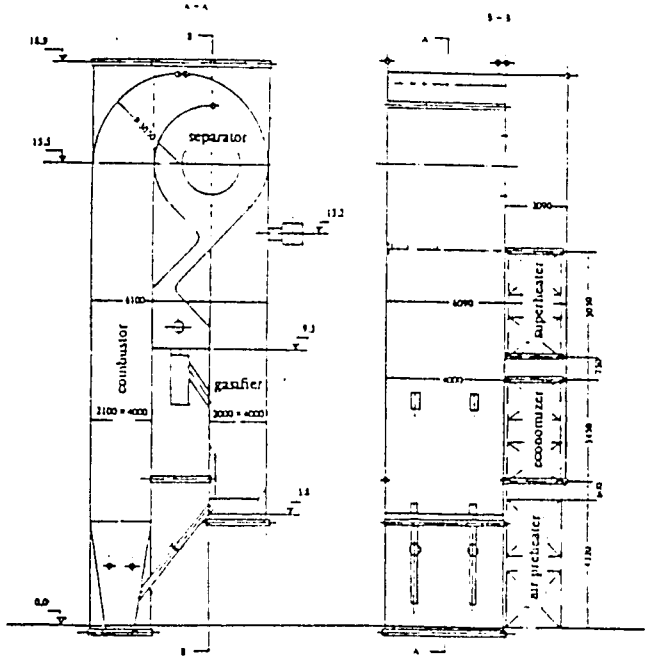


Figure 2. Conceptual design for a typical gas/steam cogeneration unit with rated steam output of 35t/h

Table 1. The main technical data for a typical CFB tri-generation unit with rated steam output of 35t/h from the combustor

Item	unit	data	item	unit	data
Rated steam output from the combustor	t/h	35	thermal effi. for coal gasification	%	65~70
Steam Press./temp.	MPa/°C	3.82/450	CO content of coal gas	%	<15
Combustor thermal effi.	%	89	Steam turbine size	MWe	3
Suitable type of fed coal	–	lignite or bitumite	Space heating load	GJ/h	66.56
heat content of coal gas	MJ/Nm^3	15	Space heating area	$10^4 \times m^2$	26.5
Gas output	Nm^3/h	950~1100	overall thermal effi.	%	42

Table 2. Gas output for typical small and middle CFB cogeneration plant *

Item	unit	A	B	C	D
Steam rating the combustor	t/h	10	20	35	75
Gas output per unit	Nm^3/h	250	500	1000	2000
minimum number of units #	—	3	3	3	3
Total daily gas supply	$\times 10^4 Nm^3/d$	1	2	4	8
Number of households supplied	thousand	3	6	12	24
Total coal consumption	t/h	3.45	6.9	12.08	24.15

* : Gas consumption per household is set down as 25MJ/(d·household); Of the total gas consumption, citizens consume 60%, other welfare projects consume 40%.

: In which, one is standby in case of accident.

For a small or medium sized city or town, several available options for coal gas supply are shown in Table 2. However, because of the low steam parameters, power generation may not always be beneficial in these options. Therefore, it would be necessary for certain steam consumers with a steady load to match themselves.

From a long term perspective, development of the CFB cogeneration plant with large steam turbine with 200 MWe or 300 MWe capacity may be the most promising technical direction. These future options are given in Table 3.

Table 3 Some CFB cogeneration plants with large capacity units

Item	unit	A	B	C	D
Power output	MWe	100	200	300	600
Generated steam from the combustor	t/h	400	670	1000	1950
Coal gas output	$10^4 Nm^3/h$	1.0	1.65	2.5	5.0
Coal gas supply per day	$10^4 Nm^3/d$	20	33	50	100
Number of households supplied	10^4	5	10	15	30

Economic Effect and Cost-Benefit Analysis

Table 4 gives a comparison of capital costs of four available options for coal gas generation. Partial costs related to gas generation has only been considered for the cogeneration option.

It can be seen from Table 4 that: of the four available options, which have approximately equivalent capacities for gas supply, the capital cost for the CFB cogeneration plant of less than 36 million yuan(RMB) is the cheapest. While the most expensive one is the coke oven, which expends almost twice as high as the former. The actual cost per thermal unit of gas for the CFB cogeneration plant is also the lowest, a little less than 13 yuan/(MJ/day) with the cost of the price of gas produced by it is as low as 0.18 yuan/Nm^3, which is acceptable for most town residential consumers as well as by industrial consumers.

Table 4. Comparison of capital cost among four options for coal gas generation*

Item [unit]	coke oven	pressurized Lurgi gasifier	two-stage gasifier plus methanation	CFB tri-generation plant
plant size	3× 2 hole	7× Ø1.8	4× Ø3.3	8×35 T/
Coal gas flow rate [10^4× Nm^3/day]	19.0	18.7	22.5	19
Caloric content of coal gas [MJ/.Nm^3]	17.5	16.2	12.14	15.0
CO volume content of coal gas [%]	< 6	< 15	after methanation <10	<15
Capital cost [10^4yuan]	7700	6230	5775	3575
Specific cost per unit of coal gas [10^4yuan/(TJ/day]	2260	2060	1800	1260
Annual operating cost (including depreciation) [10^4yuan/yr.]	—	1835	2660	1190
Cost of price of coal gas [yuan/Nm^3]	—	0.27	0 32	0.18
Specific investment cost of reducing CO_2 emission [yuan/t carbon]	—	—	4554	751

* : All costs are estimated at fixed 1992 prices.

In relation to the cost-benefit effect of reducing CO_2 emissions, the investment for reducing CO_2 emissions for CFB cogeneration is only 751 yuan/(t·c), which is only one sixth of that for the two-stage water gasification process with extra methanation preparation process. This makes the CFB cogeneration the most attractive alternative for atmospheric quality protection.

Assessment of Its Environmental Coordinate Performance

Due to its high efficient combustion as well as low pollutant emission rate, the CFB cogeneration process is characteristic of energy saving therefore of CO_2 emissions reduction. In order to assess the potential for reducing CO_2 emissions, it is necessary that the CFB tri-generation plant for gas, steam and power should be of equivalent size to a conventional cogeneration plant for heat and power plus another coal gasification station. Coal consumption for gasification of CFB trigeneration can be calculated from the total coal consumption minus coal consumption for heat and power cogeneration in an optimum design configuration. In most Chinese small or medium sized towns and cities, many dispersed small coal fired stoves are used for residential cooking and space heating as well as services. Based on this situation, the potential for energy saving is estimated. Table 5 gives the results of the analysis.

Table 5. Comparison of energy saving and CO_2 emissions reduction

Item	unit	the CFB trigeneration plant	two-stage water gas gasifier plant
Installed size*	—	4×35 t/h	2×Φ3.3 m
Dry gas rate	$\times 10^4$ Nm^3/day	8.13	7.50
Caloric content of dry gas	MJ/Nm^3	15.0	12.1
CO content of dry gas	(vol.) %	11	30
Coal consumption for gasification	$\times 10^4$ t/yr.	2.47	3.36
Specific coal consumption	kg/MJ	0.055	0.101
Energy saving (compared with coal-fired dispersed stove)	thousand t/yr.	28.3	6.1
Reducing CO_2 emissions (compared with coal fired dispersed stoves)	thousand t/yr.	15.2	3.3

* : In which, one is stand-by in case of accident.

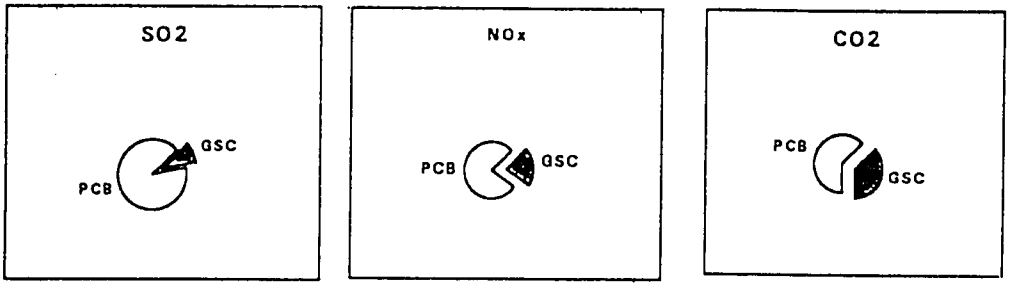
As an application of fluidization technology, the new cogeneration process has intrinsic advantages similar to a CFB boiler and even beyond the latter in the case of air pollution control.

Thanks to the gasification of coal fed to its CFB gasifier, the organic sulfur content of the coal is discharged as hydro-sulfide(H_2S) instead of sulfur dioxide(SO_2), and H_2S can be absorbed to make a by-product through a conventional chemical process. Therefore, SO_2 content in the flue gas from the combustor is far less than that by any conventional combustion method. Even if a small amount of coal was fed to the combustor for additional firing, a high sulphur retention efficiency of 80~90% could be attained when a certain sulphur sorbent (e.g., crushed limestone or marble) is put into the combustor in a low Ca/S molar ratio of around 1.5. As compared to a conventional pulverized-coal (p-c) fired boiler without desulphurization, SO_2 emissions from the flue gas is only one tenth.

On the other hand, because of its fixed-carbon firing in a lower temperature of some 850°C, the production and emissions of nitride (NO_x) can be reduced substantially. If an imaginary comparison is made between a conventional p-c fired boiler plant (PCB) and a CFB trigeneration plant(GSC), which is so designed that its available energy output (e.g., the sum of effective

energy including both gas output and power output if the premise is made that the effective heat of gas is of the same quality as electric power) is equivalent to the former, then NO_x emissions of the GSC is only 1/3 or 1/4 of that of the PCB(Figure 3).

Figure 3: Comparison of pollutant emissions



A Brief Analysis of CFBCC/CC Power Generation Technology

CFB coking and combustion combined-cycle power generation technology(CFBCC/CC), fires generated coal gas from the CFB cogeneration process to drive a gas turbine for power generation and utilizes the exhausted gas from the turbine to produce steam in a heat recovery boiler with (some) additional complementary coke-firing which is used to drive a steam turbine, as is shown by the flow diagram in figure 4.

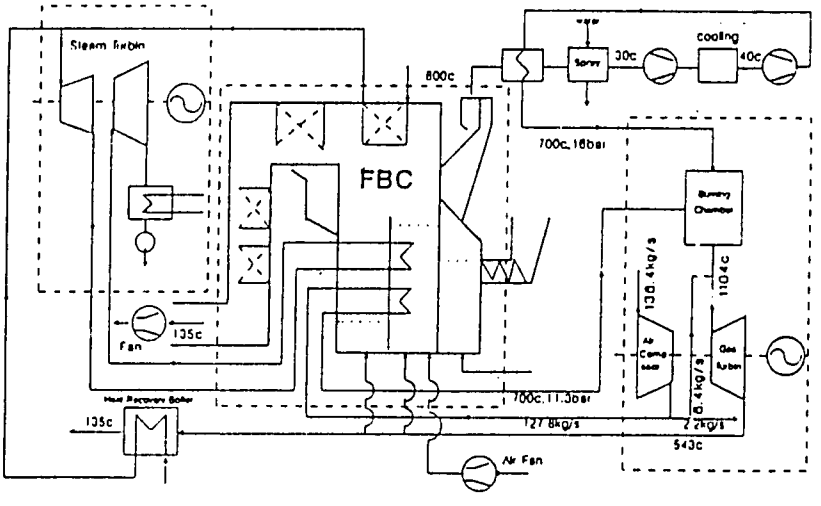


Figure 4: CFB coking and combustion combined-cycle power generation

When the inlet temperature of the gas turbine is 1104°C, a high power generation efficiency of 40% or even greater can be achieved. This is the highest efficiency of all coal-fired power generation technologies in China. The main technical data for CFBCC/CC and the potential for reducing CO_2 emissions (i.e., by saving coal sources) are given in Table 6. It is expected that the new coal-fired power generation technology will be developed to move into the commercial market with its much improved power generation efficiency and environmental poliution control by 2010 or 2020, according to existing available technical levels in China.

Table 6. Main technical data and CO_2 emissions for CFBCC/CC

Power capacity	162 MWe
Gas turbine	37 MWe
Steam turbine	125 MWe
Whole power generation effi.	40 %
Specific thermal consumption	8987 kJ/kWh
CO_2 emission	0.273 Mtc/yr.
Specific CO_2 emission ratio	226 kgc/MWh

Conclusion

An analysis of the techno-economic implications and the environmental effects of the CFB gas/steam cogeneration have been presented in the paper. A new power generation technology, CFBCC/CC has also been introduced. A series of fundamental study programs including laboratory research and industrial pilot experiments with a few technical problems to overcome are being carried out at Tsinghua University. The new cogeneration process will have a bright potential in the future because of its good energy saving characteristics as well as its environmental appropriate performance.

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IEA Second International Conference on the Clean and Efficient Use of Coal and Lignite: Its Role in Energy, Environment and Life.

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Design Considerations for Utility Size CFB Steam Generators

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ABSTRACT

Commercial circulating fluid bed steam generation technology is less than a decade old. In fact, in just seven years Combustion Engineering, Inc. (ABB C-E) has gone from commissioning its first industrial-based Circulating Fluid Bed (CFB) to starting up the two (2) largest utility reheat CFBs in the United States with a net electrical output of 150 MW each.

The current trend of cost effective, environmentally sensitive solid fuel steam generation calls for further scale-up of the CFB option to continue to meet these demands. This paper discusses ABB C-E's approach to answer this challenge for future growth of this technology.

INTRODUCTION

Fluidized bed combustion technology has been utilized in a broad spectrum of qualifying facilities and independent power projects. (For a general description of CFB technology, see Reference 1.) The fluid bed combustion process facilitates power production firing a wide range of fuels while meeting stringent required emission levels. Over the past seven years, ABB C-E has supplied twenty CFBs utilizing licensed technology from Lurgi GmbH.

Eight of these operating units have reheat capability. Interest in CFB is still related to the technology's ability to handle "waste" type fuels. However, the predominant driving force for continued interest in scaling up this technology is its ability to achieve low NOx and SOx emissions without the need for post combustion equipment such as selective catalytic reduction systems (SCRs) and wet or dry flue gas desulfurization systems.

This paper will discuss the current state of the technology and address several issues which the designer faces in addressing the scale-up issues. Finally, performance and unit design comparisons are presented for similarly-sized CFB and Pulverized Coal (PC) units and for several different-sized large CFB arrangements.

ABB C-E FLUID BED TECHNOLOGY HISTORY

Figure 1 illustrates the development of fluid bed technology within ABB C-E. With the exception of the Great Lakes and TVA installations, the predominant focus for technology commercialization has been on

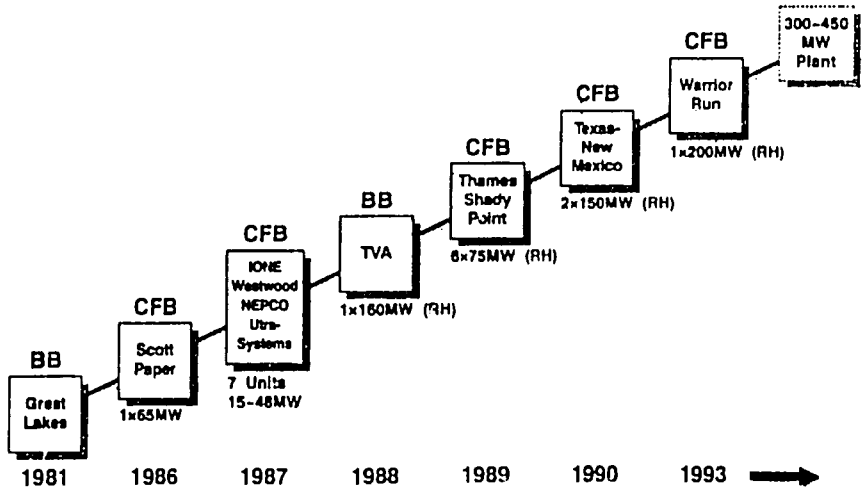


Figure 1 - ABB CE Fluid Bed Development

the circulating fluid bed process. Included in this development is a dramatic scale-up in unit capacity within a seven-year time from 65 MW to 200 MW (or 200%) and a transition to reheat applications for improvement in overall plant heat rate.

The most recent contract ABB C-E received is the AES/Warrior Run project. This IPP project, which includes a 208 MW bituminous coal-fired CFB to be located in Maryland, was awarded to ABB C-E in February, 1993 (for project specific information, see Table I). This contract reinforces market acceptance for the CFB technology based on a proven track record to meet stringent air emission requirements while maintaining high availability and capacity factors.

CFB technology has demonstrated an unparalleled ability to achieve low NOx production without the need for post-combustion equipment such as SCR (Figure 2). This is possible due to low combustion temperatures (1500 - 1600 F) and the staging of air by application of secondary and tertiary air admission zones.

Furthermore, the CFB technology has exhibited a fuel flexibility; an ability to burn waste materials and fuels, previously deemed uneconomical and/or impossible to handle by conventional boiler firing system technologies (see Table II).

Evaporation	1,400,555 LB/HR
SHO Temperature	1,005 F
SHO Pressure	1,890 PSIG
Feedwater Temperature	470 F
Reheater Flow	1,304,290 LB/HR
RHO Temperature	1,005 F
RHO Pressure	470 PSIG
RHI Temperature	674 F
RHI Pressure	490 PSIG
Gas Flow	1,838,000 LB/HR
Air Flow	1,703,000 LB/HR
Fuel Analysis	
Carbon	62.0% Weight
Hydrogen	3.6% Weight
Nitrogen	1.5% Weight
Sulfur	2.3% Weight
Ash	23.4% Weight
Oxygen	3.2% Weight
Moisture	4.0% Weight
Fuel Higher Heating Value	11,074 BTU/LB

Table I - AES/Warrior Run Preted Performance

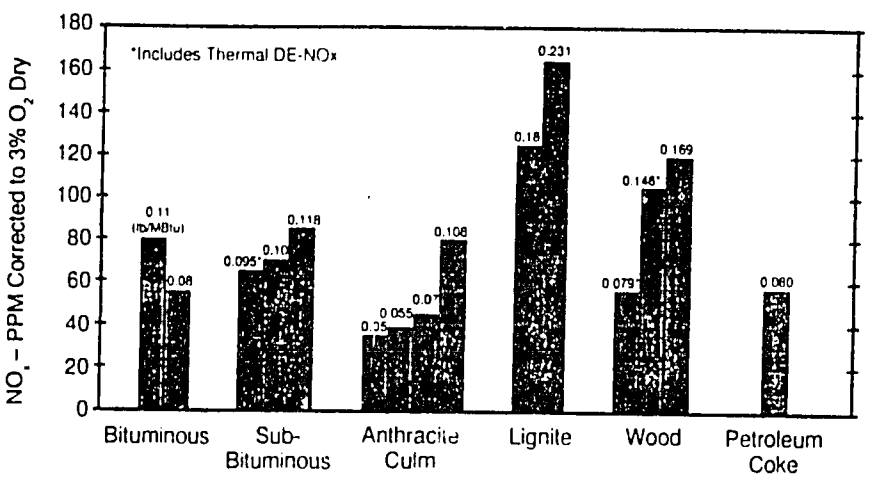


Figure 2 - Operating CFB Unit NOx Emissions

Fuel	Moisture, % Weight	Ash, % Weight	Heating Value, Btu/lb
Wood Waste	50	3.88	4,200
Anthracite Culm	6.9	69.9	2,296
Sludge	70.0	11.0	1,950
Lignite	31	16	6,682
Brown Coal	50	10	4,536

Table II – Fuels Handled by ABB C-E CFBs

Currently, based on its demonstrated scale-up ease, low emissions capabilities and fuel flexibility, the CFB technology is a serious option for many customers for their mid-sized (300-450 MW) utility unit applications.

TEXAS-NEW MEXICO POWER COMPANY (TNP) EXPERIENCE

The advancement of the Circulating Fluid Bed technology required a unique approach to minimize risk both commercially and technically. ABB C-E entered into a consortium arrangement to provide the largest operating CFB in the United States to the Texas-New Mexico Power Company. These two (2) 150 MW net generating units went into commercial operation in June of 1990 and 1991, respectively, and fire a Texas lignite with a Higher Heating Value (HHV) of 6,733 BTU/LB (Reference 2). Tables III and IV illustrate the fuel and limestone analyses, respectively, for this project.

The two TNP units are important as they have successfully demonstrated the use of circulating fluid bed technology in a utility application. To accomplish this, many significant design innovations were utilized along with a major scaling up of components and systems. Among the equipment scaled is the combustor which is 1.5 times larger in plan area than ABB C-E's next largest single combustor. The TNP combustor has water-cooled walls, grates and plenums with the lower combustor configured with two separate fluidization zones; thus giving this design the name "pant-leg" (see Figures 3 and 4).

Fuel Type	Calvert Lignite
Fuel Size	3/8" X 0 to Coal Silos
Proximate Analysis	
Moisture	30.7% Weight
Volatiles	27.0
Fixed Carbon	26.8
Ash	15.5
Ultimate Analysis	
Carbon	38.6% Weight
Hydrogen	3.1
Nitrogen	0.8
Sulfur	0.9
Ash	5.5
Oxygen	10.4
Water	30.7
Fuel Higher Heating Value	6,733 BTU/LB

Table III – TNP Fuel Analysis

Limestone Size	1-1/2" X 0 to Limestone Crusher
Chemical Analysis	
Calcium Carbonate	91.5% Weight
Magnesium Carbonate	4.5% Weight
Moisture	2.0% Weight
Inerts	2.0% Weight

Table IV – TNP Limestone Analysis

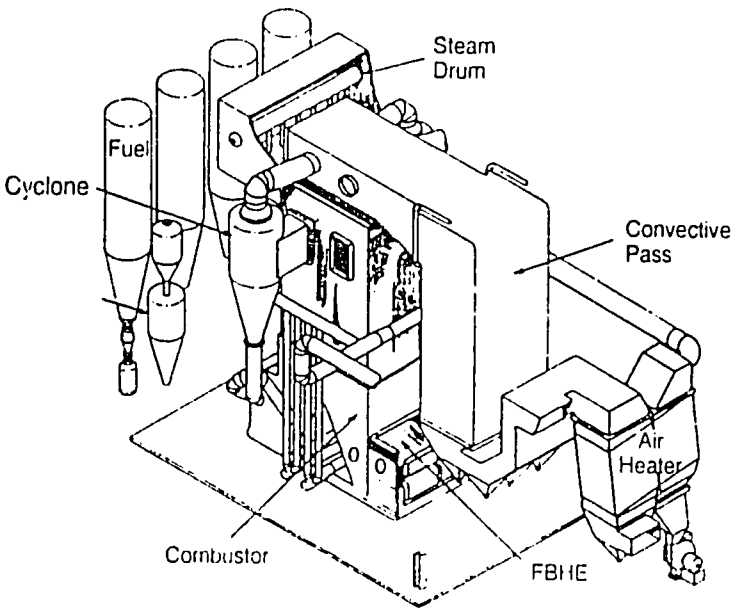


Figure 3 - TNP Equipment Arrangement

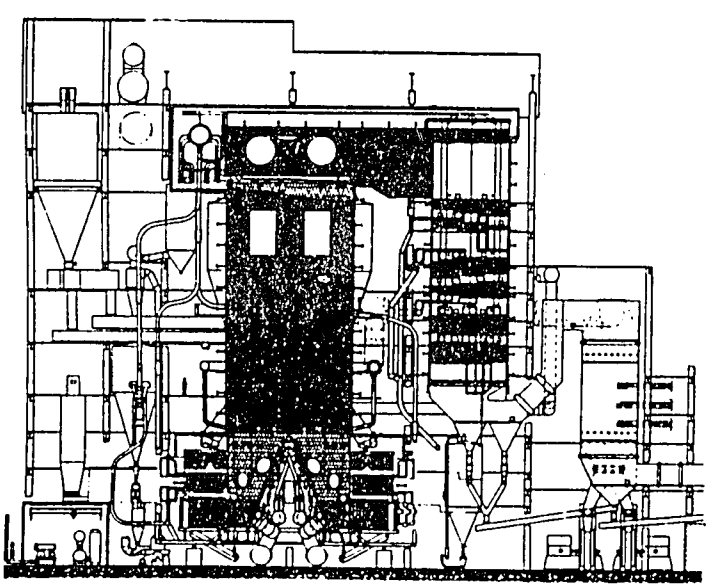


Figure 4 – TNP Side Elevation of Equipment

To accommodate such a large combustor and meet process requirements, these units are also the first to have four (4) solids recirculation cyclones operating in parallel and to be designed with cyclones located on opposite walls. This cyclone arrangement presented a design challenge in the collection of flue gas from the cyclones and the direction and distribution of this gas to the convective backpass section of the boiler. To overcome this, a uniquely designed steam-cooled enclosure is used which is integrated with the steam-cooled backpass. The final heat recovery from the gas is accomplished by using heat pipe air heaters, compact, and common on many ABB C-E CFBs.

Another significant design innovation used on the "pantleg" design is the integration of the fluid bed heat exchangers into the water-cooled envelope of the combustor. This allows for a very compact arrangement between cyclones, FBHEs and the combustor.

The capacity and availability factors for the TNP plant, shown in Table V, have been impressive. This stellar performance record has catapulted the circulating fluid bed technology into a new era. Based on the TNP experience, commercial units up to 450 MWs are now considered viable projects.

STEAM CYCLE AND HEAT DISTRIBUTION

For smaller CFBs, up to 100 MW, the units are likely to be designed for superheat outlet pressures of 900, 1200 or 1800 psi depending on particular project specifics (fuel costs, steam hosts, etc.). As boiler size continues to increase, owners tend to focus on more efficient plants that include reheat cycles and higher pressure, 2400 psi, cycles. This higher pressure, lower heat rate cycle offers lower fuel costs, lower limestone costs, and more extraction steam possibilities which more than overcome the higher pressure part costs associated with a boiler designed for this pressure.

As CFBs increase in size and add reheat cycles, FBHEs (fluid bed heat exchangers) can be added to the solids recycle loop and would play a significant role in steam-side heat pick-up (See Figure 5 for the FBHE arrangement for a large-scale CFB.). The presence of these low velocity bubbling beds offer several operational advantages for large-scale CFBs; separation of reheater and superheater steam circuitry for ideal temperature control, optimization of turndown, and maintainability of the key process parameters shown in Table VI.

Unit/Facility Number 1	
Availability	99.6
Capacity	98.9
Unit Facility Number 2	
Availability	95.2
Capacity	97.1

*Excludes scheduled outages.

Table V – TNP Availability and Capacity for 1992*

- Enables Multiple Fuels to be Burned and Maintains Performance
- Maintains Key Process Parameters
  - Combustor Temperature
  - Calcium/Sulfur Ratio
  - NOx Formation and Emissions
  - Superheat and Reheat Steam Temperatures
- Eliminates "In-Combustor" Surface on Large Units
- Provides Optimum Turndown

Table VI – Advantages of the Fluid Bed Heat Exchanger

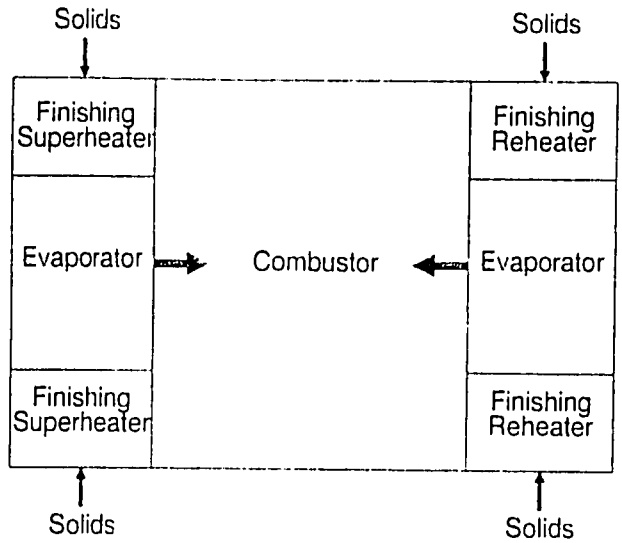


Figure 5 – Large-Scale CFB FBHE Arrangement

For a large CFB, it is possible to achieve a 30% MCR steam and reheat temperature control load (3.3:1 turndown), on a unit with FBHEs. At MCR, about 60% of the reheater, 25% of the superheater, and 45% of the evaporative duty will be done in the FBHEs. This distribution will change as load is decreased in response to changing gas weights as shown in Figure 6.

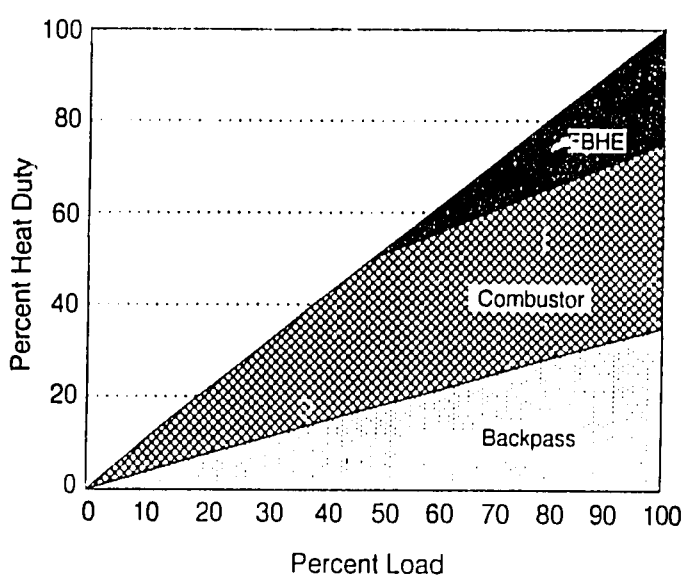


Figure 6 – CFB Typical Heat Duty Splits

SCALE-UP ISSUES

As previously mentioned, significant CFB size increase has occurred with relative ease. As the units continue to increase in size, further scale-up will be required. The discussion below will focus on the scale-up concerns with four major components on CFBs of this size; the combustor, the cyclones, the backpass, and the fluid bed heat exchangers.

These items are discussed below based on the results of a recent study on a sub-bituminous-fired 330 MW CFB shown in Figures 7 and 8. This unit has an increase in combustor size, cyclone diameter, backpass width, and FBHE width from the arrangement typical of both the TNP and Warrior Run units.

Combustor

In designing a 330 MW CFB unit, the parameters which affect the ability to meet performance requirements (emissions, Ca/S and efficiency) are analyzed along with the fuel to be fired. Careful consideration is given to the geometry of the combustor as this impacts fuel, air and sorbent mixing. Figure 9 compares the relative size of a 330 MW CFB firing sub-bituminous coal with that of the 150 MW net lignite-fired TNP CFB units. ABB C-E has chosen to increase the combustor height slightly to ensure the solids, pressure profile, and therefore heat transfer to the water wall is within our proven experience and knowledge base. The "pantleg" design employed by ABB C-E enables the fuel, air and sorbent to mix in an area that is roughly one-half of the overall combustor plan area. Figure 10 compares the fuel/air/solids mixing lengths for the 330 MW unit with the mixing lengths of operating ABB C-E units. The use of the "pantleg" design results in a fuel mixing length increase of only 30% over the TNP design. ABB C-E maintains that this increase will not cause any performance concerns for the following reasons:

- The massive amount of recycle ash (as compared to fuel) circulating through the primary recycle loop, where fuel comprises no more than 2% weight of the total material, ensures the heat of combustion is evenly distributed.
- During initial operation at TNP, fuel feed problems necessitated running the unit at full load with 3 of the 4 fuel feed points in operation over extended time periods. This meant that one operating feed train in the affected pantleg was carrying close to 50% of the total coal flow over a mixing length of 33 ft (50% increase in mixing length). During the performance of the unit under this operation, fuel flow was virtually unchanged and previous SO2 emissions levels were maintained.

The use of ash re-injection systems and additional fuel feed points is anticipated on units which fire low-volatile matter fuels.

Cyclones

Cyclones in a CFB design separate the entrained particles from the flue gas leaving the combustor and return the hot solids to the combustor. The high recycle rate of the cycle ensures a uniform temperature in the furnace. The efficiency of the cycle impacts the capture rate of the fines fraction of the solids entering the cyclone. This, in turn, affects limestone utilization and carbon burn-up. Basic cyclone theory suggests that as the cycle size increases, the collection efficiency decreases due to a reduction in the centrifugal force. In scaling up, a point will be reached where the cycle size gets so large that limestone utilization and carbon burn-up decrease. ABB C-E presently has cyclones in operation with inside diameters of 26 feet. The 330 MW plant will employ four (4) 26 feet cyclones of this proven design. ABB C-E has also done research on cyclones larger than 26 feet in diameter which may be provided on larger units.

Backpass

The convective horizontal backpass of the CFB consists of low temperature superheater, low temperature reheater and economizer surface arranged similarly to that in a conventional pulverized coal fired unit. The largest backpass used in a PC boiler is approximately three times larger than the size used for a 330 MW CFB. The light dry fly ash of the CFB enables the designer to utilize either an in-line spiral fin or bare-tube economizer in the design. On most coal-fired operating ABB C-E CFBs, a heat pipe air heater with

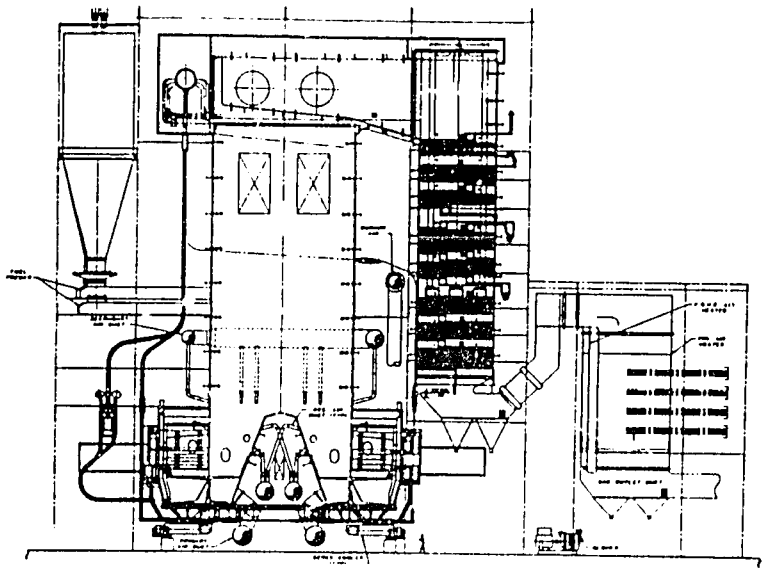


Figure 7 - 330 MW CFB Side Elevation of Equipment

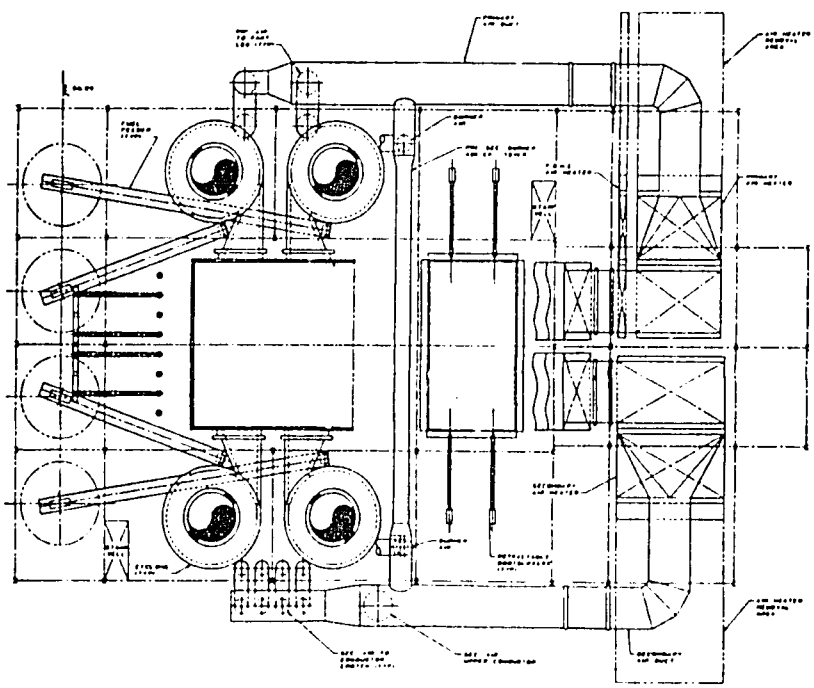


Figure 8 – 330 MW CFB Plan View of Equipment

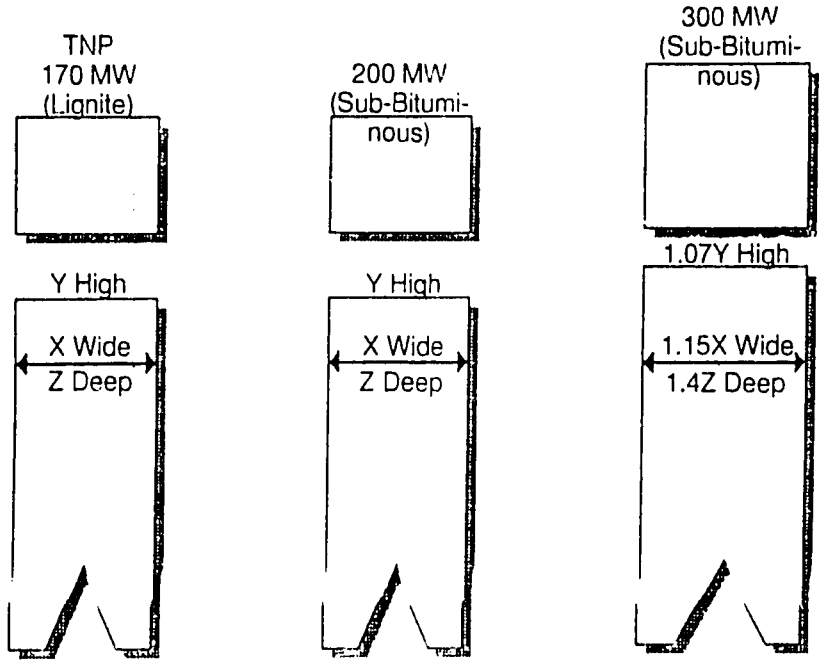


Figure 9 – CFB Combustor Sizing

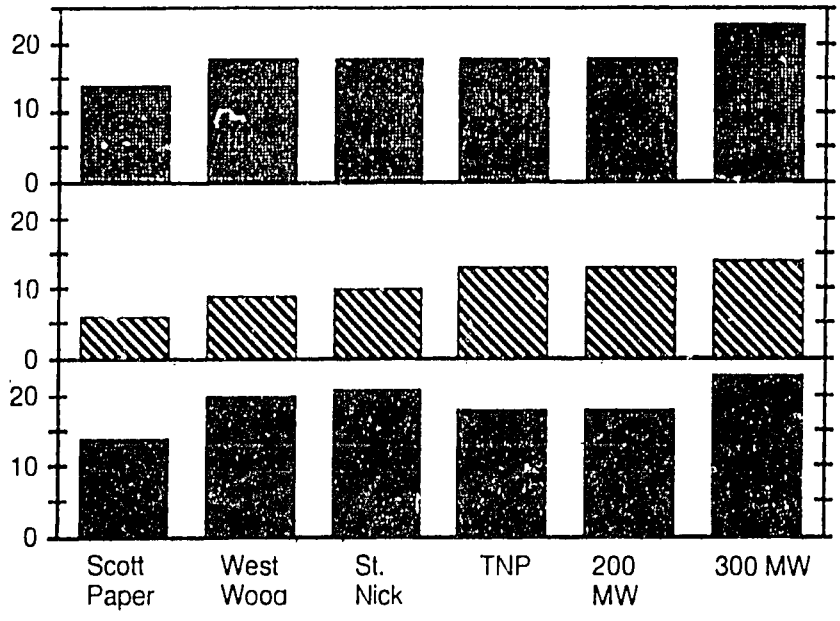


Figure 10 – CFB Mixing Lengths

finned surface has been employed without any pluggages occurring. So, spiral fin economizer surface is not expected to plug either.

Fluid Bed Heat Exchangers (FBHEs)

Recirculated ash from the furnace can be directed from below the cyclone hopper outlet at temperatures of 1550F - 1650F to a bubbling fluidized bed heat exchanger (FBHE) for the purpose of performing additional boiler heat duty. Solids are diverted using a high temperature ash discharge valve to a series of heat exchange bundles which perform superheater, reheater and evaporator duties.

As CFBs get large in size, the combustor surface to volume ratio decreases and it is not possible to perform the required evaporator duty in the furnace waterwalls. The FBHEs allow incremental evaporative duty by passing a sufficient amount of recycle solids into the bundles. FBHEs work at very low superficial velocities, around one foot/second, and are less prone to erosion than are in-combustor evaporator panels.

The FBHE enables many operational and process-related functions to be performed which are critical to smooth and reliable operation. These functions include combustion control, emissions control, low load operation stability, load control with variations in fuel and limestone qualities, and furnace temperature control.

CFB units without FBHEs cannot control furnace temperature without varying excess air, which leads to lower boiler efficiencies and/or lower than optimal fuel combustion at partial loads. The FBHE allows the heat transfer aspects of the boiler to be somewhat decoupled from the combustion requirements of the boiler. By modulating solids flow through the ash discharge valve and FBHE, cooler solids at the FBHE discharge can be blended with recycle ash to control furnace temperature. This allows the excess air to be set solely on the combustion characteristics desired.

The control of furnace temperature is a necessary feature in proper operation of the steam generator in order to minimize gas emissions; carbon monoxide, sulfur dioxide and nitrogen oxides. At a given excess air, it can be shown that there is an optimal temperature where emissions from all sources can be minimized.

Low load operation without furnace temperature control is more difficult without an FBHE since the minimum air flow rate is usually dictated by the solids fluidization requirements. At low loads and without an FBHE for temperature control, the excess air is higher than designed, producing increased levels of nitrogen oxide emissions. Also at low load, superheater and reheater spraying can be decreased by controlling the duty of the FBHE superheater and reheater bundles, which are separated from the backpass superheater and reheater convective surfaces.

With variations in the size and quality of fuels and limestones in a given unit, a FBHE is useful to maintain full load operation, without derating. Fuel and limestone purchases are functions of the economics of the time. As less expensive fuels and limestones can be found, the CFB must be able to handle these fuels without possible derating of the unit. The furnace solids inventory and convective heat transfer duties shift as different fuels and limestones are used. The FBHE can make up evaporative duty which is lost on fuel and limestone changes. The FBHE can also control the gas temperature so that harder to burn fuels can operate at elevated temperatures. Temperature control is also used to maintain the proper sulfation reaction temperature for each limestone upon limestone changes.

An inherent benefit of using a FBHE is the high heat transfer rate from the hot solids to the tube bundles. By performing the additional evaporative duty in an FBHE instead of in-combustor surface in the upper furnace, the required surface (in the FBHE) is substantially less (possibly by a factor of three).

With the enhanced ability to control combustion, maintain load and furnace temperature, and maintain fuel and sorbent flexibility, the CFB with a FBHE offers potential advantages, unparalleled with other systems.

The 330 MW unit employs FBHEs which consist of finishing superheater, evaporator and finishing reheater surface. Operating experience on CFBs with reheat FBHEs indicates that the RH temperature is controllable by using FBHEs without a need for attemperation.

The arrangement of the FBHE on the front and rear wall, Figure 5, enables the designer to increase the heat transfer surface by adding assemblies rather than increasing the tube length beyond the 14 feet successfully employed at TNP. When designing the tube bundle supports, sufficient stiffness and restraints are required to accommodate the mechanical loads and sufficient flexibility is required to accommodate the thermal expansion movements. ABB C-E has developed a finite element design tool for studying FBHE tube bundles and quantifying their thermal and mechanical loads (Reference 3). Therefore, by standardizing tube bundle arrangements and utilizing a modular approach, an increase in unit size can be accommodated without developing a new FBHE design.

A 330 MW CFB can, indeed, be designed without the need for uncertain extrapolation. While the combustor size is increased in both height and plan area for this unit, its increases have been limited to maintain overall size and operating parameters within our experience base. Height has been limited to assure accurate heat transfer predictions and to minimize overall building and steel costs. Additionally, plan area has been restricted to maintain fuel/air/solids mixing lengths within our experience and knowledge base. Cyclone diameter has also been increased. However, the use of four parallel cyclones allows the increased diameter to be maintained within our current operating base. Backpass width has been increased but not beyond that used in conventional PC firing design. Regardless of the firing technology used, backpass sizing is a well-defined, low-risk procedure. Finally, design tools have been incorporated to allow for the modularization of FBHEs. No scale-up or additional risks are presented with this approach.

A CFB AND PC UNIT COMPARISON

Circulating Fluid Bed Boilers possess some advantages over similarly-sized Pulverized Coal (PC) units. CFBs require smaller building volumes, achieve lower emissions, with less equipment, and require less fuel preparation than similarly-sized PC units. The building volume for a CFB is approximately 25% less than for a PC unit (from coal bunker to air heater outlet).

The presence of circulating hot solid particles in the CFB FBHEs make for greater heat transfer there than is achieved by the PC in-furnace radiant surface. As unit and combustor size continue to increase, the FBHE heat transfer surface would also increase. In general, the FBHEs permit separate superheater and reheater temperature control and allow for a smaller convective backpass (less required heat transfer surface). A CFB is inherently low in NOx production as a result of low combustor operating temperatures and multi-level air staging. When extremely low NOx emissions are required, CFBs use a simple Selective Non-Catalytic Reduction (SNCR) system rather than the PC unit's much larger SCR system for a further contribution to the CFB unit building volume advantage.

A SNCR achieves optimum NOx reduction and minimal ammonia slip while operating in the 1500-1700F range. On CFBs using FBHEs, the normal combustor operating temperature of 1500-1600F is maintained through much of the unit operating range. Low NOx and ammonia emissions are easily achieved through a large portion of the CFB operating range. Additionally, the lack of a catalyst makes the Selective Non-Catalytic Reduction (SNCR) system much easier to maintain than a SCR system.

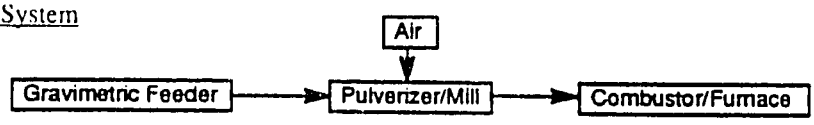
The CFB reduces sulfur dioxide emissions through the injection of sorbent directly into the combustor - thereby eliminating downstream scrubbing devices. This also results in a smaller plant footprint for a CFB unit.

A typical PC unit requires coal pulverizers to achieve the desired feed size of 80% or more less than 200 mesh. Actual emissions requirements will determine the desired percentage passing 200 mesh. A CFB does not require pulverizers. Rather a 1/2 inch top size fuel enters the CFB. The largest of the fuel particles

will form part of the combustor bed until they decrepitate and attrit sufficiently to pass into the combustor freeboard and to the cyclone. Both the CFB and PC units require coal gravimetric feeders, but from the feeder outlet to the combustor/furnace inlet, the CFB fuel feed system is simpler as shown below.

CFB Coal Feed System

PC Coal Feed System



Finally, it is the lack of fuel and emissions equipment which makes the CFB's fuel and emissions systems less complicated to operate and maintain than those of a PC unit. Basically, the CFB has no pulverizers, SCR, or scrubber to maintain. A CFB may include a SNCR, but the lack of a catalyst alone makes this system less expensive to operate and maintain.

The auxiliary power consumed by the CFB is about 1-2% higher than that used by the PC unit. This disparity is being remedied by the use of lower pressure fans, and manifolded fluidized blowers for CFB applications.

Two other advantages of the PC technology are harder to overcome. A PC unit will have lower radiation and carbon heat losses than a similarly-sized CFB unit. The use of steam-cooled cyclones will lower the radiation loss of a CFB, but these cyclones are large and a PC unit does not contain a similarly-sized piece of heat absorbing equipment. So, CFB units will always have greater radiation losses than a similarly-sized PC unit. The higher furnace operating temperature of a PC unit also ensures it will achieve better carbon burnout and lower carbon monoxide emissions than a CFB unit. The CFB solids recycle loop does allow it to overcome some of the PC unit's advantage, though. The CFB's operating temperature is lower, but its residence time is greater than that of a PC unit.

The CFB and PC technologies can be fairly evenly compared for many applications in the 200-400 MW size range. The fuel quality, emissions requirements, and particular evaluation factors for a certain project will determine the best technology for the application.

SUMMARY AND OTHER DEVELOPMENTS

The CFB technology has shown an ability to scale-up from industrial to utility applications with relative ease. Scale-up has occurred while maintaining sizing and performance parameters within our experience and knowledge base. Further product enhancements (see Table VII) have been added regardless of plant size.

With use of the pantleg CFB, ABB C-E has shown the CFB technology is a viable power plant alternative for units up to 450 MW in size. ABB C-E has also developed units for applications up to 600 MW in size. Alternatives are currently being reviewed for their ability to maintain process parameters, achieve performance air emissions, and operate with little or no risk.

- Standard Cyclone Designs
- Upgraded Refractory Design
- Simplified Fluidizing Air System
- Burner System Reconfiguration (In-Duct Burners Eliminated)
- Simplified Fuel Feed System (Rotary Valves Deleted, Feeders Pressurized)
- Rifle-tubed FBHE Evaporator Sections

Table VII – ABB C-E CFB Product Enhancements

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PRESSURIZED FLUIDIZED BED COMBINED-CYCLE; EFFICIENT, CLEAN AND COMPACT POWER GENERATION

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ABSTRACT

Pressurised Fluidised Bed Combined Cycle (PFBC) plants are now in operation in Sweden, Spain, United States and Japan. Over 30 000 operational hours have been achieved so far in these plants.

PFBC technology provides high thermal efficiency in the generation of power from coal. This is a result of the combined cycle arrangement. Even with modest inlet temperatures of below 850°C to the gas turbine, a PFBC plant has an efficiency that compares to what can be achieved with the most highly integrated gasification combined cycle (IGCC) plants proposed with today's most advanced gas turbines.

Additional firing of fuel before the gas turbine to increase its inlet temperature above 850°C leads to very substantial efficiency increases. Hybrid cycles that allow such an increase are now under development and ensure that the PFBC process will allow continous development.

Environmental control is also excellent. The Värtan PFBC plant in Stockholm, Sweden is considered to be one of the cleanest coal-fired power plants in the world.

The success of the first PFBC plants has led to further orders. A number of other equipment manufacturers have also begun development of PFBC. Clearly, PFBC is fully commercial and recognized as being the leading clean coal technology for several decades ahead.

INTRODUCTION

Coal provides for about 40 % of the world's electricity production. World demand for energy, and especially for electricity, is likely to grow substantially during the next century. This is a result of the expected increase in world population and also of economic growth in countries that are currently less developed. Coal use will most probably continue to grow with electricity demand. Estimates of the global market for power generation equipment suggest that about 800 GW will be needed just during the next decade and that approximately half of that will be coal-based.

Pulverized coal-firing (PC) is currently the mature coal technology and has been in use since the early part of the present century. Efficiency improvements in PC plants took place gradually between the late 1940's and the middle of the 1960's. Most plants world-wide

have little emission control equipment other than some particulate removal. Many also have a low thermal efficiency as a result of being old, small, or because they burn low-grade coal. Generally, plants that were built in the early 1950's use about 25 to 30 % more fuel than today's modern plants to produce a kWh of electricity. The tend now is towards coal-fired combined cycle plant with pressurised fluidised bed combined cycle (PFBC) and Integrated Gasification Combined Cycle (IGCC) showing the way.

Although global coal usage for electricity production accounts for only a small fraction of anthropogenic global carbon dioxide release to the atmosphere, and although there is still no real understanding of the relations between the changes in composition of the atmosphere and the global climate, the mere perception that fossil fuels may cause climate change is likely to influence the choice of power generation technology. Political decisions in a number of countries have already begun to cause such changes, typically through the use of taxes or fees that distort the free market cost of fuels in connection with their utilization.

COAL-FIRED COMBINED CYCLE PLANTS

Coal-fired combined cycle plants have not been available until recently. But development work has been underway during the last two decades. The two technologies that have now reached the market place are pressurised fluidised bed plants (PFBC) and integrated gasification plants (IGCC) with PFBC plants now operating commercially and some demonstration IGCC plants under construction. They share the feature of incorporating gas and steam cycles. But there are also substantial differences.

In a PFBC plant, Fig. 1, coal is burnt, cleanly and efficiently, directly under pressure in a fluidised bed, which typically operates at a temperature of about 870°C. The flue gases from the fluidised bed are cleaned from particulates, presently with the aid of cyclones, before expansion in a gas turbine which drives the air compressors and a generator. The steam is expanded through a steam turbine which also drives a generator. Today's PFBC plant therefore uses a low inlet temperature (below 850°C) for the gas turbine but can have very advanced steam data, since the combustor temperature is substantially above the temperature of the steam which is generated. Combustion efficiencies are of the order of 99.5 %. Excess air levels are around 20 %.

Emission control in a PFBC plant occurs primarily in the fluidised bed where also combustion takes place. Desulfurization involves the reaction of limestone or dolomite with the sulfur dioxide which is produced from sulfur present in the coal. Nitrogen oxide levels in the combustor flue gases are low as a result of the low bed temperature, which prevents the formation of "thermal NO_x". Naturally, the possibilities also exist to reduce NO_x emissions further through the use of de-NO_x techniques.

By comparison IGCC plants can reach comparable efficiencies but must use gas turbines with a high inlet temperature to compensate for losses in the gasification step. The steam data achievable is seriously limited because most of the energy transfer to the steam cycle occurs downstream of the gas turbine in a waste heat recovery boiler where the inlet gas temperature is typically low (below 560°C).

IGCC plants that can be built currently use wet pressurised cleanup systems for removal of sulfur dioxide and other chemical compounds from the fuel gas which is produced in the gasifier, before combustion of this gas in the gas turbine combustor. The wet cleanup system reduces the thermal efficiency of the IGCC cycle, but it does, naturally, have characteristics that allow very low emissions of sulfur dioxide, and it can also lower the levels of NO_x precursors like hydrogen cyanide and ammonia in the fuel gas.

Fig. 2 shows a comparison of the achievable efficiencies with PFBC and IGCC plants as a function of gas turbine inlet temperature (1). It is notable that thermal efficiencies for PFBC plants with current gas turbine inlet temperatures give combined cycle efficiencies of 44 to 46 %, whereas IGCC plants require approximately 300°C higher gas turbine inlet temperatures, or up to 1180°C (ISO), to reach the same cycle efficiencies. Such high temperatures can only be reached with today's most advanced gas turbines.

It is significant that the already very good efficiency of PFBC plants can be increased further when the gas turbine inlet temperature is raised. This involves firing of additional fuel before expansion in a higher inlet temperature gas turbine. The "Hybrid PFBC" band in Fig. 2 shows the efficiency improvements which can be achieved with such arrangements. The bands marked "Development potential" illustrate further achievable efficiency improvements for PFBC and IGCC plants. These depend, among others, on the application of more advanced steam cycles, and on the continued improvement of gas turbine technology.

STATUS OF PFBC

The world's first PFBC plants are currently in operation in Sweden, Spain, United States and Japan. These four plants use ABB Carbon's technology, developed during the past 17 years in close cooperation with the customers (2).

All of these units utilize ABB Carbon's P200 PFBC module, which consists of a combustor vessel that contains the fluidized bed, cyclone cleanup systems and a few other components, and also ABB's GT35P gas turbine.

The net output from a PFBC plant which uses one P200 module is typically 80 to 85 MW_e depending on the steam cycle used. The larger P800 module has an output of 350 MW_e and uses the GT140P machine, which is a scaled-up version of the GT35P machine. Manufacturing of the first GT140P machine is now underway for the commercial 350 MW plant in Japan.

The Värtan Plant

The Värtan PFBC plant in Stockholm, Sweden, which burns low sulfur imported coal, is a new combined heat and power (CHP) plant with two P200 modules and one new steam turbine. It is built on an old site, where there are also oil-fired boilers, an oil-fired CHP plant, electric boilers and electrically driven heat pumps. The Värtan plant, Fig. 3, is owned and operated by Stockholm Energi and provides the city of Stockholm with electricity and district heating (3).

Because of its location near the center of the Swedish capital, and the very strong environmental concerns among the population, the Värtan PFBC plant environmental regulations are very strict. Initially, annual SO_x and NO_x limits of 60 and 50 mg per MJ fuel input were imposed. These values correspond to 170 and 140 mg/Nm^3 respectively, at 6% oxygen in the flue gases, i.e. substantially below the current German regulations.

Following first fire on coal in January 1990 and a successful availability test during the spring of 1991, the Värtan PFBC plant was taken over by the customer in September 1991.

When the Värtan PFBC plant was shut down for the summer at the end of the 1992/1993 heating season, the two units had operated 8271 and 6200 hours, respectively, on coal. The emissions of SO_x and NO_x, respectively, during 1993 have been approximately 25 and 30 mg/MJ, respectively. Very low emissions of N_2O, CO and particulates have also been achieved.

The Escatron Plant

The Escatron plant in Spain, Fig. 4, is owned by ENDESA, which aims at installing larger size PFBC plants, using the P800 module, to burn local coals. In order to demonstrate the technology at a smaller scale, ENDESA decided to repower an existing, old steam plant with a P200 module. The European Community and some Spanish authorities provided partial financial support to ENDESA for this project. The fuel used at Escatron is local "black lignite" with typically about 6.8 % sulfur, 36 % ash and 20 % moisture. This is a very difficult fuel, but it is available in large amounts in the Teruel region of Spain. There are also similar coal deposits in other parts of the world.

Following first coal-fire in the Escatron PFBC plant in November 1990, a total of 7598 hours of operation on coal had been achieved by the end of July 1993. The operation of a PFBC plant on this very difficult fuel has been shown to be possible. The major problems that have been experienced have related to the feeding of fuel and sulfur sorbent and to the removal of ashes from the cyclone outlet pipes have been resolved.

Desulfurization that exceeds 95 % with limestone at a Ca/S-ratio below 2.0 has been demonstrated. NO_x emissions meet requirements and have been seen to depend on the excess air level. This is in agreement with earlier laboratory and pilot plant observations, and it also agrees with observations from the other PFBC plants.

The Tidd Plant

The Tidd plant in the United States, Fig. 5, is owned by Ohio Power Company, a subsidiary of American Electric Power (AEP). The old steam plant has been converted to a PFBC demonstration plant with financial support to AEP from the U.S. Department of Energy under its Clean Coal Technology Demonstration Program, and from the Coal Development Office of the State of Ohio (4).

The Tidd PFBC unit uses also an existing steam turbine and other site facilities together with one P200 module. The fuel is Pittsburgh Number 8 coal with a sulfur content of about 4 %. First fire on coal was again in November 1990. An acceptance test was completed by mid June 1992, after which the plant was accepted by AEP. By the end of July 1993, the plant had operated 3884 hours on coal.

Like ENDESA, AEP is planning to build larger PFBC plants. Under phase two of the Clean Coal Technology Demonstration Program, AEP proposed to repower a large steam plant with PFBC. This would use the P800 module with a net output of 350 MW_e. This project was selected for partial funding. Later, AEP decided to build instead a new "greenfield" PFBC plant when new coal-fired capacity is needed. Preliminary engineering for such a plant is currently underway.

The Wakamatsu Plant

The Wakamatsu PFBC plant has been built at EPDC's Wakamatsu site on the island of Kyushu, Fig. 6. This is also a repowering project, but is more advanced than the other two in that it has reheat and also a high steam temperature of 595°C. EPDC, like ENDESA and AEP, see their project as a demonstration on the way to larger PFBC plants with an output of 700 MW_e (two P800 modules with a common steam turbine). The Wakamatsu plant is equipped with a ceramic hot gas filter (5).

The order for the Wakamatsu plant was signed in October 1991 and commissioning of the plant has begun. First fire was achieved on 14 July and operation on coal began on 2 September. Commercial operation is scheduled to begin in early 1994. Most of the plant

equipment has been supplied to EPDC by IHI, which is ABB Carbon's licensee in Japan.

OPERATING EXPERIENCE FROM THE WORLD'S FIRST PFBC PLANTS

The Gas Turbine

From the time when PFBC was first conceived and throughout the development phase, a major question has been whether a gas turbine can operate in the flue gases from a pressurised fluidised bed burning coal. Especially, there have been concerns about erosion, corrosion and fouling of the gas turbine blades.

The results from pilot plant tests showed that well functioning cyclones, which pass only very small particulates to the turbine, would allow expansion of the still dust-laden gas through the turbine.

The major concern about corrosion relates to the fact that measurements have indicated that the concentration of volatile alkali compounds in the flue gas leaving the combustor is substantially higher than would normally be accepted for gas turbines burning gaseous or liquid fuels.

Since the concentration of particulates in the gas that reaches the gas turbine typically is between 200 and 500 ppm by weight, there is an obvious possibility for deposit formation within the gas turbine. It is significant that only minor deposits have been found to form on rotor vanes and blades.

The results from over 25 000 hours of operation in the Värtan, Escatron and Tidd PFBC plants have confirmed that it is possible to operate the specially designed GT35P gas turbine in the PFBC environment. A requirement is, however, that the cyclone cleanup system functions well.

There were some early incidents, especially at the Escatron plant, when the outlet pipes that carry collected cyclone ash from the base of the primary cyclones have been plugged. At such times, the particulate loading to the turbine, and also the size of particulates, have been greatly increased. It is significant, however, that the erosive damage also under such extreme conditions has been gradual and that the gas turbine continued to operate well, although with decreased output, even during such periods (6). Design modifications have been successfully applied to eliminate this problem.

A phenomenon, the nature of which in no way is specific for the PFBC application but which has recently been experienced is high-cycle fatigue damage to the root section of the variable speed low-pressure turbine blades. High-cycle fatigue is not uncommon in rotating machinery but had not been expected based on design calculations. A modification has been made to the shape of the blade "fir tree" root section to decrase stress concentrations and thus eliminate the problem.

The PFBC Boiler

Another concern, which typically is valid for all fluidised bed systems, has been erosion or wear of boiler tubes. Such wear is quite common in atmospheric fluidised bed units but "fixes" have been developed to handle the matter. ABB Carbon has taken several steps to minimize wear of the tube bundle in the PFBC plants. First, the design of the tube bundle is such that high velocity paths for solids are avoided. Second, the low temperature evaporator tubing is coated with a wear resistant material.

Since it has become clear from many test rigs and other fluidised bed plants that higher temperature tubing is less sensitive to wear, superheater tubing typically does not require wear protection. The reasons for this are still not fully understood, although it appears that oxide films and also deposits on high temperature tubing may be responsible (7).

In October 1991, there was a case of membrane wall damage at the Värtan PFBC plant. This was caused by down-flow of bed material along the wall, around an observation port where the wall tubes have been bent to accommodate the port. Once a hairline opening in the wall tube had been formed at this location, a steam jet caused damage to an adjacent part of the tube bundle, which finally damaged further the membrane wall. Although the membrane wall has a low temperature and wear therefore might be expected, such damage had not been experienced in pilot plant testing, and therefore these walls had no wear protection. However, it did not cause any sudden problems for the operation of the plant. Rather, it was noted through the gradual increase in the water content in the flue gases and in an increase in gas turbine output.

The solution was to stud and install a ceramic liner on the membrane wall. For new plants, there is also the alternative of applying a wear resistant metal coating on the membrane wall surfaces.

COMMERCIAL STATUS OF PFBC

It is clear from the above that ABB Carbon's introduction of PFBC technology has been successful. The experience gained during operation of the first three PFBC plants with widely different fuels is of considerable value for the continued development and commercialization of this leading clean coal technology. The P800 modules planned for use in ENDESA's and AEP's larger PFBC plants will have many features in common with the demonstration plants.

A number of PFBC plants will be built in the near future (8). Kyushu Electric (KYEPCO) have ordered a 350 MW_e PFBC plant from IHI, with ABB Carbon's technology. This plant will be commissioned at Karita in 1996 and will be the first P800 plant to be built. In September 1992, a contract was signed for the supply of a PFBC combined heat and power plant at the Trebovice power plant near Ostrava in the Czech Republic. Commercial operation of that plant is scheduled for 1996.

Southern Company of the US have now studied the availability to be expected of PFBC plants in their system (9) and predict an Equivalent Forced Outage Rate (EFOR) of 5.62 % and an Equivalent Availability Factor (EAF) of 87.14 %. These measures of reliability and availability already compare very favourably with PC plants.

Predictably, the high visibility and success of ABB Carbon's projects has also caused other equipment suppliers to begin PFBC development. Among these companies are Lurgi-Lentjes-Babcock, Ahlström/Pyropower, Foster Wheeler and Mitsubishi Heavy Industries (MHI). None of these organizations have so far built a PFBC plant, and most of them have only recently operated a PFBC test facility. Nevertheless, Hokkaido Electric (HEPCO) have ordered an 85 MW_e PFBC unit from MHI for operation in 1996. Chugoku Electric have also announced their plans to have a utility size PFBC plant in operation around 1998. In the U.S., Midwest Power have been selected to receive financial support from the Clean Coal Technology Demonstration Program for repowering an old steam plant with PFBC. This will be Ahlström's PFBC technology.

ABB Carbon is currently discussing a number of other PFBC projects with utilities in different countries. The interest is very great. It is obvious that PFBC is, indeed, recognized as the leading clean coal technology for the next several decades.

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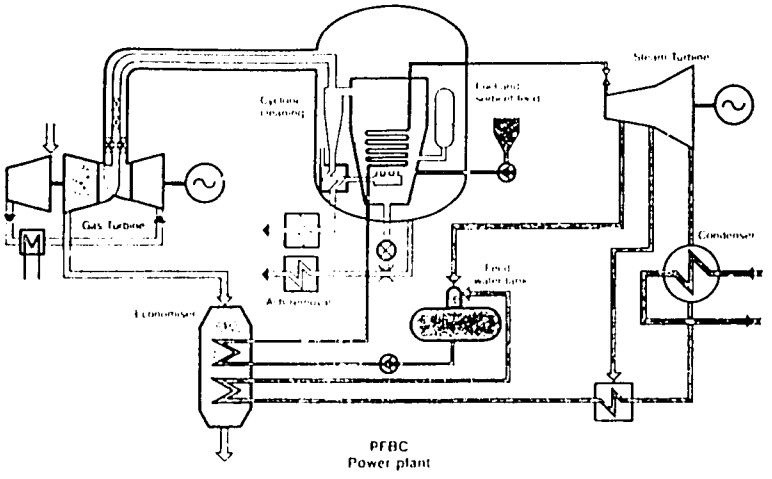

Fig. 1 The PFBC cycle

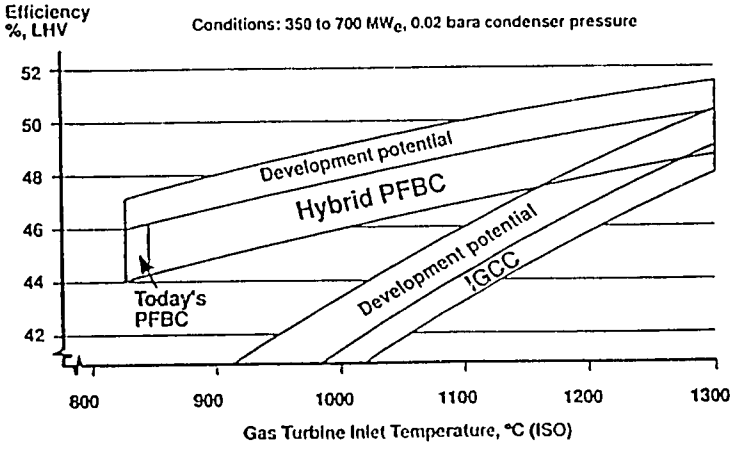

Fig. 2 Calculated thermal efficiencies for PFBC and IGCC plants

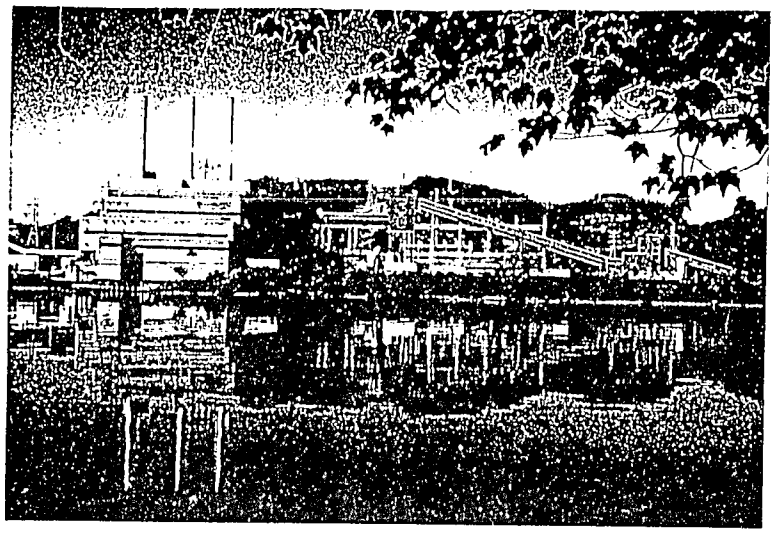

Fig.5 Photo of the THDD site with the PFBC plant (at left center)

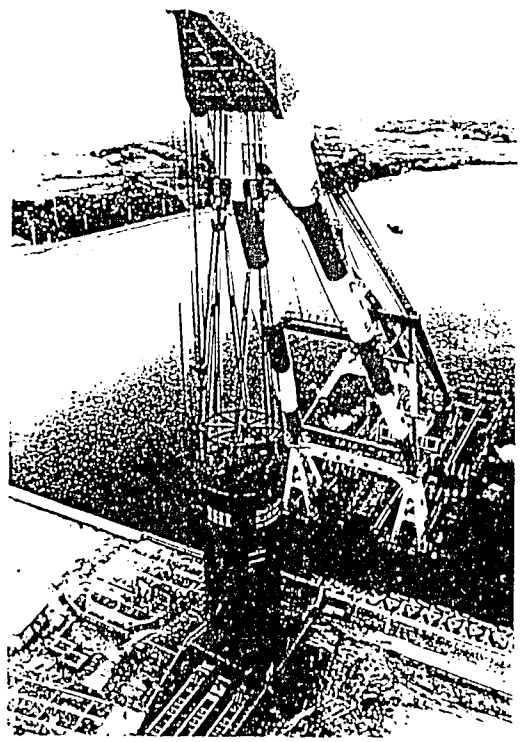

Fig.6 Photo of the Wakamatsu PFBC combustor on arrival to the site

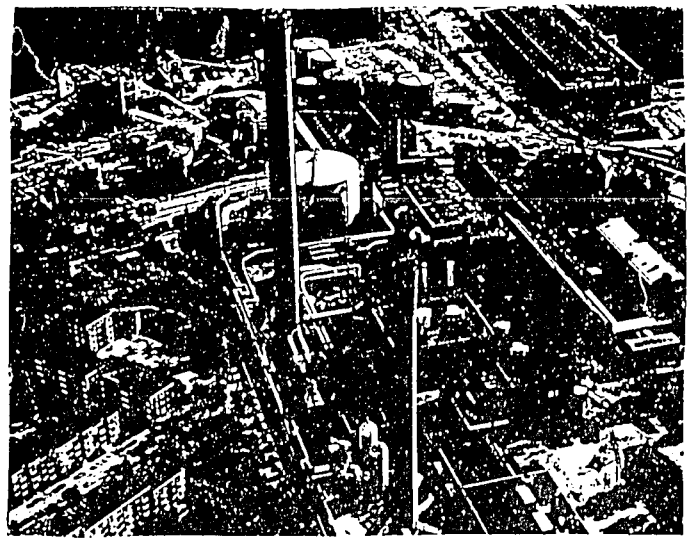

Figure 3. Aerial view of the Vartan power plant with the PFBC plant (at center)

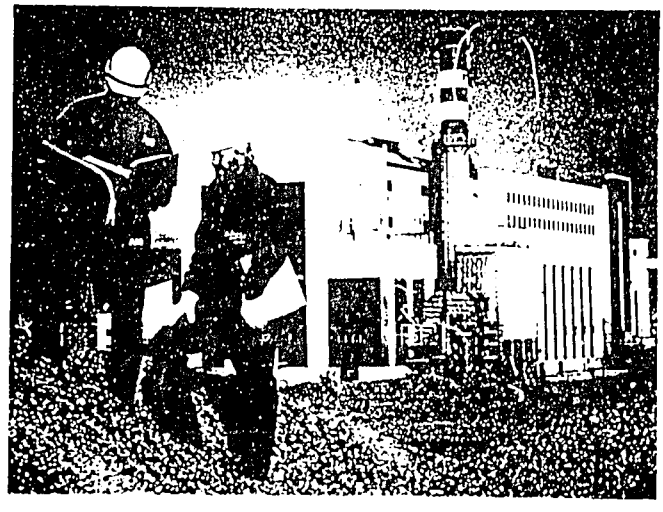

Figure 4. Photo of the Escatron PFBC Plant

Technology Integration in Efficient and Clean Coal Use for Utilities

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§ 1. Introduction

According to the structure ratio of power sources by type of fuel in power generation facilities in Japan, oil fired plants accounted for about 60% of all power generation facilities in 1975.

However, the oil crisis served as a turning point for the Japanese electric utilities to promote development of alternative power sources such as nuclear power, coal, LNG, etc. with the result that in 1990 the ratio of oil fired power plants dropped to 31%.

In order to raise the ratio of coal fired power plants in Japan it is necessary to take thorough environmental protection measures such as removal of SOx and NOx. And the next important issue is the efficiency improvement of power generation.

This paper will explain about the following two projects which the Electric Power Development Co., Ltd. is now undertaking in order to achieve these objectives.

(1) Atmospheric fluidized bed combustion (A-FBC) 350MW Takehara Project
(2) Pressurized fluidized bed combustion (P-FBC) 71MW Wakamatsu Project

§ 2. History of development of fluidized bed combustion boiler

Technological development of the fluidized bed combustion boiler in Japan started with surveys and studies on development situation in foreign countries conducted by the Japanese government in 1975. This report pointed out the

necessity of promoting our own research and development, and it was decided to first establish technology on atmospheric types which can be developed at an early stage and then tackle the problems that might arise from the development of pressurized types.

The technological development has been promoted based on the guidelines given in this report concerning the scale of pilot plant and details of development schedule. Fig. 2-1 shows the development schedule.

§ 3. Atmospheric fluidized bed combustion (A-FBC) 350MW Takehara Project

(1) Features

Electric Power Development Co., Ltd., subsidized by the Ministry of International Trade and Industry, is now constructing a 350 MW atmospheric fluidized bed combustion boiler which is scheduled to start commercial operation in the summer of 1995. This project aims at replacing the existing 350MW heavy oil fired boiler with the same output. Fig. 3-1 shows the outline of this project.

Features of this project are:

① By structurally integrating Main Burn up Cell with CBC, which can burn unburned carbon from MBC, the size of boiler facilities is reduced.

② For flue gas treatment, a combined system of the electrostatic precipitator with a pulsed energized method for a low temperature side and the flue gas DeNO $_x$ system using activated char is adopted.

This paper will explain, among other features, the "flue gas DeNO $_x$ system using activated char".

(2) Flue gas DeNO $_x$ system using activated char

In Takehara A-FBC project, SOx is removed inside the furnace of A-FBC and the flue gas DeNO $_x$ system using activated char is adopted to reduce the level of nitrogen oxides.

At present, in Japan the selective catalytic reduction process (SCR) using ammonia is quite popular to remove nitrogen oxides. The flue gas $DeNO_x$ system using activated char installed at Takehara A-FBC has the following features.

① The optimum $DeNO_x$ reaction temperature of the dry activated char method is relatively low at about 140℃ while that of the selective catalytic reduction process using ammonia is between 350 ℃ and 380℃. A high $DeNO_x$ performance can be expected from the lower flue gas temperature range when the plant is started up.

② Slip ammonia from SCR reacts with sulfur oxides in the downstream of SCR to form ammonium sulfate compounds which adhere to the downstream equipment, causing such harmful effects as clogging and vibration of Fans and Air-Preheaters so that periodical cleaning is required. On the other hand, in case of the dry activated char method the equipment can be installed right in front of stacks because of its low reaction temperature.

③ In the dry activated char method, it is necessary to keep SO_2 concentration under 100 ppm in order to achieve a high $DeNO_x$ performance rate, because reaction of $DeSO_x$ occurs in preference to that of $DeNO_x$. In the fluidized bed combustion SO_x concentration of flue gas can be kept under 100ppm because of the in-furnace $DeSO_x$ function so that a high $DeNO_x$ performance can be obtained through integration of the fluidized bed combustion boiler and the flue gas $DeNO_x$ system using activated char. Since the activated char layer has a dust collecting effect, a high-performance dust collection is possible when used in combination with electrostatic precipitator.

④ A high performance of activated char is always maintained through recycling and constant make-up of aging activated char. Fig. 3-2 shows the "Low Temperature De-Nox System for Takehara A-FBC".

The mechanism of removing NO_x can be explained below.

① Followed by injection of ammonia, flue gas containing NO_x passes through the activated char layer which acts as $DeNO_x$ catalyst.

② NO_x in the flue gas undergo a chemical reaction in the presence of catalyst, and are decomposed into nitrogen and water.

Reaction formula is as follows:

$$4NO + 4NH_3 + O_2 = 4N_2 + 6H_2O$$

③ In the flue gas $DeNO_x$ system using activated char, dust in the flue gas can be also removed while passing through the activated char layer.

(3) Simultaneous Dry $DeSO_x$ / $DeNO_x$ process using activated char

In addition to the above-mentioned system, entrusted by the Ministry of International Trade and Industry, Electric Power Development Co., Ltd. is now conducting a demonstration test of a new flue gas treatment system using activated char at Matsushima Thermal Power Plant. (The demonstration test is scheduled from February 1993 to January 1994.)

This system is intended to remove nitrogen oxides as well as sulfur oxides by using activated char. Fig. 3-3 shows the "Simultaneous Dry $DeSO_x$ / $DeNO_x$ Process". By adopting this flue gas treatment system using activated char, SO_x and NO_x can be removed from a pulverized coal fired power plant very efficiently.

Furthermore, this flue gas treatment system using activated char can be applied to the fluidized bed combustion boilers (A-FBC and P-FBC) as well as to the pulverized coal firing boilers (PCF boiler) through an appropriate combination of each system.

§ 4. Pressurized fluidized bed combustion (P-FBC) 71MW Wakamatsu Project

(1) Features

Subsidized and entrusted by the Ministry of International Trade and Industry, Electric Power Development Co., Ltd. is now installing a 71 MW P-FBC at Wakamatsu Coal Utilization Research Center, and is planning to commence a demonstration test in February 1994. Fig. 4-1 and 4-2 show the "Outline System of Wakamatsu P-FBC" and "General description", respectively. The objective of the Wakamatsu demonstration project is to verify the new technology which will be expected as future power sources of large-scale P-FBC's in Japan.

The features of Wakamatsu P-FBC are as follows:

① For cleaner P-FBC

- Adoption of a high-temperature ceramic filter
- Installation of $DeNO_x$ facilities

② For P-FBC with a higher thermal efficiency

- Adoption of ultra super critical steam condition (USC)
- Adoption of reheat regenerative cycle for the steam turbine

Among these characteristics, this section describes the high temperature ceramic filter and the ultra super critical steam condition (USC).

(2) High temperature ceramic filter

The dust removing system of the P-FBC in operation abroad is two-staged cyclone, supplies gas to the gas turbine by installing a cyclone at the second stage after dust is removed with a cyclone at the first stage. This system requires a high dust type of the gas turbine. However, if we aim to make a large -size P-FBC in the future, it will be necessary to develop a new large-size gas turbine with a high dust specification. For this reason, we adopted a method to remove dust intensively by installing a cyclone at the first stage and a ceramic filter at the second stage in Wakamatsu P-FBC demonstration facilities. That is, we aim to apply a gas turbine with a low dust specification, which is conventional gas-turbine, to the P-FBC by adopting a ceramic filter.

(3) Ultra super critical steam condition

It is possible to enhance thermal efficiency by improving the conditions (pressure and temperature) of steam introduced into the turbine even in the conventional Rankine system. The present steam condition is called Super Critical (SC). The steam condition superior to this is called Ultra Super Critical (USC) and Electric Power Development Co,. Ltd. developed boiler and turbine material which can withstand the USC and conducted a test on it. The conventional thermal power plant has adopted a single reheat regenerative cycle with pressure of 246 kg/cm^2g and temperature of 538 ℃ as super critical steam condition. It is quite possible to develop USC STEP-1 with the expansion of the

present technology but it is necessary to establish production technology such selection and processing of new heat and pressure resistant material for STEP-II.

Electric Power Development Co., Ltd. started the technological development of USC, subsidized by the Ministry of International Trade and Industry in 1982. The company developed boiler and tube material and conducted a basic test on the main material of the turbine and so on by utilizing the existing coal thermal power plant from 1981 through 1988.

Afterwards, we conducted a demonstration test of the boiler and turbine by using a 50 MW A-FBC demonstration plant from 1986 through 1991. We conducted the demonstration test of STEP-I for total 14,300 hours and that of STEP-II for total 5,130 hours and obtained a bright outlook for putting it to practical use in the future. Fig. 4-3 shows "the USC Development Target and Improvement in efficiency.

The USC technology can be applied to improvement of the power generating system in addition to FBC. The adoption of USC in the newly installed pulverized coal fired boiler has become more popular in Japan. Fig. 4-4 shows "Adoption Situation of USC Steam Condition (pulverized coal firing)".

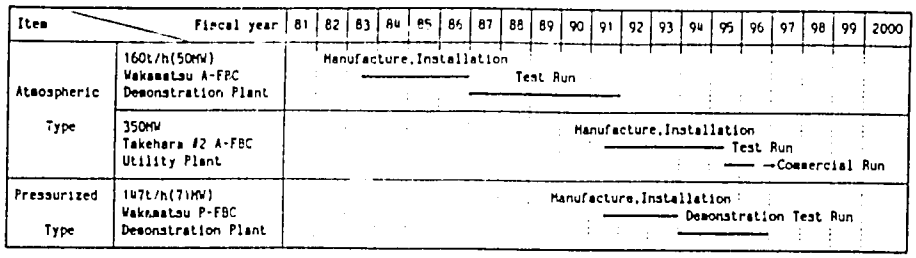

Fig. 2-1 Fluidized Bed Boiler Research and Development

Summary of the Retrofit Project

Item	Present Condition	After Retrofit to FBC
Output	350,000kW	(Unchanged)
Period of Commissioning	June 1979	After 1995
Boiler Type	Outdoor Type of Heavy Oil-Fired Boiler	In-door Type of Coal-Fired A-FBC Boiler
Dust Collector	Electric Precipitator	Cyclone and Electric Precipitator
$DeSO_x$ System	————————	(In-Furnace $DeSO_x$)
$DeNO_x$ System	————————	Dry Type(Activated Char Method)

FBC Specification (After Retrofit)

Item	Specification	Item	Specification
Evaporation	1,115t/h(MCR)	Space Velocity	MBC Upper:1.7m/s
Main Steam Conditions	176kg/cm²		MBC Lower:2.1m/s
	571℃(S.H.Outlet)		CBC :1.5m/s
Rheated Steam Conditions	541℃(R.H.Outlet)	Number of Cell Divisions	MBC Upper:6cell
Boiler Efficiency	>88.6%(Target)		MBC Lower:9cell
Flue Gas Temperature	140℃(A.H.Outlet)		CBC :3cell
Environmental Protection Facilities	SO_x : 50ppm(O_2=6%)	Number of Coal Feed nozzles	MBC Upper: 91 (2.0m² each)
	NO_x :250ppm(O_2=6%)		MBC Lower:173 (2.0m² each)
Ca/S mol ratio	> 5		CBC :36 (2.4m² each)
Layer Temperature	MBC: 760~860 ℃ CBC: 980℃	Number of Ash Feed nozzles	CBC :70 (1.0m² each)

(MBC: Main Burn up Cell, CBC: Carbon Burn up Cell)

Fig. 3-1 Outline Specification of Takehara A-FBC

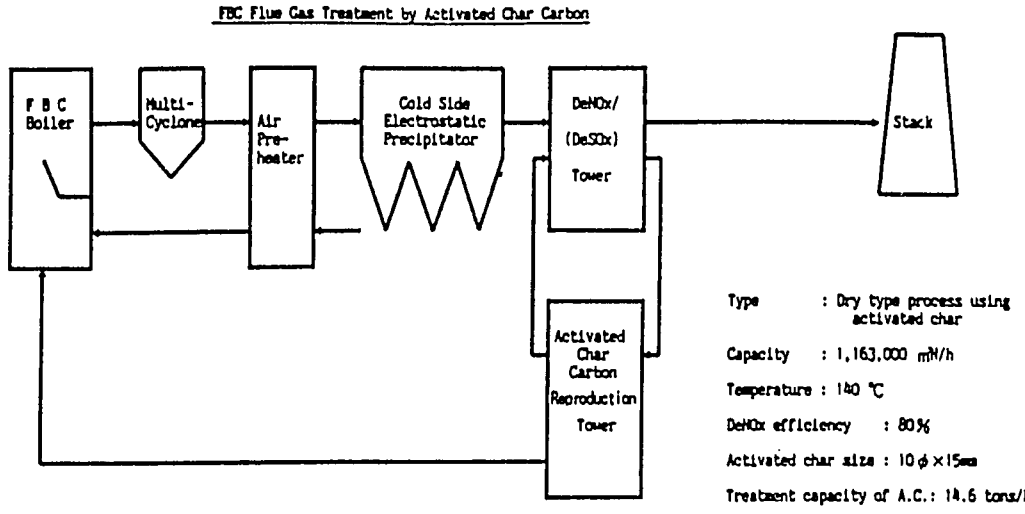

Fig.3-2 EPDC Takehara 350MW FBC Low Temperature DeNOx Systems

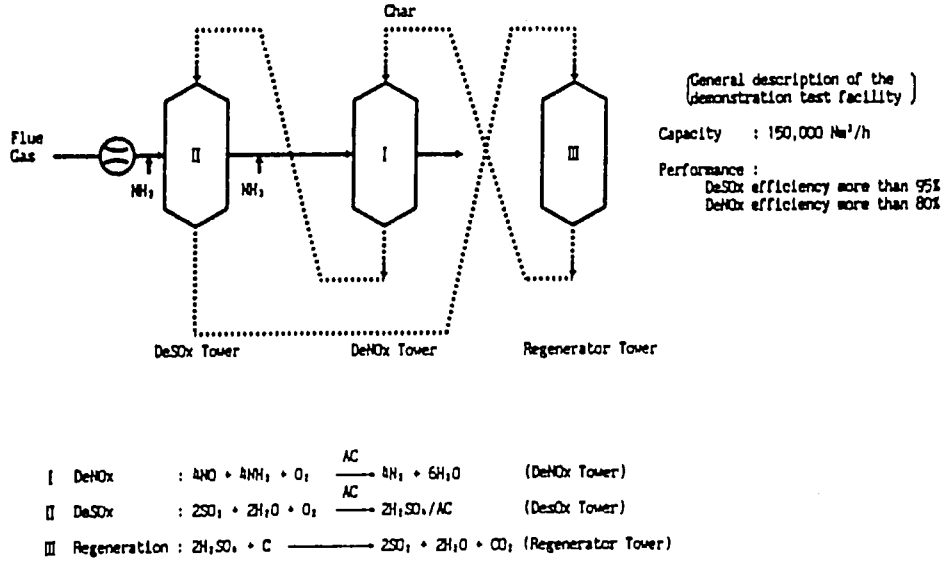

Fig.3-3 Simultaneous Dry DeSOx-DeNOx Process

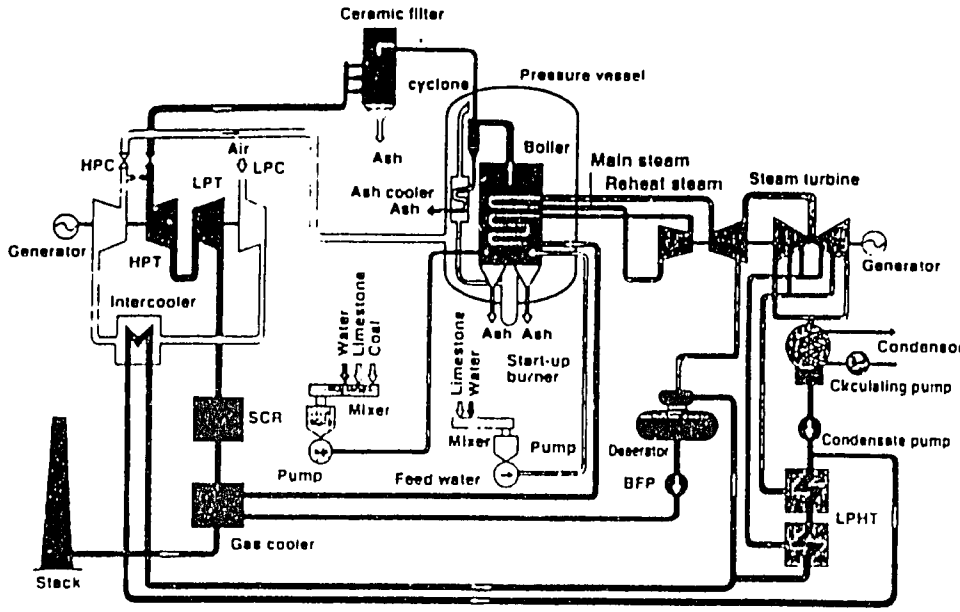

Fig. 4-1 Outline System of Wakamatsu P-FBC

PFBC Boiler (New Equipment)

Type	PFBC One-through Boiler, Indoor Type
Evaporation	147t/h
Gas Pressure	Ca. 11kg/cm²g
Combustion Temperature	Ca. 860°C , Bed Height Ca. 3.5m
Fuel Consumption	Ca. 30t/h , Slurry Feed

USC Steam Turbine (Existing Equipment)

Type	Tandem-Compound, Double Flow, Reheat, Regenerative Condensing, Indoor Use
Output	56,200kW
Steam Pressure etc.	103/26.7 kg/cm²g , Steam Temperature 593/593°C

Gas Turbine (New Equipment)

Type	Two-Shaft. Impulse Output 14,800kW
Inlet Gas Pressure etc	Ca. 9kg/cm²g Temperature Ca.830°C

Fig. 4-2 General description of Wakamatsu P-FBC

[Trial Calculation]

		700MW P-FBC*	700MW - PCF**		
		USC STEP－Ⅰ	Present	USC STEP－Ⅰ	USC STEP－Ⅱ
Steam conditions	Pressure (kg/cm²g)	246	246	246	316
	Temperature (℃)	593/593	538/566	593/593	593/593
Net Thermal Efficiency (%)		40.3	38.0	39.2	40.1
Efficiency Improvement (%)		+ 2.3	Base	+ 1.2	+ 2.1

*) P-FBC:Pressurized Fluidized Bed Combustion

**) P C F:Pulverized Coal Firing

Fig. 4-3 USC Development Target and Efficiency Improvement

Unit Name	Output(MW)	Pressure(kg/cm²g)	Temperature(℃)	Start-up
Kawagoe #1	700	316	566/566/566	'89- 6
Kawagoe #2	700	316	566/566/566	'90- 6
Hekinan #3	700	246	538/593	'93- 4
Nanaoohta	500	246	566/593	'94-12
Noshiro #2	600	246	566/593	'94-12
Matsuura #2	1000	246	593/593	'97- 7
Haramachi #1	1000	246	566/593	'97

Fig. 4-4 Adoption Situation of USC Steam Condition :PCF

WORKSHOP B4

REGIONAL NEEDS AND PUBLIC OUTREACH

IEA Second International Conference on the Clean and Efficient Use of Coal and Lignite: Its Role in Energy, Environment and Life

30 November–3 December 1993

Regional Needs and Public Outreach

Energy–Environmental Issues in Shanxi Province and Taiyuan city

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Abstract

In the last ten years, China progresively formed its own idea on "Sustainable Development Strategy". The basic ideas are: Environmental problem must be intergrated into economic and social problems, and be solved with the development of economy and society.

Shanxi province is the largest base of coal production in China. In 1989, the output of coal in Shanxi was 270MT, which is 27% of the national total coal production.

The industrial structure is a heavy industry form: The important industrial efficiency indices are lower than the national average value.

In Taiyuan, coal is the main primary energy, all the liquid fuel is transported from other parts of the country. In the final energy consumming structure, raw coal takes 42.4%, and the 53.2% of coal transform to secondary energy.

The annual energy consumption per capita in Taiyuan is 3.25 tons, which is 3.56 times above national average level.

Consequantly, in order to ensure the comprehensive economic development in China, it is require that Shanxi's coal production base should continuously take on the important task of coal produciton. By the year 2000, the on-schedule goal of raw coal being produced annually 450 MT. It is a heavy environmental pressure in the province, including Taiyuan city.

Energy–Environmental Issues in Shanxi Province and Taiyuan City

Xia Shaowei, Zhang Ruhao
Luo Xiao, Ruan Hui

In the last ten yeras. China progressively formed its own idea on "Sustainable Development Strategy". The basic ideas are: Environmental problem must be integrated into economic and social problems, and be solved with the development of economy and society.

1. The Influence of Global Warming on China and the Counter Measures

The rise in carbon dioxide and global temperature is causing increasing world wide concern. Chinese government and scientists have paid close attention to the tendency of global warming.

For utilization of energy, two subjects remain to be solved in China. First, the proportion of the fossil energy in primary energy is very large (about 95%), and the coal accounts for 76% of the consumption of the primary energy. Second, the energy utilization efficiency is quite low, which is about 30% in average. The secondary energy transformation from coal is less than one third.

China has great potentialities in improving energy utilization. Energy–saving will be the direction which we must insist on for a long time. The objective is: in 2000, the energy consumption for thousand yuan GNP is 0.72 tce. (in 1985, the data is 1.05 tce). The emission of CO_2 in Chinese will be reduced 0.282 GTE (billion tons) during 1988 to 2000. The goal of our government is that the forest coverage will increase from 12% to 18–20% at the end of this century.

Table 1

waste gas	unit	1986	1990
flue gas	$10^9 Nm^3$	4647	5952
being dedust	$10^9 Nm^3$	2870	4394
tail gas	$10^9 Nm^3$	2321	2590
being treated	$10^9 Nm^3$	1103	1602
SO_2 emission	MT	12.5	15.0
particulate emision	MT	13.8	13.2

In 1985, central heating covered $55 \times 10^6 m^2$ of building area, accounting for only 6.4% of the total building area in the cities of northern area. Most of the houses got heat supply from individual small boilers (50%), and coal-fired small stoves (44%).

2. Case Study in Shanxi Province and Taiyuan City

Shanxi province is the largest base of coal production in China. In 1989, the output of coal in Shanxi was 270MT, which is 27% of the national total coal production.

Taiyuan is the capital of Shanxi province.

The industrial structure is a heavy industry form: The important industrial efficiency indices are lower than the national average value.

In Taiyuan, coal is the main primary energy, all the liquid fuel is transported from other parts of the country. In the final energy consumming structure, raw coal takes 42.4%, and the 53.2% of coal transform to secondary energy.

The annual energy consumption per capita in Taiyuan is 3.25 tons, which is 3.56 times above national average level.

The comparing for the unit energy consumption of 16 sorts of products from the key enterprise with the national average level of the same products in 1989, 10 of them were 15% higher than the national average value.

In table 2, the comparision of Energy consumption indicators of Shanxi privence and Taiyuan City with the average of the whole nation in the year 1991 are shown. The energy consumption indicators of Shanxi and Taiyuan are about 2 times larger than the average level of nation.

Table 2

	Nation	Shanxi	Taiyuan
Energy consumption (tce) per RMB 10,000 yuan GNP	5.11	11.32	10.71
Energy consumption (tce) per RMB 10,000 yuan industrial output	2.88	7.21	6.81
Coal consumpution rate of power generation gce / KWh	390	409	420

In shanxi province, much emphsis is laid on the construction mine area power generation or pithead station to alleviate the pressure on coal transportation and to raise the combined benefits.

Shanxi is not only a key coal production province, but also a large coal consumption region. The 80% of coal consumption was from burning of coal directly, causing serions air pollution. The air emission from burning 1 ton coal contents 20 Kg SO_2, 880 kg CO_2, 15kg particle and 260 kg coal cinder and flyash. The comparison of air pollution level in selected cities including taiyuan is shown in following table 3.

3. The Energy Environment Characteristics in Taiyuan City.

1) Air contamination

It is obviously typical pollution of smoke and soot discharged by coal combustion which contained mainly particle and SO_2 from industrial furnaces and stove used. Particle and SO_2 emission in industrial origin are 82% and 76.2%, and the same in domestic usage origin are 15.4% and 22.4%.

In 1986, 0.88 mg / m^3 of particle in the air stayed, higher than its average value of 23.08% in northern cities of China, SO_2 of 0.27mg / m^3, 2.57 times its average value also.

Taiyuan occupying an area of 7000 Km^2 with 2.8×10^6 of population. The energy consumption in Taiyuan is about 7.4 MT, but its environments volume holds small and self-purification capacity is limited.

Because in urban area, more than 60 percent of Gross Industrial Product is produced, most of the coal is burned. Therefore, urban air pollution must be the thrust of environmental protection in China. The annual averages of TSPM in Taiyuan is higher than 750 $\mu g / m^3$ in winter, near doubling that of the Grade-3 National Ambient Air Quality Standards (NAAS). The pollution in summer will be lower than winter.

Table 3 gives concentrations of total suspended particulates (TSP) and SO_2 in air in selected cities.

Table 3. Air pollution level in selected cities of China (1988)

	TSP ($\mu g / m^3$)	SO_2 ($\mu g / m^3$)
Taiyuan	700-800	150-250
Beijing	321-506	73-249
Shengyang	304-598	78-213
Xi'an	495-708	124-170
Shanghai	192-360	13-115
Chongqing	620	300-400
Guangzhou	118-325	7-143

There are two environmental problems in the use of coal in Taiyuan, one is the coal leakage and coal fly on exploition, transportation, processing, transformation and utilization, this is the physical loss. The other is the chemical material emission in the transfer of energy.

The cheap price of coal restrict the reasonable use of energy. At present, the price of raw coal is only 50-100 Yuan / ton in Taiyuan market, but the saving investment is as high as 200-250 Yuan / ton. The price should be adjusted to suit the requirement of energy conservation.

In fact, the more advanced technique is adopted to transform and utilize coal, the more completely coal is burned. The smaller emission physical shape is, the bigger emission chemical one is.

The coal flow chart shows that the ration of available energy against the unavailable stays 24 to 65 in its energy consumption. It means that the useless energy loss arises too heavy.

2) CO_2 emission.

The :aban coefficient being calculated in Taiyuan is 0.735 Tc-Tce. higher 12.9% than the national average value. The value of CO_2 in 1990 was 3.27 MT-c, per capita average C emission was 1.26 Tc / P.

To reduce CO_2 emission in Taiyuan, the potential can be studied from two aspects. Firstly, with the updated equipment and technology on a large scale, the efficient energy utilization would be increased. Secondly, with the reformation of end energy consumption pattern, the adoption of secondary energy with clean and high efficient quality and the promotion of management level, the tremendous reduction would come into energy consumption, so that CO_2 emission would be deescalated respectively. It is estimated that the potential reduced CO_2 emission may be 2.2 million tons.

4. Some measures for the urban environment improvement.

In recent years, the government have made a hard effect to improve the efficiency of coal utilization and reduce environmental pollution, intensify the management and improve the technology, such as:

• the government give big support to the manufactories in processing and transforming coal, In the period of 1981 to 1988, the total urban investment adds up to 570 million yuan (about 100 million us $), in which 230 million yuan is used for energy-saving technical innovation. Taiyuan was one of the cities where has got this support.

• the end energy consumption has been changed, the urban gas used coverage and increased from 41% in 1986 to 58.1% in 1990. In this period, the coverage of briquet coal for domestic use has increased from 39% to 73.3%. The urban heat supplying coverage has been increased from 3.6% in 1988 to 16.6% in 1990.

• Economic structure should be adjusted and urban multi-functions would be expended. Some urban enterprises consuming too much coal should be moved out of the urban area or stopped in production.

• Promote the technical innovation of energy saving and raise the rate of energy utilization. From 1980 to 1989, the total investment in "three wastes" treatment has got to 46 million yuan (about 8.4 million us $) covering 9.7% of total investment in the industry technical innovation of the whole Taiyuan city.

• Legal system should be strengthened. Articles of policies, laws, rules and detailed regulations have been made out for energy use and environmental protection.

• The results of these measures are: the elasticity coefficient of energy consumption is about 0.4; the major pollutant emission value decreased in 1990; (particle in atmosphare fall down from 1.06 mg/m^3 in 1985 to 0.57 mg/m^3 in 1990; SO_2 emission declined 6.2% per year.)

5. The forecasting of Energy in Taiyuan.

In order to built up the heating system for the city, the priority would be given to heat-power, co-generation and district heating. In addition with big size of high efficient heating boilers and with full use of industrial residual heat. coal may be used in many way in the future shown in Fig.1.

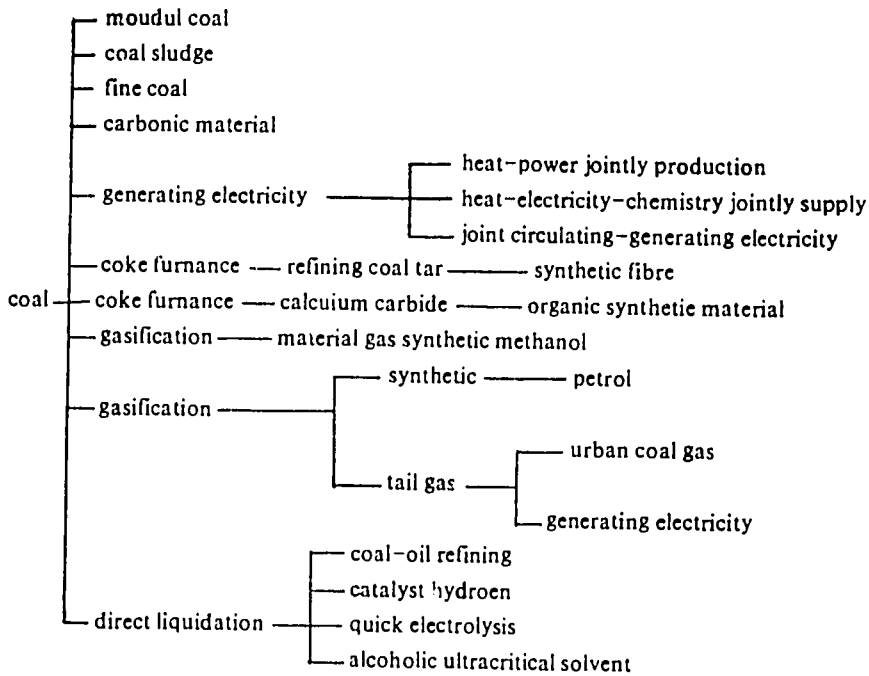

Fig.1 The flow chart of coal processing and transformation in Taiyuan city

According to the "eight-five year" plan and ten year forecasting of Taiyuan's development. By the year 2000, the GNP of the city will predictively reach to 15 billion yuan, (annual growth rate: 7%), the gross output value will be 26 billion yuan, the total energy demand is about 10.9 million tons of standard coal, (anuual growth rate:3.38%).

Taiyuan is one of the biggest coal production cities in China. Its prospective economic growth is closely related to coal exploitation and utilization. In the coordinate development of handing economy-energy-environment, no where in a city of China can have more difficult than in Taiyuan.

Consequantly, in order to ensure the comprehensive economic development in China, it is require that Shanxi's coal production base should continuously take on the important task of coal production. By the year 2000, the on-schedule goal of raw coal being produced annually 450 million tons. It is a heavy environmental pressure in the province, including Taiyuan city.

In Shanxi province and Taiyuan city rich resource of coal has been discovered, high coal output is produced and the consumption pattern of coal is quite out of date. There are many difficulties which have to be solved. In the recent years, Shanxi province has conducted extensive economical and thecnical cooperation with the World Bank and many countries, in the aspects of capital introduction, technical transfer and research coorpation. In the future, according to the economy reform and open policy of China, Shanxi will like to further increase the coorpation and exchange with more nations and regions.

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Coal-fired Power Stations and Their Affection on the Environment in Shanxi, China*

Ruan Hui Xia Shaowei
Luo Xiao Zhang Ruhao

The Production and Transportation of Coal and Electricity in Shanxi

There are rich coal resources in China. The main primary energy resource will be the coal in a long period. Shanxi is the biggest base of coal production in China and its output of coal is one forth of that of the country. In recent ten years, the output of its coal increase at a rate of 8% every year. The output of electricity in the province was only several percent of the total amount of the country.

Because Shanxi is the biggest base of energy resource production and main consumer of energy its society progress and economy development are closely relative to the production and transportation of coal. Now the development of coal production in the province is limited by the low transportation ability. A plenty of coal is overstocked. Since 1990, there have been 40 million tones of coal overstocked every year. It reached 70 million tones some year. Only 18 million tones were used to electricity production in 1991. It was only 6.2% of output in the year. Because the focus is on the coal transportation the development of transportation can not keep balance.

*This research was supported by National Nature Science Funding

Recent years more than 90% of its ability of railway are used to transport the coal outside the province, and the transportation of other materials outside and inside province have been effected seriously. This limited the development of other industry production of the province to a certain degree. If the primary energy resource coal is transformed to the secondary energy resource electricity and then transported outside the situation of railway transportation will be relieved. As a result this will promote the economy development healthily.

If the ratio of coal transforming to electricity increases the industrial and civic consumption of coal which is used directly and air pollution will decrease. Shanxi will adopt a strategy that pays equal attention to coal and electricity. The province will give energetically support to the development of fired-coal power stations and increase the transportation of electricity out the province and make the electricity industry be a second industry following the coal industry. The capacity of coal-fired power stations will reach 18-20 million KW. Among them 7.16 will transport out the province. Based on that the capacity of the fired-coal power stations will reach 20 million KW and 6.7 million tones of coal will be consumed. Then the output of coal will reach 400 million tones a year and 16.8% of them will used to produce electricity. It will increase 10.6 percent points.

Present Environment Situation in Shanxi

At present, the air pollution of the province is a type of fired-coal pollution. The most pollutants are the type of grain and SO_2. Based on the data from the environment monitoring in 1986 to 1990 the load coefficient of TSP and SO_2 were 0.458 and 0.447 respectively. TSP in all cities of the province exceeded the Grade 2 of the National Air Quality Standards(NAQS) in this period. The TSP of Taiyuan and other three cities exceeded the Grade 3 of the NAQS. As a sample, annually mean concentration of SO_2 in the suburb of the capital Taiyuan exceed Grade 3

of the NAQS and it was the 2.5 times of average level of the cities in north China. Its TSPM was 123% of the average level of the cities. Among the TSPM, 82% of it was released from industrial sources and 0.5% of it was from coal-fired power stations. Fifteen percent was from daily life of the residents. The 76.2% of SO_2 discharge was from industrial sources and among them 30.7% was released by coal-fired power stations. The 22.4% of SO_2 came from the daily life of residents. Based on the primary estimate the discharge coefficient of carbon C was 0.735 and it was more than 13% of the average level of the country. The discharge of CO_2 of Taiyuan in 1990 was 3.2 million tones-C.

Table 1 *Discharge coefficients of different coal-fired equipment*

	Boiler of Power Stations	Common boiler	Resident stove
Discharge coefficient of CO_2 (T-C/Tce)	0.76	0.694	0.752

Taiyuan is a represent. Based on the statistic data, the waste air discharge of the province was 398.4 billion standard M^3 in 1988. Of them 322.6 billion standard M^3 were from burning and it was the 80.9% of the total discharge of waste air. The discharge of SO_2 was 0.8 million tones and it was 88% of the total amount. The main pollution source of the air in Shanxi is burning of coal. The investigates suggest that more than 70% of the total SO_2 and dust discharge come from the boilers in the province. The pollutants from the boilers is the main source of coal-fired pollution.

Moreover, a lot of solid waste materials has produced and pile up and as a result the effective

Table 2 *The harmful material discharge in industrial waste air of Shanxi*

Industry	Discharge (%)	SO_2	NO_x	dust	ash
Electric industry	21%	40.3%	53.4%	38.8%	0.5%
Metallurgical industry	39.5%	8.6%	13.6%	19.5%	22.9%
Chemical industry	12.7%	17.1%	9.5%	7.82%	13.3%
Coal industry	5.8%	7%	5.3%	7.8%	5.7%
Building material industry	8.6%	5.4%	3.1%	9.5%	53.6%
Engineering industry	3.6%	5.8%	2.2%	5.0%	0.6%

The data in table 2 show that the discharge of SO_2 from the coal-fired power stations is 40% of the total amount, discharge of NO_x from them reached 53.4% and dust discharge was 38.8% of total amount. So the coal-fired power stations is the main source of the air pollution.

The coal-fired power stations is the third main pollutant source of the solid waste materials. Nine percent of waste residue are released by them and 1.6 million tones of waste materials that

with the coal consumption of the coal-fired power stations synchronously. The coal-fired stations will be the main pollution source.

The measures to improve the environment

Based on the analysis above, The coal-fired power stations are responsible the environment pollution. As electric industry develops fast in Shanxi, China the measures must be adopted to limit pollutants produced by coal-fired power stations. To do this,

1.To increase the burning efficiency This will decrease the consumption of coal relatively and therefore to decrease the pollution. Now as a feature of the coal-fired power stations in Shanxi, the coal burning is incomplete and physical consumption is high. Based on the investigation the carbon in the cinder discharged by coal-fired power stations is as high as 15%. The coal consumption of coal-fired power stations in Shanxi is: from minimum 390g/KW.h to maximum 743g/KW.h and average 493g/KW.h. More attentions must be paid to increase the burning efficiency of the coal as the coal-fired power stations are built in a large-scale. The advanced techniques should be imported and the improvement of the techniques and equipment adopted now should be speed up to save the energy and increase the efficiency. If the coal consumption of the coal-fired power stations decrease to 400g of standard coal/ KW.h and the capacity of the coal-fired power stations is 20 million KW 12.64 million tones of coal will be saved and 18.9% of pollutants discharged will decrease at same time.

2.To improve the technique level controlling the dust of the coal-fired power stations. Now most generating sets that its capacity is more than 200 MW and a part of medium-sized and small-sized generating sets in the cities are equipped with efficient dust removers. Low-efficient dust removers equipped have been improved. The discharge rate of coal-fired power stations has decreased year after year. But the efficiency of the dust removers in coal-fired power stations all

area and environment quality of the land decrease. The environment is polluted seriously. Now the industrial waste materials have reached 300 million tones and 30 million M^2 of land have used to pile up them. Forty million tones of solid waste materials are released every year and 60% of them are gangue and coal ash.

The environment problems caused by developing coal-fired power stations

Based on the investigation of the harmful materials discharged in the air the sequence of the discharge from the top to bottom is as follows.

Metallurgical industry, electric industry, chemical industry, building material industry and coal industry.

The harmful materials discharge of these 5 kinds of industries amount to 87.5% of the total amount.

The sequence of CO2 discharge is as follows:
Electric industry, chemical industry, metallurgical industry, coal industry, engineering industry and building materials industry.

The discharge of NOx is as follows:
Electril industry, Metallurgical industry, Chemical industry, coal industry, building materials industry and engineering industry.

The discharge of the dust is as follows:
Electric industry, metallurgical industry, building materials industry, chemical industry, coal industry and engineering industry.

The discharge of the ash is as follows:
Building materials industry, metallurgical industry, chemical industry, coal industry, engineering industry and electric industry.

over the province rarely reaches 98%. It is necessary to improve the efficiency of the dust removers further.

The discharge of cinder from the coal-fired power stations brings disaster to the environment and agriculture. To speed up the multipurpose use of cinder and change the waste materials into things of value are the urgent problems. Changzhi city has accumulated the experience in this field. Commercial lime, outdoor color bricks, hollow brick and bricks for protecting dam had been produced by cinder from the coal-fired power stations. The Efficient water-proof and heat-insulating powder and cinder air alkali block were developed. There is advanced experience that the cinder as a kind qualified materials is used to produced building materials or backfill materials too. At "91' The international conference on the utilization technique of cinder and burning coal production" the experts from the country and abroad agreed that some items of multipurpose use of cinder which developed by Shanghai Baoshan Steel Factory were on the leading world level. To make use of cinder to produce tubes and cinder-silicon fertilizer has profound significance in field of developing agriculture through the science. If a part of the irrigation canals are replaced by the underground tubes made from cinder not only evaporation and leakage of the water will be prevented but a lot of lands will be saved. This is useful to increase agricultural output and save the water.

The problems to be resolved

The coal-fired power stations have not been equipped with sulfur-cleaning devices because of the factors of economy and technique. Some coal-fired power stations have been equipped the moist smoke-air sulphur-cleaning devices imported from Japan. Because the limited capital construction invest and high production cost for this technology it is difficulty to popularize extensively. Since the 1970s electric departments in China have worked for the research of the

most of them are cinder are released by the coal-fired power stations. It accounts for 87.1% of cinder discharge in the province. As a sample, there are several million tones of cinder stocked in Datong and it increases at a rate of 0.5 million tones a year. It occupies a lot of land, and can fly easily, especially with the wind. It is harmful to the residents and the crops.

Table 3 *Discharge of solid waste materials of different industries in Shanxi*

Industry	Discharge/year	Cinder	Stock	Land occupied
Coal and its processing	46%	2.5%	59%	47.6%
Metallurgical industry	31%	4.8%	22%	20.5%
Electric industry	9%	87.1%	12%	24.7%

Along with the development of electric industry in future, the strategy "transforming coal-transportation to electricity-transportation" will be adopted, The coal consumption of coal-fired power stations will increase rapidly. The coal consumption of them was 18.12 million tones in the province in 1991 and was the 20.9% of the total coal consumption of the province. The coal consumption of the coal-fired power stations will reach 67 million tones and increase 269% in the end of this century. Because the coal consumption of the electric industry increases the focus of monitoring and controlling environmen. pollution will be on the coal-fires power stations. If the conditions for calculation of pollutants do not be changed the discharge of SO_2, NO_X and Dust from the coal-fired power stations will reach 477000, 250100 and 408800 tones respectively in the end of this century. The cinder discharge will be 4. 89 million tones and it will increase

low-cost sulphur-cleaning technique, active-well absorbents and additives that promote the fast reaction. All of them should be suited to the conditions of the country. The technology should be practical and cost should be low.

There are some successful experiences and techniques for the multipurpose utilization of the cinder and it is not enough for us. The multipurpose utilization ratio of cinder is only 26%. We suggest that all departments pay attention to the problems. The funds should be collected by coal-fired power stations which release pollutants, local residents and governments. To loan on favorable terms, decrease the tax and encourage and reward should be consider.

Conclusion

The energy resource-environment strategy for Shanxi, the coal energy resource base of China should be based on the conditions of the country. That is to pay equal attention to the development of energy resource and save of the energy resource , to improve the energy resource structure and technique of energy utilization continuously, to search the ways for constant and steady development of energy resources, environment and economy. This strategy is in keeping with the development strategy of the world " harmless to the environment and clean energy resource"

The electric energy produced by coal-fired power stations is the essential energy resource and burning coal will pollute the environment. To change the energy resource structure of Shanxi, relieve the pressure of coal transportation out the province and maintain the economy development continuously, steadily and coordinately, a strategy "to pay equal attention to coal

and electricity" should be adopted. The construction of coal-fired power stations should be supported energetically. To decrease pollution, improve the environment and save energy resource, the important policy which suits the conditions of the country is to choose the harmless to environment and sound coal technique and support the multipurpose utilization of the cinder at the same time. All of them will helpful to improve environment.

Otherwise, China is a developing country. Shanxi which locates inland only has limited financial resources and technique conditions. There are no enough funds using to study, develop and apply the advanced sound coal techniques that have been applied in western developed country. We hope that all countries in the world and international society pay attention to it, give supports in this field and deliver the techniques to the protect the globe environment and supply funds according the uncommercial conditions to promote the application of the new techniques. The environment should be improved effectively as coal-fired power stations are built.

The Way of Utilization of Lignite in Yunnan Province of China

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Abstract

Coal reservation in Yunnan Province are $15*10^9$ ton, where is a favorable condition to produce the liquid transportation fuel and substitutional natural gas from lignite. The Xianfeng and Zhaotong lignites are suitable for direct liquefaction and gasification to produce the transportation fuel and substitutional natural gas. They are also in a good condition for industrial production. These are important ways of technology development.

Keywords: Lignite, Direct Liquefaction, Gasification

Introduction

Yunnan Province have abundant coal resources where is located in the southwest of China. It is far from seaside. There are not any oil and natural gas discovered. The total coal reserves are $23.2*10^9$ tons if which lignite reserves are $15.0*10^9$ tons. Lignite distribution in Yunnan province is shown in Table 1 which is shown that lignite is the main energy resource in the province.

Table I Lignite distribution in Yunnan province

Coal field	Reserves $*10^9$ ton
Zhaotong	81.8
Xianfeng	2.94
Xiaolongtan	10.93
Mongzhi	20.20
Jiangchuan	1.58
Mile	7.81
Yuxi	0.61
Luxi	0.71
Baoshan	0.36

The features of these lignite coal fields are that the coal seams are thick (maximum thickness more than 200 meter), but not deep, hence they are suitable for surface mining.

At present, lignite is mainly used for electric power. approximate about 75% of power stations are using lignite and most industrial boiters are also using lignite. The chemical utilization of lignite is only to produce montan wax and humic acid and make char (used for making silicoferrite). The yields of these products are several thousand tons per year.

By lack of oil, to produce liquid fuel is considered as the way of utilization of lignite in Yunnan province in future.

2. The general conditions of Xianfeng and zhaotong coalfields

2.1 Xianfeng coalfield

Xianfeng coal field is located at Xundian county and 99 km north from Kunming City. The coalfield area is about 7 Km^2, The average thickness of lignite seam is 57.5 m. The demonstrated reserve is 280 million tons. The lignite seam is covered by silicon earth about 77 million tons. In Xianfeng mine, the annual output of lignite will grow up to 3 million tons by 1995. Xianfeng lignite is of fine quality. The ash content is low (average 9.24%), of which 118 million tons having ash content less than 6.0%. The total moisture

is about 30-40%, the sulfur and phosphorous are very low, as well as the reactivity is very high. So that Xianfeng lignite is very suitable for chemical usage, such as gasification and liquefaction. The analysis data of Xianfeng lignite are shown in Table 2.

Table 2. The analysis data of Xianfeng & Zhaotong Lignite

Item		Xianfeng	Zhaotong
1, Proximate analysis			
W_{ad}	Wt%	10.0	10-15
A_d	Wt%	7.4	18-33
Y_{daf}	Wt%	50	52-59
$S_{t,d}$	Wt%	1.2	1-2
$Q_{DI,ad}$	Wt%	23.4	14.7-17.2
2, Ultimate analysis			
C_{daf}	Wt%	66.4-71.7	67.54
H_{daf}	Wt%	5.0-5.9	5.72
N_{daf}	Wt%	1.5-1.9	1.38
$O+S_{daf}$	Wt%	21.1-26.2	25.36

2.2 Zhaotong Coalfield

Zhaotong coalfield is located in the northeast of Yunnan province. It has coal reserves of 81.8 billion tons which are the maximum ones in south area of China. The average thickness of coal seam is 40-120 m. (maximum 194 m). The cover earth on the coal seam is thinner. The degree of coal metamorphism is low. The nature of the coal is soft. These conditions are well suitable to construct a larger surface mine which the output up to 10 million tons per year.

The average moisture is 66.7%, the average ash content is 21.8%, the volatile matter is 56.8%. So this lignite is not suitable long distance transportation, but only suitable to be utilized in situ. The analysis data of Zhaotong lignite are shown in Table 2.

3, The technical way of utilization of lignite

3.1 Liquefaction of Xianfeng lignite

By lack of oil and gas, liquid fuels have to be transported from outside, *t is expected that 12 million tons of gasoline and diesel oil will be needed per year by 2000. However, the coal will be surplus in the market. Therefore the government of Yunnan province is very interested to produce liquid fuels from coal.

In 1990, Beijing Coal Chemistry Research Institute carried out the liquefaction and coprocessing experiments of Xianfeng lignite by 0.1 t/d bench scale liquefaction test unit. The results of these experiments are shown in Table 3.

These results indicated that Xianfeng lignite is good for liquefaction under the proper reaction conditions. The conversion can be up to 94%, the oil yield can be up to 55%. Coprocessing test results indicated that the oil yield can be up to 71%. The hydrogen usage efficiency is up to 16.6.

The economical analysis on demonstrative plant of Xianfeng lignite have indicated that if a 0.5 Mt/y plant is constructed, the capital investment will be 1.076 billion yuan with the rate of return of 18.3%. It is confirmed that the economic benefits of the liquefaction project is acceptable.

Table III The results on liquefaction and co-processing tests of Xianfeng lignite

Item	Liquefaction		Co-processing	
	1	2	1	2
1. Experimental condition				
1) Slurry concentration (wt%)				
Coal	40	40	34.13	34.13
V.T.B	-	-	32.35	32.35
Recycle solvent	58.38	58.38	32.35	32.35
Red mud	1.13	1.13	0.93	0.93
Sulfur	5	5	3	3
Mo compound	0.13	0.13	0.16	0.16
2) Slurry flow rate Kg/h	3	3	1	1
3) Make up H_2 flow rate(Nm^3/h)	-	-	0.08	0.08
4) Recycle gas flow rate(Nm^3/h)	10	10	10	10
5) Reaction pressure MPa	6.15	6.18	6.05	6.06
6) Reaction temperature °C	24	24	24	24
2. Experimental results	24.9	24.9	25.1	25.1
1) Conversion of coal(wt%)	450	445	460	465
2) Gas yield (wt%)	94.8	94.4	93.7	95.9
3) Water yield (wt%)	13.4	12.6	7.4	10.7
4) Oil yield (wt%)	23.4	21.7	12.5	13.6
5) H_2 Consumption (wt%)	57.3	52.6	65.8	71.9
6) H_2 efficiency	6.3	5.8	4.1	4.3
	9.1	9.1	16.0	16.6

3.2 Gasification of Zhaotong Lignite

Zhaotong coalfield is located near to Sichuan province which is rich in natural gas resources and there are gas pipeline nets. The synthetic natural gas (S.N.G) will be produced by gasification of Zhaotong lignite in situ and transported to industrial user by the N.G pipeline or used to generate electricity by IGCC which is under developing now.

The expected scale on a proposing project will be S.N.G of 4.2 million m^3 per day. The proposing process is the Lurgi liquified ash drain process.

4. Conclusion

Yunnan province is far from seaside, rich in coal resources especially lignite resources, but lack of crude petroleum as well as N.G. Liquefaction and gasification of lignite are predicted with good economical benefits.

The government of Yunnan province is very enthusiastic about it and warmly welcome the investigator or investor go there.

Clean Coal Transport System CWM Chain Between China and Japan

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ABSTRACT

A project combining Coal Water Mixture (CWM) production in China and its transportation to Japan as a boiler fuel has been carried on since March 1992 through the sincere cooperation of the companies involved with a China-Japan joint venture company, YANRI CWM Co.,Ltd., funded by Yanzhou Coal Mines Bureau (Shandong, China), Nissho Iwai Corporation of Japan and JGC Corporation.
Construction of the CWM production plant with a capacity of 36 tons/hour (250,000 tons/year) began in March 1991 and was completed in February 1992. CWM production started in March 1992. Up to September 199 the plant has produced about 70,000 tons of CWM, which have been exported from China to Japan as the world-first bilateral CWM trade in the international fuel market. The CWM is firstly received by a CWM relay station and then distributed to end users. More than 55,000 tons of the CWM distributed via the relay station has been smoothly burnt in the boiler of an end user since April 1992.

INTRODUCTION

The highly concentrated coal water mixture (CWM) is a mixture of about 70wt% of coal and about 30wt% of water with a little amount of dispersant to prevent the agglomeration and sedimentation of the coal. The coal particles are ground to have a specific coal particle size distribution to achieve highly loaded particle packing in the mixture. The maximum particle size is generally less than 500 micron and average particle size is between 15 and 30 micron. The rheological characteristics of the CWM are thought to perform as a Bingham plastic fluid. The viscosity of CWM is about 1000 mPas and the density is about 1250 kg/m^3.

The basic concept of the CWM production process is a combination of coal comminution and mixing fine coals with water and small amounts of additives. The three key factors of the CWM production technology are the coal particle size distribution, the additives and mixing of water, coal particles and additives. There are various kinds of CWM production processes because of the many combinations of units.

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Many investigations on CWM have been done since the first oil shock, which was in 1973. Pioneer projects have been conducted in Canada, China, Italy, Germany, the U.S.A., USSR and particularly in Japan[1]. It has been proved that CWM having a good stability is capable of being handled just like oil through a number of experimental, demonstration and commercial works on production, storage, transportation and combustion [2],[3],[4],[5],[6].

PROSPECTS FOR CWM FROM THE ENVIRONMENTAL POINT OF VIEW

Because the CWM is a mixture of coal and water, it is safety and has many environmental benefits such as no spontaneous ignition, no explosion and no dust problem during storage and transportation to the end users. CWM allows for the elimination of solids handling equipment at the boiler site of the end users.

CWM offers the following merits due to its safety characteristics:

1) Compaction of the storage volume compared with oil and coal itself, because there is no limitation of the distance between storage tanks. And also, CWM has higher calorific value per unit storage volume than coal because the packing density of coal in CWM is higher than that of coal in coal pile.

2) Underground tank storage and utilization of the space over the tank. An imaginary picture of CWM underground storage tanks designed by JGC is shown in Photo-1.

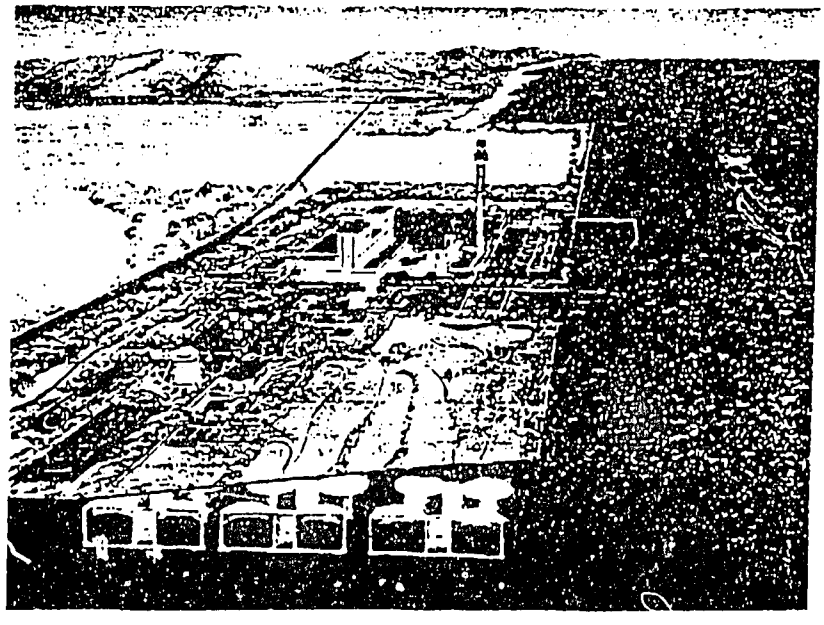

Photo-1 CWM underground storage tanks

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Beneficiated coal-based CWM can be obtained, if a coal cleaning process is combined in the CWM production process. There are, in principle, two kinds of processes combined with the coal cleaning step in producing CWM as follows:

1) Coal beneficiation step is placed prior to CWM production[7].
2) Coal beneficiation is placed in the CWM production process[8].

In general, 30 to 50 % of ash in raw coal is taken out by the coal cleaning process. Sulfur reduction in washing is relatively difficult. Recently many new coal cleaning technologies are being investigated, and it is reported, for example, that the new processes have resulted in reduction in pyritic sulfur contents of 50 to 80%[9].

CWM technology is offering the combined possibilities of pre-combustion physical beneficiation (reduction of ash and sulfur in coal), in-flame combustion sulfur capture and post-combustion absorption[10]. Since CWM is inherently an aqueous mixture, it lends itself to treatment steps prior to combustion, and also during the process of combustion as follows[10]:

1) In-Combustion Absorption: Calcium carbonate is used as absorbent which is mixed in the slurry as a part of the slurry matrix.
2) Post-Combustion Absorption: Limestone absorbent is injected during the combustion process.

CWM FROM CHINA TO JAPAN

YANRI CWM Co., the China-Japan joint venture company, started production and export of CWM in March 1992 as the world-first bilateral CWM trade in the international fuel market. The CWM moves through the following stages from its production to combustion.

- Production of CWM (36 tons/hour) at Shantong, China
- International transportation from China to Japan, 1100km, by 5,000 DWT CWM tanker
- 10,000 m^3 storage tank at relay station of CWM at Wakamatsu port, Kyushu, Japan
- 400km internal transportation by 700 DWT vessel from the relay station to a CWM end user, Tayca Co., in Okayama.
- CWM combustion in a boiler with 45 tons/hour steam generation capacity

Figure 1 shows the CWM chain from China to Japan.

(1) Production of CWM (36 tons/hour) at Shantong, China

YANRI CWM Co.,LTD was founded in May 1990 for production of CWM which is to be exported to Japan. The company owns a CWM production plant with a capacity of 36 tons/hour(250,000 tons/year) constructed by JGC at Rizhao, Shandong, China. A general view of the plant is shown in Photo-2. The process of the plant is licensed by JGC. A

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schematic flow diagram of IGCC process is shown in Figure 1.

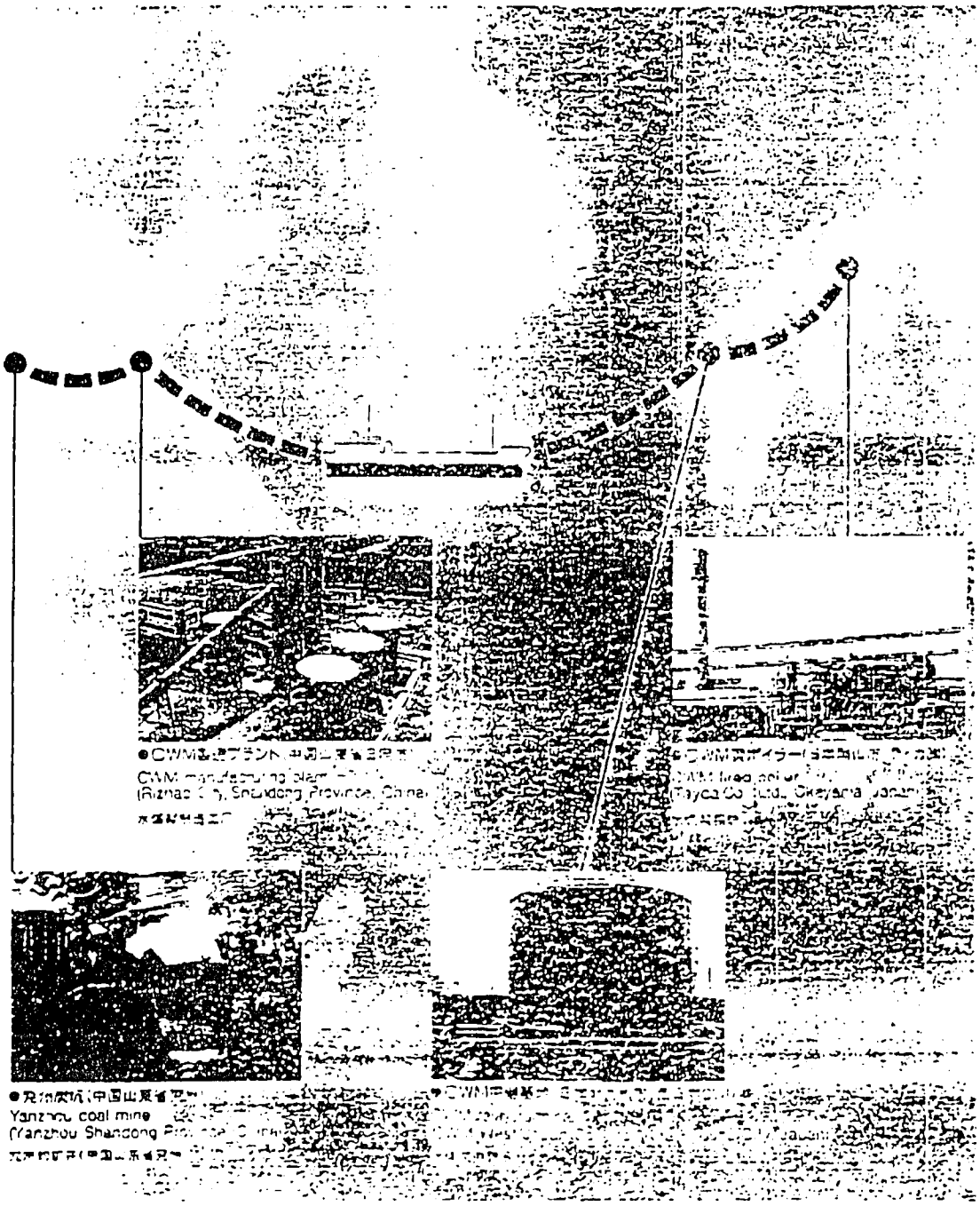

Figure 1 [illegible]

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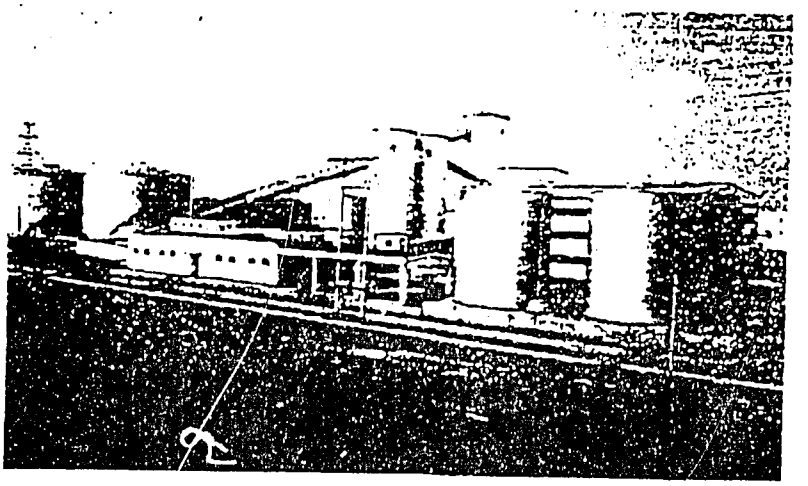

Photo–2 General view of the plant of YANRI CWM Co.,

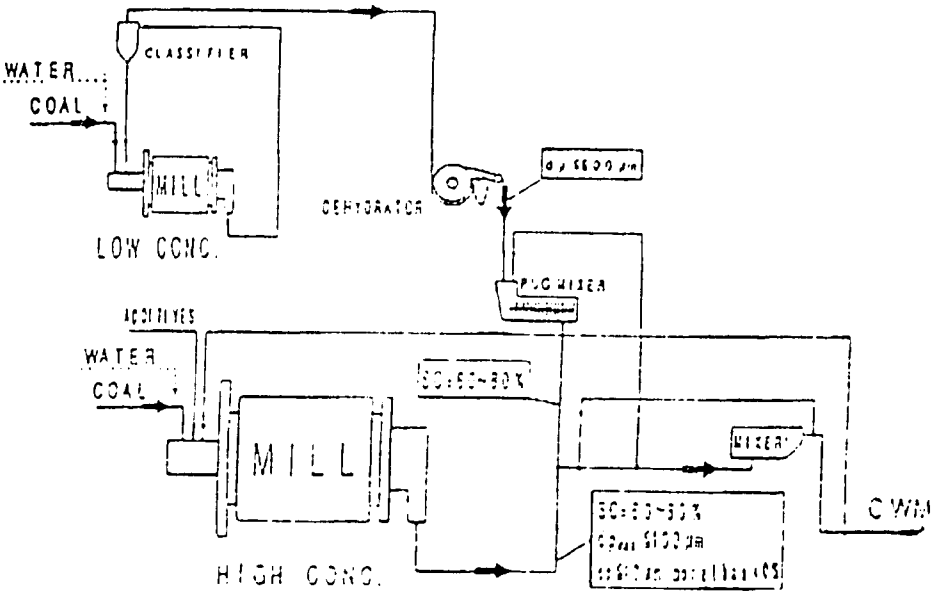

Figure 2 Schematic Flow Diagram of JGC's CWM Production Process

In the process, about 50 to 70% of raw coal goes into the high concentration wet ball mill with additive and water. The rest of the raw coal is treated in the following sequence, low concentration wet mill, vacuum filter and mixers. The main equipment is

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shown in Table 1.

Table 1 Main equipment of CWM plant

Coal storage silo (3500 ton)
Silo reclaimer (50 ton/hour)
Crushers (Cage mill 50 ton/hour x 2)
Ball mill (High concentration wet mill 4.2 m x 13.2 mL)
Ball mill (Low concentration wet mill 2.[illegible] m x [illegible] mL)
Vacuum drum filters (1.5 ton/h-dry)
Twin screw pug mixer
High shear mixers
CWM storage tanks (10,000 m³ x 2)
Loading pumps (400 m³/h x 3)

The CWM produced by YANRI CWM Co. is transported to Japan by a 5,000 DWT oceangoing CWM tanker which was somewhat modified mainly cargo pumps from a heavy oil tanker. There are two underground pipelines from the storage tanks to the wharf for shipping. The pipeline diameter is [illegible] inches and its length is 1.2 km. A rubber hose is connected between the pipeline and the CWM tanker for CWM loading at the wharf. The loading of 5,000 tons of CWM takes about five hours. Photo-3 shows the simple system of cargo handling using the rubber hose at Rizhao port in China.

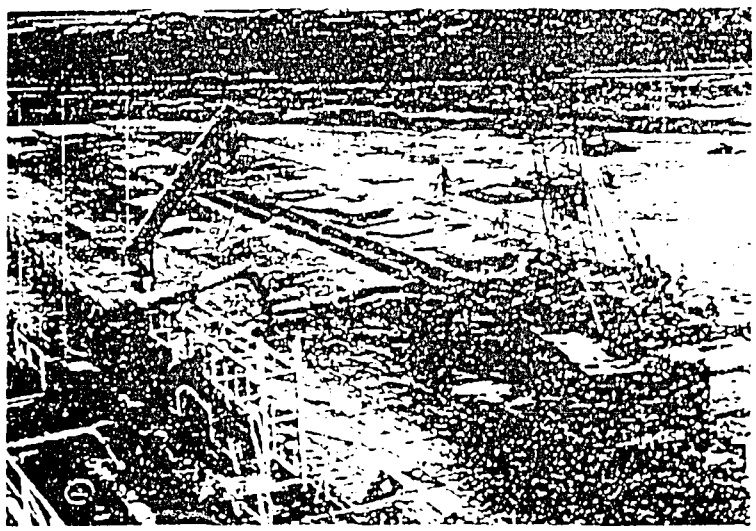

Photo-3 Cargo handling using the rubber hose at Rizhao port in China

The raw coal for the CWM is supplied by rail from Yanzhou coal mines 300 km away from the plant site. Yanzhou coal and CWM properties are shown in Table 2.

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Table 2 Yanzhou raw coal and CWM properties

Raw Coal	
Proximate Analysis, %(wet basis)	
Moisture	3
Volatile Matter	31
Fixed Carbon	52
Ash	9
Heating Value(HHV), Kcal/Kg	7080
Ultimate Analysis, %(dry basis)	
Carbon	75.8
Hydrogen	5.3
Nitrogen	1.4
Oxygen	8.1
Sulfur	0.4
Ash	9.2
CWM	
Design Properties of CWM	
Solids loading, %	70
Particle Size,micron (max.)	300
(ave.)	25
Viscosity, Mpas	1000
Density, g/cm^3	1.25

(2) 1,100 km internationaltransportationfrom China to Japanby the 5,000 DWT CWM tankerand storage in a 10,000 m^3 tank at the relay station of CWM at Wakamatsuport, Kyushu, Japan

A joint venture company, CWM WEST JAPAN Co.,Ltd. was founded in March 1991 by Nissho Iwai, Mitsui Mining Co., JGC and Tsurumi Yuso Co.. The role of the company is to provide the relay station for the CWM from China to Japanese users. This company has a 10,000 kl dome-roof CWM storage tank constructed by JGC at Wakamatsu, Kyushu, Japan. Photo-4 shows the storage tank.

This relay station has been operating as one of the key functions in the world's first bilateral CWM trade. Center for Coal Utilization, Japan is cooperating with CWM WEST JAPAN Co., in the operation of the relay station.

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The CWM is transported over 1,100 km from YANRI CWM Co. and the CWM is kept in the relay station's tank. The first lot of CWM produced in China was shipped to Japan in March 1992. This has been the first demonstration and commercial project in the world to sell CWM in the international energy market as an oil alternative fuel. Thereafter, 63,000 tons of CWM has come from China by the CWM tanker, up to September 1993. And 55,000 tons of CWM have been shipped from this relay station to Tayca Co., by a 700 DWT coastal CWM tanker. Eighteen 1,100 km oceangoing shipments and eighty eight 400 km coastal shippings have been carried out within 18 months since March 1992.

Unloading of the 5,000 tons of CWM from the tanker to the storage tank takes about five hours using two cargo pumps on the ship. At the relay station, the rubber hose system is also used for CWM loading and unloading.

The tank at the relay station is equipped with four mixers to prevent CWM sedimentation. The other main facilities of this relay station are two 14 inch diameter and 1,300 m length pipe lines between the tank and the pier and two 120 m^3/h cargo loading pumps.

The storage quantity of the tank averaged 6,000 tons a day for one and half years from the beginning. On the average, CWM was received once a month from China and a domestic delivery was carried out every five days. Generally, the mixers of the tank were operated simultaneously when receiving the CWM from oceangoing tanker.

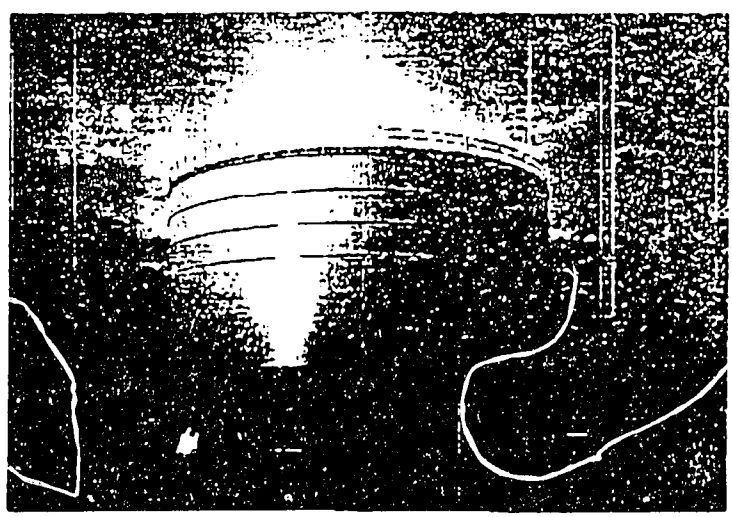

Photo-4 10,000 m^3 CWM storage tank at Wakamatsu, Kyushu, Japan.

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(3) 400km internal transportation by the 700 DWT [illegible] from the relay station to a CWM end user in Okayama and CWM combustion in a boiler with 45 tons/hour steam generation capacity

The first user of the CWM distributed from the relay station [illegible] Co., a chemical company in Okayama prefecture, is using annually [illegible] tons of CWM as a fuel for a boiler built in 1991 with 45 tons/hour steam generation capacity. The boiler was designed and constructed by Tsukishima Co. Ltd. [illegible] heavy oil and CWM firing.

The coasting vessel which was originally designed as a CWM carrier transports 700 tons of CWM crossing 400 km of inner sea Wakamiya-Okayama [illegible] day. The 700 tons of CWM are unloaded within two hours by cargo pump. Photo-5 shows CWM unloading at the user's berth. The CWM is stored in the user's service tank (1,000 KL).

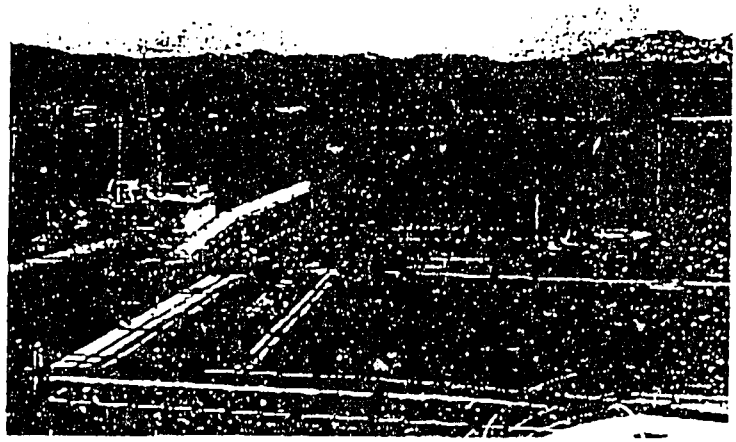

Photo-5 CWM unloading at the user's berth

More than 5,000 tons of CWM have been [illegible] since April 1992.

CONCLUSIONS

The above-mentioned [illegible] CWM can be reliably supplied in the [illegible] The fact that production and [illegible] together with the bilateral [illegible] development [illegible]

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the international CWM market as fuel for large scale utility boilers.

CWM will be further promoted toward large scale application as techniques for handling CWM on a large scale could be become available on an even further reassured basis in the future.

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COAL USE: PUBLIC PERCEPTIONS

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COAL USE : PUBLIC PERCEPTION AND ITS ROLE IN ENERGY AND ENVIRONMENT MANAGEMENT IN INDIA

ENVIRONMENT MANAGEMENT IN INDIA

Within this century, and more so in the past five decades, the world has witnessed destruction of vast tracts of land denudation of forests, energy consumption and carbon emission has landed us to the brink of disaster. It is this realisation that had brought together 150 nations for a historic summit at Rio de Janeiro in June 1992.

Coal being the abundant energy source contributes alongwith other fossil fuels and nuclear sources to this pollution scenario, Coal India Ltd. (CIL) realises its part of responsibility to bring the situation back to an accept able annospheric level.

Grim statistics confirm the dire consequence of deforestation. In the past decades the conservation of forest was referred to only for the sake of saving green on earth. But more we became aware that forests are directly engaged in arresting atmospheric carbon dioxide and controlling erosion of land, more we got plunged into afforestation programme in an accelerated pace. Out of our country's land surface of 328.98 m.ha., coalfields cover an area of 3.47 m.ha. Require ment of land for coal projects is large and the site is also specific. Unfortunately, power grade coal reserves occur mostly underneath forests. Therefore deforestation cannot be altogether avoided while starting a new project though CIL have accorded high priority for reclamation of post mining land.

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In the afforestation sphere, Bharat Coking Coal Ltd. (BCCL) has already done a commendable job by planning 16.36 Lakhs of saplings only in one year (1990-91). Till the year 1991-92 a tale of 89 lakhs of saplings have been planted in BCCL areas to protect the environment. In Jharia coalfields alone 62943 ha. of land has been rendered derelict due to subsidence, fire, reject dumps and abandoned voids. Out of this, 1,900 ha. of land has been already reclaimed. The areas like Kustore and Rajapur which have been reclaimed, revegetated are worth mentioning. Subsidence areas like East Katras, Dharmaband, Nichitpur, Laysbad, Bhalgora have also been reclaimed and revegetated. 35 Kms. of avenue plantation project has been completed along Hirak Road on the periphery of Jharia.

The reclamation effort of Central Coalfields Ltd. (CCL) includes construction of various public places surrounded with greenery and tall trees. Nehru stadium has been set up on the reclaimed area of Sauda Colliery. Reclamation centres are getting developed in Sirka and Argada and a good No.of quarries like Phusro Bermo Seam, Dhori are being used for storage of water.

One may also have a look at Dhanpuri Opencast Project in South Eastern Coalfields (SECL) in MP. Eye-catching greenery and the forest have been developed on 109.3 ha. reclaimed land. Northern Coalfields Ltd (NCL) with the help of MP and UP forest Department and Banaras Hindu University is involved in experiments for identification of biological reclamation technology over reclaimed land and OB dump and suitable species of plants. Nurseries have been set up at Bina, Jayant, Dudhichua, Amlohri and plantation has been done over an area of 2600 ha. The unique feature of plantation is survival rate exceeding 80%. The green belt all around Bina, Jayant, Singrauli coalfields add another feather to its cap. Till 1991-92, 48 lakhs plants have been planted on an area of 1520 ha. Quarterly, monitoring with respect to air, water and noise is being done in all projects at mine site workshop, CHP and residential township. The data help in controlling the pollution levels and to check efficacy of control measures.

North Eastern Coalfield (NEC) in Assam is hilly and covered with thick rain forest. Leisure Recreation Centre in Munshi Colliery, Comprising water filled quarry, with boating facilities on 35 ha. of reclaimed land is a place which demands appreciation. Reclamation in Jaintia Opencast has also been completed.

Over the period of last 6 years and by 1991-92 almost 450 Lakhs of trees of different species have been planted in the subsidiary companies of CIL as a social forestry operation. Species of plants, with higher longivity and survival rate have been carefully chosen for carrying out this afforestation programme. Shisham, Babul, Neem, Cassia, Karanj, Amal, Tamarind, Acacia, Eucalyptus, Mango, Guava, Jamun, Silver Oak are broadly covering the scenario. No.of nurseries in different subsidiaries are engaged in growing and distributing saplings to promote the afforestation project in an enhanced pace.

Carbon dioxide, the 4th most common gaseous compound in atmosphere, possesses a unique property of selective absorption of infra red radiation. This may lead to green house effect on global climate when atmospheric concentration of Carbon dioxide (CO2) increases due to fossil fuel utilisation. This aspect of environment problem is also taken up as one of the major

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thrust areas. Mine fire is one of the related problems.

Coal by its very composition is liable to spontaneous combustion. Over 70 mine fires have been reported from Jharia Coal belt till 1976. These mine fires cause a huge loss of good quality of coal polluting air by emission of carbon- dioxide and other noxious gases. With due concern to pollution control 5 mine fires in Jharia coalfields have been controlled and 59 mine fires have been dealt with, through 33 integrated fire control projects. In Raniganj there are 5 fire projects to deal with this mine fire

Manufacture of soft coke by burning coal in "Open Bhattas" was a traditional practice in Indian Coal Industry. One Tonne of sized coal yields 0.75 T of soft coke and 0.25 tonne is released in the form of fine particles of carbon, coal tar vapour, unburnt and partially burnt hydro carbon, CO2 and gasses of nitrogen and sulphur. Central Mine planning & Design Institute Ltd (CMPDIL) through its relentless effort had added another positive stroke to control the pollution caused by this process CMPDIL has developed and patented a special smokeless fuel (SSF) Technology, major advantage of which is a significant reduction in air pollution besides recovery of tar as by-product. 22 SSF plants as per CMPDIL design have already been commissioned at Varanasi, Nagpur, Hazaribagh Dhanbad and at other places. 20 More are under installation at Rajnandangaon (MP), Hazaribagh, Aurangabad, Palamau Akbo(MS) and at other places.

In Dankuni Coal Complex (DCC) different pollution control measures were introduced in the design of the plant. The entire operation of coal carbonisation, tar separation and gas purification will be done in closed system to control hazardous emmissions.

Till 1980s. Environment Management Plan (EMP)) for new coal projects and EMP's for major coalfields have become mandatory. This is a sincere effort which will keep the mining areas free from air pollution, noise pollution and water contamination and consequently will keep CIL to earn social acceptance for mining operations. In the Earth Summit in Rio, the tussle is going over whether nations should enter into a legally binding pact to preserve forest and whether a tax should be introduced on emission of carbons and polluter should pay it. It has become the prime issue in the summmit to share the responsibility and bear the cost amidst the haves and the have-nots. In this sub-continent, CIL accepting its moral responsibility, has silently geared up its machin ery to perform with its limited capacity to undo the wrong what has already been done.

Limits of Resources and Population Explosion :

The primary task of development is to eliminate poverty. Economic development and sound environmental management are complimentary aspects of the same agenda. More than one billion people today live in abject poverty. World population would be more than double from the current level and would stabilise at about 12.5 billion around the middle of the twenty-second century. Population growth increases the demand for goods and services, and if practices remain unchanged, result into increased environmental damage. Population growth also increases the need for employment and livelihood, which especially in crowded rural areas, exerts additional direct pressure on natural resources. More the people more is the

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mineral consumption, more the waste production, which threat [illegible] environmental damage, local health and imply additional stress on the earth's assimilative capacity and leads to poverty. Alleviating poverty is both morally imperative and essential for environmental sustainability. Economic growth is essential for sustained poverty reduction. But growth has often caused serious environmental damage. Fortunately, such adverse effects can be sharply reduced, with effective policies and institutions. Income growth will provide the resources for improved environmental management.

Environmental Issues of Mining :

To support an ever increasing population and to maintain continuation of supply of raw materials to the industrialised society and to improve the quality of life larger and larger quantity of earth's resources have to be supplied. The quantity and variety of mineral resources used by the society is considered as an index of development and progress.

Rational utilisation and adequate extraction through well directed and environmentally friendly technologies is a prerequisite for sustainable mining policy. The increasing demand for minerals and fuel to cater to the needs of increased population exerts a tremendous pressure on the life support systems such as land, water, forests and mineral resources. Some of the issues of mining environment are briefed below :

Land Degradation: Increasing the nation's output of coal production at a faster rate is possible only with giant opencast projects. Opencast mining results in a constant decline of green and cultivated afforested areas as it involves removal of overburden to exploit the underlying valuable mineral deposits. Stripping of overburden is disturbing to environment at the area of the digging sites, vegetation is removed, micro flora and fauna are destroyed, the soil sub- soil and underlying strata are ruptured and displaced. After the coal is removed and the mined areas are back-filled, graded, levelled and top soiled, a unique equilibrium between the physical, chemical and micro biological factors which determine the soil's productivity and arabality of land is disrupted to unknown extent. Depending upon the geo-chemical characteristics of the overburden material and the sequence of the replacement, the restoration surface and sub-surface layers constituting the future rooting media often exhibit [illegible] physical and chemical characteristics which are not congenial for the normal growth of plants.

Acid Mine Drainage: Mining operations cause water pollution through the discharge of acidic water which affect the hydrology of mining areas. Acid Mine Drainage results from the passage of water through mines when Iron disulphide, usually pyrite, are exposed to the oxidising action if air, water and bacteria. Coal and adjacent rocks beneath the earth contain Sulphur in the form of various compounds. In the process of mining, sulphurated materials are uncovered and exposed to air and moisture, with the result that the sulphide is oxidised to sulphate and sulphuric acid. Approx.84 of the acid mine drainage comes from underground mines. Acid mine drain age also sometimes contains objectionable trace elements, dissolved solids, precipitating collides and sediments, Coal Mine spoil due to typical AMD may exhibit pH values about 3.5-3.0. Under such strongly acidic conditions the toxicity, high concentration of Al and Mn and Non-availability of MO are the principal deterent for plant growth [illegible]

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of acid spoils and sub-soils to about pH-4 may reduce the toxicity of Mn ion, but between 4.5 to 5pH,the toxicity of Al, Mn and their interaction with other essential nutrients of many plant species and varieties persists.

Hydrology Alterations : Mining activities viewed in the context of local geomorphology reveal drastic changes in surface drainage, run-off pattern, hydrological balance and change in the permeability of soils leading to the formation of salinity in the local soil and initiating the process of desertification. It is a grim reality that the process of desertification through salinity is rapidly affecting a vast tract of agricultural land in the vicinity of mines. Water regions are affected by underground mines too though in a different manner. Large quantities of water is pumped out and released on the surface where it causes flooding, silting and waterlogging. At the same time, it would lower the water table in the neighbourhood affecting vast quantities of water, as also the natural vegetation.

Air Pollution : Though to a muchlesser degree, air pollutions also caused by mining activities due to Suspended Particulae Matter (SPM) like Silica, coal dust etc and gaseous pollutants like Sulphus Dioxide, oxides of nitrogen and sulphur.

Noise Pollution : With the increase in mechanisation, noise pollution problem has become very acute.

Wild Life & Ecological Disturbances : The scalping of vegetation and removal of overburdened displaces can sometimes destroy wild life. Mining can and does cause some long last ing wild life habitant imprisonment of changes of habitat. Mining in the forest area has direct impact on existing wild life.

Massive Afforestation : The Company has planted more than 60.00 lakh trees so far and proposes to plant 10.00 Lakh more every year. About 0.3 to - 4 million mandays employment is generated through these affected area through planting of 10 Lakh trees with their maintenance for 3 years. This massive afforestation is being done with the help of local population and forest department. In addition to the employment generation opportunities the need of fuel and fodder can also be met.

Energy Plantation on Overburden Dumps : Clustered population due to the growth of ancilliary units around the mines cause biotic pressure on the natural resources like water and forests. In order to check soil erosion and stabilise over burden dumps, the company is taking care to revegetate these dumps. To meet the additional demand of fuel and fodder, these dumps can be effectively utilised for energy planta tion. Since the spoil on the dumps is devoid of any organic matter or humous, other industrial organic wastes are beingused to support the vegetation on the barren hillocks of overburden. Western Coalfield's Ltd has taken up a joint R&D programme with National Environmental Engg. Research Instt. (NEERI) and Ballarpur Paper Mill to stabilise the overburden dumps at Durgapur Opencast Mine, using industrial organic wsaste from Ballarpur Paper Industry. The utilisation of bioculture and organic wastes from Paper Industry is showing good results.

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Community Development : Western Coalfields Ltd has made 3 different plans under the 20 point Action programme of the Govt. of India. These Plans are -

* Special component plan for upliftment of Scheduled Castes.
* Tribal Plan for upliftment of Scheduled Tribes.
* The Community Development Plan for the benefit of general public at large and specifically for the bene fit of physically handicapped and aged persons.

The activities undertaken under the SC & ST plans are -

Construction of roads;
Arrangements for supply of potable water,
Medical care;
Help in self-employment generation;
Organising rural sports.

Under the Community Development Plan, Financial assistance is being provided to handicapped persons, aged persons through charitable institutions doing social works.

Twenty four villages have beencovered in the above mentioned programme covering approx. 62,000 population of these villages.

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IEA Second International Conference on the Clean and Efficient Use of Coal and Lignite:
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30 November - 3 December 1993

Workshop B(4)
Regional Needs and Public Outreach

"The Affects of Environmental Compliance on Coal Use in the Midwestern United States: How Regulators Balance the Competing Interests"

J. Michael Biddison, Commissioner
The Public Utilities Commission of Ohio
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There are many reasons why coal has always been king in the Midwestern United States. In Ohio, Indiana, Illinois, Kentucky, West Virginia, and Pennsylvania, coal is locally abundant; it is relatively shallow and easy to mine; it is generally good quality with low ash, low moisture and high BTU content; it is easy to transport from portal to portal; it is the least cost, most practical fuel per million BTU's; it is the basis for continued engineering and development of next-generation power plants in the region; it is associated with strong labor unions, fraternal leadership, and close political relationships; and probably most importantly, in the more recent past it has continued to provide secure jobs and a stable tax base to an Appalachian region that has been devastated by the downsizing and/or departures of old mainstay industries such as steel, timber, industrial manufacturing, and oil and gas, just to name a few.

However, with the passage of the Clean Air Act Amendments of 1990 (CAAA), high sulfur coal (which is predominant to some extent in the Midwest) is threatened with losing a considerable piece of the power generation market, due to the excessively high cost of environmental compliance. As a goal for the year 2000, the CAAA require reductions of sulfur dioxide (SO_2) emissions by ten million tons and nitrogen oxide (NO_x) emissions by two million tons below 1980 levels, which will result in a two-phase tightening of the restrictions placed on coal-fired power generation plants. Phase I begins in 1995 and requires affected plants to lower their SO_2 emissions to 2.5 pounds per million BTU's; Phase II begins in 2000 with an emissions cap at 1.2 pounds per million BTU's. In addition to SO_2, there will be NO_x emissions limits in place by 1995. Indeed electric utilities are subject to great costs and uncertainties when projecting 30-year forecasts for system-wide compliance plans since alternatives exist in least emissions dispatching,

demand-side management programs, co-firing or seasonal-firing with natural gas, fuel switching to low sulfur coal, reducing off-system sales, retiring older non-compliance plants, building scrubbers, accelerating demonstration stage clean coal technologies (CCT) to commercial stage, and trading/purchasing emissions allowances. On a national annual basis, the total cost of compliance for utilities with existing high sulfur coal-fired power generation plants is estimated to be $2.7 billion to $4.0 billion during Phase I for 268 units and possibly $4.0 billion to $8.0 billion after Phase II for over 2200 units.

Citing Ohio as a representative Midwestern state concerned with balancing the CAAA with local coal use, government and industry leaders soon discovered that a process was needed to facilitate the wants and desires of the state which ensures that electric utilities minimize any negative economic impacts and maximize the use of locally produced high sulfur coal while maintaining strict environmental compliance standards. After all, coal mining has been an integral part of the Ohio economy for well over 100 years. In 1992 alone, high sulfur coal was mined in 14 underground and 134 surface coal mines, employing 5500 miners in 23 out of 88 counties and resulting in the production of 30 million tons of coal with sales of $1.0 billion. During the same year, Ohio was the third largest coal consuming state, burning over 50 million tons to produce 125 million megawatt-hours of electricity at 86 power generation facilities. In addition, the U.S. Department of Energy (DOE), Ohio Coal Development Office, and private industry has invested over $600 million in Ohio-based CCT projects in the last nine years. Over 100 CCT projects have been commissioned in Ohio, 40 of which are still in various stages of development to ensure the continued use of locally mined high sulfur coal in an environmentally responsive manner. Because of the combined federal, state, and industry

commitment to funding, Ohio is recognized as the leader in CCT research in the U.S.

In response to the federal mandates of the CAAA, the Ohio General Assembly passed new legislation in July, 1991 authorizing electric utilities to submit an environmental compliance plan for review and approval by the Public Utilities Commission of Ohio (PUCO), the state agency responsible for regulating investor-owned utilities, for Phase I affected units. Senate Bill 143 provides that, after hearings, the PUCO shall issue an order approving a proposed environmental compliance plan only if it finds that the plan is adequately documented and makes all of the following findings:

- the plan is reasonably designed to meet the CAAA control requirements;

- the plan constitutes a reasonable and least cost strategy for both Phase I and Phase II compliance that is consistent with providing reliable, efficient, and economical electric service;

- to the maximum extent, the plan provides for the use of Ohio coal and that any choices of fuel type that result in the displacement or decreased use of Ohio coal represent least cost;

- the utility has evaluated and compared the relative risks to its customers for all alternative compliance measures;

- the utility has evaluated: emission controls at each affected generating unit to reduce annual emissions levels below base allocations of allowances received for each unit; advances in technological means of emission mitigation; and means of reducing compliance costs through the acquisition, transfer, and utilization of allowances;

- the estimated costs of implementing the plan is reasonable; and

- the schedule set forth for implementing the proposed compliance measures is achievable.

In addition, the PUCO may require the utility that has submitted a compliance plan proposing a fuel switch which would displace or decrease the use of Ohio coal, to provide a complete analysis of the estimated short-term and long-term statewide and local socioeconomic impacts resulting from the implementation of the proposed compliance measures. The PUCO may require the company's analysis to address the following:

- employment impacts on mining jobs, mining-related jobs, and nonmining-related jobs;

- revenue impacts on corporate franchise, income, property, severance, sales, and other state or local taxes;

- impacts on public assistance, employee benefit, and employment service program costs;

- unusual or extraordinary impacts on municipal corporations and townships; and

- such other economic impacts deemed reasonable to consider.

Senate Bill 143 also provides for certain tax incentives for utility investment in CCT and a two-year anniversary review of an approved plan, at which time alternative courses of action will be considered in view of current circumstances.

Due to this legislative action, electric utilities in Ohio have a tool for gaining PUCO up-front approval on environmental compliance decisions, albeit through an open and public process, regarding their actions in response to Phase I of the CAAA. The utility compliance plans, when formally reviewed and approved by the PUCO, allow the utilities to reduce a certain element of risk in moving forward with investment and construction of compliance facilities, since the management decisions have been deemed prudent. However, the utility will still have to demonstrate in a rate case proceeding that all expenditures for used and useful assets are reasonable and were prudently incurred before revenues can be recovered through rates charged to customers.

PUCO decisions are articulated in written Opinions and Orders (Orders) which are arrived at after a thorough review and deliberation of transcribed records of a legal proceeding in which PUCO staff, company representatives, and all stakeholders and interested parties present evidence and opinions on the reasonableness of the environmental compliance plan developed by the utility company involved in the proceeding. The PUCO approved environmental compliance Order, as well as the

complete transcribed records of a particular hearing process, can be introduced into evidence in subsequent regulatory proceedings that establish rates for electricity service and allow recovery of expenditures related to environmental compliance implementation. In addition, Orders are subject to potential state and federal appeals processes at the request of an interested party.

Limitations on the contents of any particular Order arise from applicable statutes and constitutional due process requirements. First, Orders must issue from the record of the proceeding. Second, Orders cannot overstep the constraints imposed by legislatively-conferred authority. For example, the PUCO has not been given the authority to make management decisions for utilities in those cases in which environmental compliance plans are reviewed, so it could not unilaterally order any specific compliance measure, such as the installation of scrubber technology or the switching to low sulfur coal. Third, PUCO decisions must withstand challenges based on alternative readings of the manifest weight of the evidence that is contained in the record of any particular case.

While the evaluation of environmental compliance plans was conducted within formal guidelines, the actual dynamics of the decision-making process were much more fluid. All but one Ohio electric utility has submitted detailed and complicated plans which offered several strategies for compliance to CAAA Phase I standards. In general, the evaluation process has taken approximately six months for each filing and a record of each proceeding has been developed on two tracks. One track recorded the expression of public opinion, relatively unrestrained by the formal courtroom rules in which sworn testimony is subject to cross-examination and

other legal tactics. The other track of record development was through a formal adjudicatory hearing, focused on the technical components of the plan.

Any Order regarding environmental compliance plans issued on the basis of a proceeding has to balance the competing interests of a range of intervenors in each case. As well as representatives of the stockholders and management of the utility submitting the plan and PUCO staff, other participants in virtually every case included the United Mine Workers (coal unions), Ohio Mining and Reclamation Association (coal suppliers), Ohio Coal Development Office (state CCT funding agency), Ohio Industrial Energy Consumers (industrialists/manufacturers), Sierra Club (environmentalists), Ohio Consumers' Counsel (consumer advocates), competitive fuel industries, municipalities and local government, congressmen and state legislators, and the public at large.

Public testimony in each case was held in the service territory of the utility whose environmental compliance plan was being reviewed for the purpose of allowing all participants an opportunity to document their personal opinions regarding proposed utility decisions. Much of the public testimony centered around the direct economic fallout of compliance plans to locally impacted communities and individuals. Testimony from small business owners, coal miners, union representatives, environmentalists, politicians, construction workers, bankers, industrialists/ manufacturers, educators, hospital administrators, and concerned citizens generally documented fears of economic devastation to their particular families, businesses, associations, schools, communities, or interests if the proposed plan was perceived to be to their detriment. Responses were predictably related to the industrial base of the utility service area. In Southeastern Ohio, where coal

mining is a traditionally secure industry, there was nearly unanimous agreement that installing scrubbers on large generating units and/or maintaining the use of Ohio coal was essential for least cost strategies and to prevent the disintegration of the economy and the social fabric itself. In those areas of Ohio dominated by a strong manufacturing industry, public testimony generally supported fuel switching to out-of-state low sulfur coal, which was presented to be the most flexible, and quite possibly, the least cost strategy in assuring low electricity rates, therefore maintaining high paying manufacturing businesses and jobs.

At the formal adjudicatory hearings each utility presented its environmental compliance plan in detail, supported by evidence from expert witnesses. In addition, witnesses representing the PUCO staff and all intervening parties presented testimony supporting or challenging aspects of a utility's plan, or suggesting other possibilities for least cost compliance that the utility had overlooked. All testimony was subject to cross-examination by legal representatives of any intervenor participating in the hearing. Each utility presented the thoroughness of their attempts at evaluating all possible compliance scenarios (economic modeling, forecast projections, technologies assessments) and emphasized that the proposed compliance plan reflected the least cost to consumers while providing the utility with maximum efficiency. The PUCO staff provided testimony regarding thoroughness, a technical evaluation and financial analysis of a utility's plan, and general agreement or disagreement that the plan was reasonable.

The responses of the various intervenors to each utility position again followed predictable economic or environmental concerns. The Industrial Energy Consumers generally favored switching to out-of-state low sulfur coal, due in part to their

concerns regarding the short-term rate impact of capital intensive investments in compliance technologies, such as scrubbers. Manufacturing groups wanted energy costs to remain low over the short-term to keep plants in Ohio and maintain global competitiveness. The Sierra Club and other environmental groups also supported fuel switching scenarios, but for different reasons. Environmentalists expressed concerns that scrubber technologies would only create more pollution in the form of scrubber sludge by-products and would not prepare Ohio for potential future federally mandated investments in the reduction of carbon dioxide and other greenhouse gases. The Ohio Coal Development Office, United Mine Workers, and Ohio Mining and Reclamation Association supported the installation of scrubbers or other CCT's. These groups presented evidence that out-of-state low sulfur fuel switching could not be regarded as least cost, due to uncertainties in future transportation and supply costs, particularly during Phase II, and that fuel switching would eventually devastate the local high sulfur coal mining industry resulting in severe economic and social consequences for the entire state. The Ohio Consumer's Counsel, representing the residential ratepayer, took the position that the truly least cost plan should be adopted to minimize rate impacts to their residential customers and that utilities should develop aggressive demand-side management programs to forestall investment in new plant.

At the conclusion of the adjudicatory hearing and the public testimony process, a PUCO adjudicative law judge drafts an Order reflecting the facts in the case and the proposed decision regarding the environmental compliance plan offered by a utility. The five Governor-appointed PUCO commissioners must then review the findings of the administrative law judge, along with the entire record developed in the proceeding, and either accept or reject the opinions presented in the draft Order, or

recommend changes based upon their evaluation or particular interpretation of the case record. An Order is adopted once a majority of the commissioners agree, which is subject to an appeal process by any intervening party.

Discretion in the interpretation of various legislative direction, combined with the political will of the state and the consideration of the uncertainty embedded in the projection of company revenue requirements, environmental concerns, changes in technology, socioeconomic impacts, and flexibility measures allow for considerable latitude in the balancing of interests in each environmental compliance plan filed by utilities for review and approval. As the scope of uncertainty increases, regulatory discretion to consider qualitative evidence also increases, making it even more important to have a review and approval mechanism for electric utility environmental compliance plans that will allow for a public forum of all competing points of view and to assure the utility with some level of confidence in implementing a least cost plan. At this time, six of the eight Ohio electric utilities have had compliance plans approved with one utility currently undergoing the review process. Of the six PUCO approved environmental compliance plans, all but one were stipulated agreements by all of the intervenors. The utility compliance plan that was not stipulated was approved by all five commissioners and is currently being appealed at the Ohio Supreme Court due to disagreements over the issue of least cost. Once approval was granted, the utilities proceeded to implement Phase I compliance actions without fear of management decision repercussions in future rate cases.

In the development of this process to review and approve environmental compliance plans in response to the CAAA, Ohio has attempted to establish a

"model" that balances competing interests in view of considerations such as stability in economic viability, effect on industrial competitiveness, impact to ratepayers, investment grade health of utilities, continued production and development of coal resources, and socioeconomic effects, both statewide and to specific regions. The PUCO, and indeed, regulatory bodies of all states and nations must work to insure that electric power generation environmental compliance decisions are balanced, fair, and reasonable with technological change, economic constraints, and societal needs for overall best public policy.

Heat Rate Improvement Technology Transfer to Asian Countries : A US-Japan Initiative

Frank Wong, FKW EnerTech Inc., USA
&
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Background

As the major industrialized nations struggle in recent years to revitalize their own domestic economies, the developing countries in the Asian Pacific region has continued to attract attention with its phenomenal economic expansion with double-digit growth rates in some areas. Such rapid economic growth in this region is accelerating industrial development in virtually all aspects of its infrastructure systems, and very notably in its electric power generation sector. This increasing demand for electric power has prompted the need for installing large numbers of new power generating facilities and also the upgrading/repowering of existing units. Table 1 shows the magnitude of the existing MW power capacities in the key Asian countries, and their near term projected growth rates.

Many of the existing and planned power generating units in the developing Asian countries use or plan to use indigenous fuels which comprise typically of low quality oil and coal. As such, proper technologies are really required to maximize performance and minimize their impact on the environment. Unfortunately, most developing countries are much more concerned with meeting power demands to keep factories running, streets and homes lighted, and addressing other pressing daily needs while not placing the environmental issues high on their list of priorities.

Herein lies an opportunity in which the industrialized nations can effectively help their developing counterparts meet their power demand challenges efficiently, and minimize the environmental impact at the same time. Both the US and Japan have developed and implemented many mature and advanced technologies that provide solutions for efficient and low emission power generation. These technologies are applicable for new generating unit implementation and also for retrofitting or upgrading of existing ones. The World Bank estimates that the majority of the existing generating units in the Pacific Rim do not meet the current definition of good practices.

It is anticipated that policies and aid from organizations such as the World Bank, ODA, and the Green Aid Plan (MITI) will encourage the adoption of technologies by developing nations that are more energy efficient and less emission producing. Governmental actions such as free trade, and open market incentives will further foster pursuance of efficiency and system improvements. In any case, it is a noble cause to advocate an internationally collaborated response when it comes to concerns that are not defined by national borders such as global warming, air pollution, acid rain, and increased efficiency to preserve natural resources. This paper describes a project on the study and transfer of US and

Japanese technologies to the Asian developing countries that will provide both performance and environmental improvements for their new power generating units, and also for upgrading their existing units.

Project Goals

The objective of this initiative is to work with selected Asian developing countries to determine the optimal power generation technology options that should be considered for implementation. Another objective is to create an awareness among utilities regarding the importance and the value of heat rate performance improvement in existing units. The technology options to be studied will be governed by country specific conditions or requirements such as power demand needs, fuel supplies, and other resources/restrictions. The goals of accomplishing a 5% improvement in plant heat rate performance and emissions in developing countries for their new generating units (over its old designs), and a 3% improvement for their existing units are considered achievable with the proper technology selection and implementation.

The potential benefits could be very substantial. For example, at a conservative fuel cost of $1.00 (US)/ million BTUs, a 5% heat rate improvement for a 300 MW unit could translate to about $1 million annual savings. When applied collectively to all new and existing units in the developing Asian countries, the total savings for the entire region could be conservatively estimated at $500 million per year In addition, the amount of emissions will also decrease correspondingly when fuel consumption is reduced due to improved heat rates.

Table 1
Current MW Capacities of Major Asian Countries (Ref 1)

	Current MW Capacity	Projected Growth Rate
China	165,000	8 %
India	60,000	10 %
Indonesia	12,000	9 %
Malaysia	4,500	9 %
Philippines	7,000	N.A.
Republic of Korea	24,000	10 %
Taiwan	17,000	N.A.
Thailand	8,000	N.A.

Asian Market Assessment

As an initial task of this study, a survey will be conducted to better understand the power generation needs in the Asian developing regions. The survey will address topics such as the energy supply and demand, electricity supply and demand, heat rate performance of existing units, and preliminary technology needs. Attention will be given to bench marking and analyzing the current heat rate levels of the major operating units, and characterizing them according to design, fuel, mode of operation, and other critical parameters. This effort is needed to establish a credible and firm foundation from which preliminary technologies can be prescribed for new plants as well as for retrofitting existing plants where appropriate. While some information may be available through existing reports or documents, others will need to be collected and compiled. This effort will be accomplished by literature survey and specific utility visits.

In terms of fuel mixtures for power generation, China and India are mostly coal users with about 79% and 57% respectively of their primary energy source in coal (Ref. 2). Indonesia and Malaysia depend heavily on oil as a fuel source: 72% and 58% respectively, as they produce oil indigenously. The Philippines, Thailand, Korea, and Taiwan depends on oil although they do not produce much oil : 88%, 66%, 54%, and 5[illegible]% respectively. Singapore depends 100% on imported oil. Malaysia, Indonesia and Thailand depend on natural gas 38%, 18%, and 19% respectively, since they produce natural gas indigenously. Around 15% of primary energy is supplied by nuclear in Korea and Taiwan.

Appropriate US and Japanese utilities and supporting organizations will be selected as partners in transferring heat rate improvement technologies to the Asian countries. An Asian Heat Rate Improvement Awareness Group (AHRIAG) will be formed as part of this study. Asian utility companies and associated organizations will be invited to join this group, and participate in this study. The AHRIAG will serve as a committee to review technology options and exchange ideas regarding recommendations or selections. Existing trade barriers such as tariffs and customs regulations will be addressed in order to facilitate technology transfer. It is anticipated that AHRIAG members will visit various US and Japanese facilities to observe demonstrations of advanced technologies, and to establish a working interaction with their counterparts overseas. These visits are intended to help Asian utilities visualize technologies in practice and foster business relationship with the US and Japan. There are many leading utilities and associated organizations in the US and Japan who are very active in technology and business development. The AHRIAG members will serve as candidate host utilities for technology transfer and implementation in the future.

The Importance of Heat Rate

Recent heat rate improvement projects and studies in the US and Japan concluded that utilities can realize sizable economic benefits from implementing technologies that can reduce fuel consumption and plant emissions. For example, a new pulverized coal-fired power plant designed with the state-of-the-art technologies will have a heat rate which would be 6 -7 % better than most units operating today, and with corresponding reduction

in emissions. In addition, the reliability and maintainability of the unit is also improved with the latest design features. The heat pipe air heater, for example, increases equipment reliability, reduces maintenance requirement, and improves plant heat rate. Similar improvements on existing units may also achievable. Industry studies on existing operating units concluded that a 2-4 % improvement in heat rate can be achieved cost effectively. The higher the fuel costs, the easier it is to justify heat rate improvement activities.

Figure 1 shows the major factors that affect unit heat rate. These factors indicate that there are many facets to heat rate improvements ranging from the original designs and modifications of a unit to operational procedures and strategies, and also to conditions imposed by outside factors. All these elements however are bound and governed by either economics or regulations. Figure 2 is an example of how one utility account for its heat rate performance. This example presents a quantitative perspective of heat rate effects by some of the factors presented in Figure 1. Design features and controllable parameters clearly have major impact on heat rate. Not every parameter is equal in its effect on heat rate. Some parameters, such as the condenser back pressure or the boiler exit gas temperature, have a much more pronounced effect on heat rate than others. In fact, these factors are now used by many utilities to predict maintenance. Examples of maintenance activities which can be influenced by heat rate data include: condenser tube cleaning based on condenser back pressure; or soot blowing/air heater washing based on boiler exit gas temperature. Among the imposed conditions, fuel characteristics offer potential opportunities for heat rate improvements.

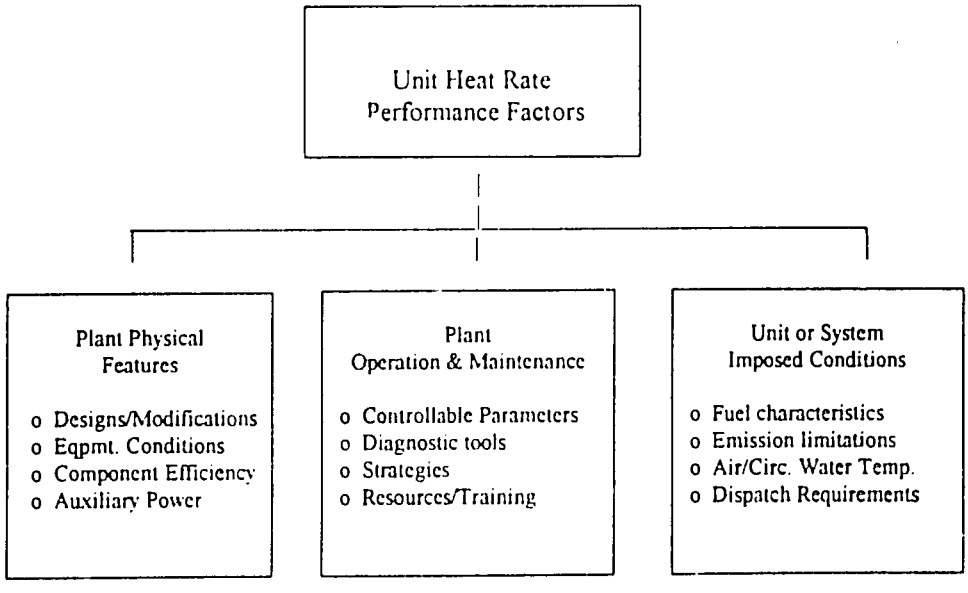

Figure 1 Major Factors Affecting Heat Rate Performance

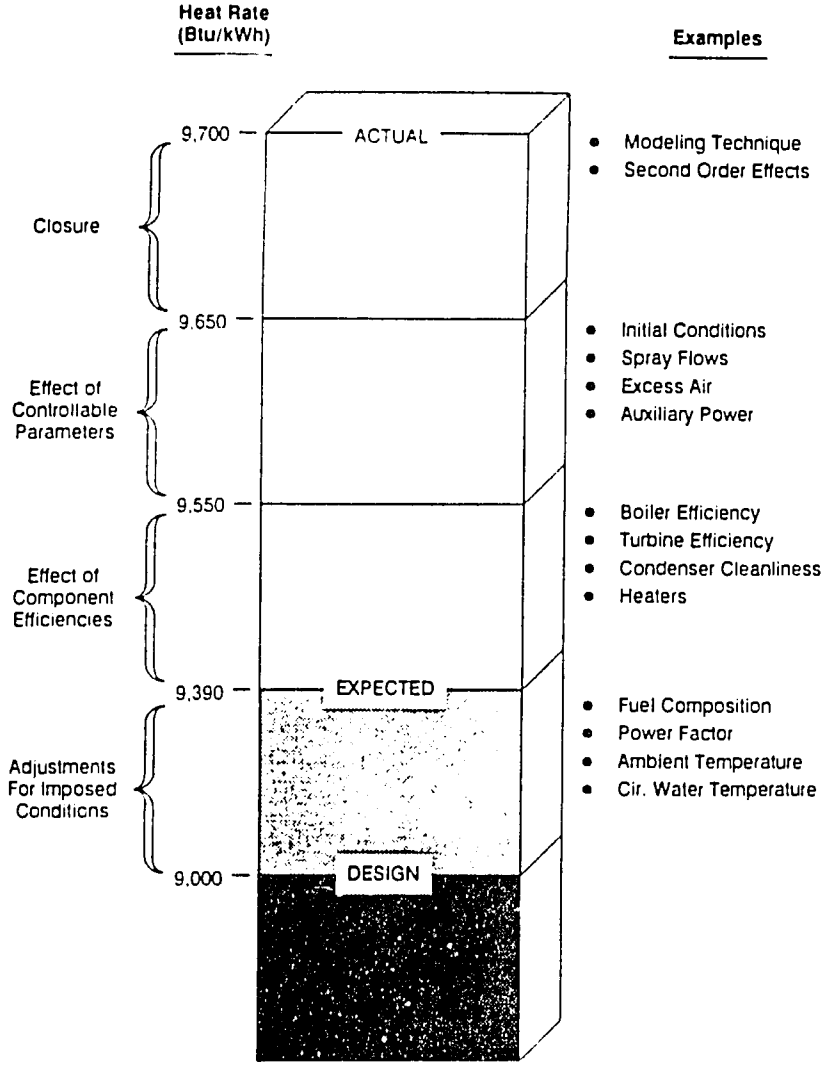

Figure 2 A Heat Rate Accounting Example (Ref. 3)

In its most basic form, the heat rate performance of a power plant is a function of the turbine performance, boiler performance and its auxiliary power requirement. The unit heat rate is defined by the following formulae

$$\text{Unit Heat Rate} = \frac{\text{Turbine Cycle Heat Rate}}{\text{\% Boiler Efficiency/100} \times (1 - \text{\% Aux. Power/100})}$$

Potential Technology Options

For New Power Generating Plants

Advanced technologies for new units are available in a variety of power generation options and fuel selections. Country specific conditions and requirements would determine the types of options to consider, and whether conventional or advanced cycles should be adopted. Some technologies are applicable to many different power options whether it is pulverized coal plant, fluidized bed combustion plant, or combustion turbines with or without combined cycles. Super 9Cr material, and advanced control valves are examples of such technologies that are not specific cycle application limited.

Developing countries in Asia always use their indigenous fuels, usually low quality oil and coal, for power generation before importing cleaner and more expensive fuels. Concerns about pollution is generally not emphasized unless it becomes a pressing safety issue locally. Noting that the priorities in the Asian developing region are different than those of the US and Japan, the following basic criteria for new power plants are envisioned in the Asian region:

- Low capital costs
- Quick construction to startup
- Low heat rates
- High availability
- Simple maintenance
- Deep cycling capability
- Low emissions at no/very low incremental cost

The last item leads to the need for improved heat rate technologies which essentially will allow the generation of an intended amount of power with less fuel which translates directly to less emissions

Conventional 3500 psig, 1050 F double reheat supercritical plants have been utilized in industrialized nations for some time already. Operating experience with this efficient design has been very favorable particularly in Japan and Europe. The more advanced 4500 psig, 1100 F double reheat ultra-supercritical unit design provides an even higher level of heat rate benefits. An ultracritical unit cycle, when compared to a conventional 2400 psig/1000 F double reheat cycle is expected to provide an 8% improvement in unit heat rate. A high efficiency turbine cycle, a high boiler efficiency, and low auxiliary power requirements are all needed to meet this heat rate goal.

Ultra-supercritical plant has been developed in Japan and is ready for commercial application. It is expected that the operational capability, reliability and availability will be the same or higher than the conventional subcritical plants. The turbine rotor design would include the use of an improved 12Cr steel for high temperature, coated buckets for solid particle erosion protection, and improved steam path geometry for higher efficiency. As

many as nine feedwater heaters and two topping desuperheaters may be added to maximize heat rate improvement in the turbine cycle.

The boiler design would include low excess air and low NOx burners along with heat pipe air heaters with optimal exit gas temperature controllers. The low excess air burners provide boiler efficiency improvement by reducing the dry gas and moisture losses. The heat pipe air heater offers virtually no air leakage, thus allowing the lowering of the flue gas economizer outlet temperature while maintaining an appropriate air heater exit temperature.

In the auxiliary power reduction effort, all major pumps and draft fans would employ high efficiency rotor and motor designs with variable speed drives where applicable. Emission control equipment and systems operation will be optimized with unit load requirements to minimize auxiliary power consumption.

Supercritical or ultra-supercritical plant designs would best suit countries such as China which expect to deploy large grid capacity and require large size units (500 MW or larger). These steam conditions could be combined with fluidized bed combustion both at atmospheric and pressurized condition, but only suitable for smaller size units.

Pressurized fluidized bed combustion plants are now in the demonstration stage in Sweden, Spain, US, and Japan, in unit size of 70 MW. It is expected to be applied to plant size up to 350 MW before the turn of the century. The plant could be prefabricated in the factory and transported to the plant site. The plant efficiency is expected to be 10% higher in relative value for this design. In-situ desulfurization in the pressurized boiler can eliminate the need for add-on deSOx plant. It could use low quality coal. In fact, in Spain, a very low quality (high ash and high sulfur) black lignite was used. It has a rather low gas turbine inlet temperature (around 1560 F, 850 C) to eliminate alkaline metal problems and achieve better desulfurizing performance. It has a relatively small plant area and height requirement, and its capital and generating costs are considered moderate. Once this design is demonstrated in the industrialized countries, it will be best suited for the developing countries which require medium to small size (50 - 350 MW) units with high efficiency.

In recent years, combustion turbine power plants are becoming increasingly popular as the preferred choice for power generation. Although natural gas, the primary fuel for combustion turbines, is abundant, its cost has increased sharply (over 100%) in the last two years due to the rapidly rising demand. However, with its relatively clean power provision, and efficiencies at 50% or greater when coupled with combined cycles, the dollar per kW installed cost is still lower than conventional coal plants. In addition, most manufacturers are now offering new machines with large, high inlet temperature units in the size of 200 MW in 50 Hz countries and 150 MW in 60 Hz countries, thus making them a very viable option for utility applications. New design features also provide reduction in emissions particularly for NOx. The caveat is that of the long term reliability of power producing combustion turbines which has yet to be documented. The price of natural gas is another item that requires caution in terms of long term fuel planning.

For Existing Power Generating Plants

It is anticipated that substantial heat rate improvement benefits can be reaped from existing power plants in the Asian developing countries. Correspondingly, emission levels can also be reduced. Technologies that are suited for new power plants are often applicable for retrofitting in existing plants. Improved turbine rotor and blade designs, and advanced condenser designs are examples of such technologies. Conversely, some technologies such as heat pipe air heater or low level heat recovery economizer may not be suitable for retrofitting in developing countries because of the high capital cost requirement and low fuel cost justification. In any case, the applied economics are often not the same when it comes to justifying retrofits for existing and especially older plants. But in terms of the large population of power plants that are currently in operation, and are considered inefficient and polluting, it is reasonable to predict that the improvement potential could also be very large. Less expensive alternatives are typically needed to help justify heat rate improvement activities for existing plants

The key to improving the heat rate of existing plants lies in the availability of correct information and data about the plants This would be analogous to a doctor requiring correct information about a patient before medicine for a cure can be prescribed. Figure 3 shows an example of a heat rate diagram with the major performance data displayed. Figure 4 shows a typical heat rate logic tree tracing all the basic losses. The following are some examples of technology implementation that can reap big payoff in heat rate improvements for existing power plants

(i) Refurbish HP Turbine

Refurbish blade path so that nozzle trailing edges are back to original design thickness and that blading surfaces are smooth with seal clearances restored to original design values. This will reduce blading profile and leakage losses. Refurbish control stage nozzle block with abrasion resistance material to withstand solid particle erosion, and install new retractable seals that will not rub during startup.

(ii) Decrease Condenser Back Pressure

Install monitoring system to measure the pressure drop between inlet and exit water boxes. High pressure drop measurements indicate that tube and tube sheet cleaning is required. Another potential improvement in this area involve adding fairings to streamline any major supporting elements within the turbine-condenser transition piece that may impose high pressure drop between turbine exhaust and condenser inlet.

(iii) Establish Operator Training and Awareness Program

Establish a formal program to increase the awareness of operating staff to plant heat rate, and to train them to optimize controllable parameters for maximum plant efficiency. Operators are the key staff who are responsible for running the plant efficiently regardless of what kind of latest technologies are installed. However, operators can only improve plant heat rate as long as they have adequate training on

what to do and how to do it. Hardware and software programs are now available to facilitate such training courses. State-of-the-art programs can now combine performance data with plant load requirements and emission limits, and automatically compute and recommend operating setpoints to meet load and emission constraints at the least operating cost.

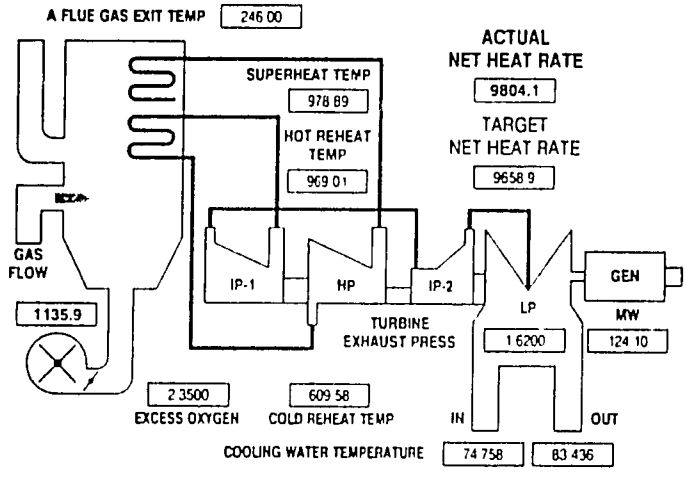

Figure 3 Example Heat Rate Diagram (Ref. 4)

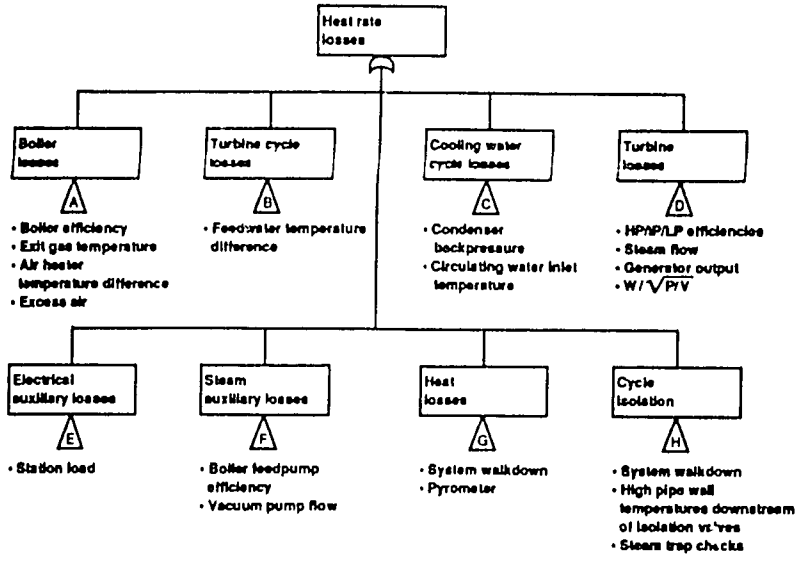

Figure 4 Example Heat Rate Logic Tree (Ref. 4)

Conclusion

As the developing nations in the Asian region continue to grow in a rapid pace, their impact on the global market also increases. The shortage of financial and energy resources, and technical expertise is already imposing severe limitations on the economic development of these countries. These developing nations may continue to use indigenous low quality oil and coal for power generation regardless of the impact on the environment. Technology transfer would therefore be crucial both in terms of providing these developing nations with the latest energy efficient technologies and also in embracing the global environment.

The most cost effective way of technology transfer to ensure lasting benefits in this region is not simply to provide turnkey projects. Joint ventures in which local companies and expertise are involved from the planning studies to construction and startup/operation would be more meaningful. The implementation of energy efficiency and environment conservation projects requires long term commitment from the local operating companies, and the proper training of their staff to instill the concept.

The project described in this paper is intended to study and plan the transfer of US and Japanese technologies to the Asian developing countries that will provide both performance and environmental improvements for their new power generating units, and also for upgrading existing units. An Asian Heat Rate Improvement Awareness Group (AHRIAG) will be created to help review and evaluate heat rate technology options. Members from AHRIAG will be invited to serve as hosts for specific technology transfer and implementation. In addition to technical concerns, it is noted that financial, institutional and legal barriers will also need to be addressed in order to facilitate the approval of any joint ventures. For example, limitation on overseas investment, protection of property rights, energy/electricity privatization policy, and human resource development are all important aspects that required attention.

This project, which will start in early 1994, is targeted to save the Asian developing countries $500 million annually along with emission reduction at virtually no incremental cost. In the short and long run, this project will foster technical and business cooperation among industrialized and developing nations in adopting energy efficient and environmentally conserving technologies.

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WORKSHOP B5

ENVIRONMENTAL STRATEGIES: ENVIRONMENTAL CONTROL AND MANAGEMENT

IEA Second International Conference on the Clean and Efficient Use of Coal and Lignite: Its Role in Energy, Environment and Life

30 November - 3 December 1993

Environmental Strategies

Energy Efficient Air Pollution Control For Fossil Fueled Plants

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ENERGY-EFFICIENT AIR POLLUTION CONTROLS FOR FOSSIL-FUELED PLANTS

INTRODUCTION

The New York State Energy Research and Development Authority was established as a public benefit corporation in 1975 by the New York State Legislature. Based on its enabling legislation, the Energy Authority's goals are to obtain and maintain an adequate and continuous supply of safe, dependable and economical power and energy for the State, thereby promoting the State's economic growth and protecting its environment.

To accomplish this mission, the Energy Authority's research program focuses on technologies and resources specifically applicable to New York State and its needs. Ninety percent of New York State's energy requirements are met with imported petroleum products, natural gas, coal and electricity from Canada. This disproportionate reliance upon external energy sources has had a major effect on shaping State energy policies.

The Energy Authority operates under the guidance of a multiyear research, development and demonstration program plan that focuses on expanding the use of the State's own energy resources, furthering the use of clean coal technologies, and promoting energy efficiency and thereby contributing to economic development in the State and reducing or mitigating adverse effects of energy facilities on the environment.

Within this context, the Energy Authority's program plan components include diversifying the State's energy supply mix through use of clean coal technologies.

Legislation passed by the United States Congress in 1990, known as the Clean Air Act Amendments, requires most fossil fuel-fired power plants to reduce sulfur dioxide, nitrogen oxides, and particulates from current stack gas emission levels. While emission-control equipment is available to help most New York State utilities comply with the new regulations, current technologies consume significant amounts of energy, increase carbon dioxide emissions, reduce plant operating efficiency, and may produce large amounts of solid and/or semisolid by-products that require additional energy for processing and disposal.

I wish to describe the operating characteristics several energy-efficient technologies use for controlling sulfur dioxide, nitrogen oxide, and particulates that are either in commercial use, under development, or in the demonstration phase.

TECHNOLOGY

The Clean Air Act Amendments were enacted to reduce environmental impacts from many sources, including fossil fuel combustion. The most problematic combustion products are sulfur dioxide, nitrogen oxides, and solid particulates. However, the environmental benefits achieved by technologies that minimize release of these combustion products to the atmosphere are offset by increased parasitic power requirements, reduced plant operating efficiency, increased carbon dioxide emissions, and the need to dispose of the emission-control system's by-products. Parasitic power includes that needed to 1) overcome the additional pressure drop of the flue gas through the sulfur dioxide scrubber vessel, nitrogen oxides removal reactor, and/or particulate emission control device; 2) circulate and inject sulfur dioxide scrubber limestone slurry, inject reagent for removing nitrogen oxides, and energize particulate collection systems; and, 3) prepare reagents for injection into the flue gas.

The cumulative incremental parasitic power consumption by pollution-control equipment for limiting emissions of sulfur dioxide, nitrogen oxides, and particulates from coal-fired plants may be as high as nine percent of gross plant generation. A coal-fired plant producing 300 MW for distribution and sale must generate up to an additional 27 MW to provide power for pollution-control equipment. Making up for this lost generating capacity imposes not only additional costs on ratepayers, but also additional environmental impacts. For gas-fired plants, when nitrogen oxides are the major pollutants, about one percent of gross plant generation may be required for emission control. An oil-fired plant's parasitic power consumption is higher than a gas-fired plant's, but lower than a coal-fired plant's if low-sulfur fuel oil is used to meet sulfur dioxide emission regulations. The net effect of this increased power consumption is a reduction of about one to four percent in the plant's generating efficiency.

In addition to reducing plant generating efficiency, pollution-control systems increase carbon dioxide emissions. For coal-fired power plants, carbon dioxide emissions are on the order of 1.3 tons per MW hour. Pollution-control equipment will produce an incremental 200,000 tons of increased carbon dioxide emissions annually from a 300-MW coal-fired, baseloaded plant, with a 0.65 service factor, due to required add-on sulfur dioxide, nitrogen oxides, and particulate pollution-control systems. For natural gas-fired steam generating plants, carbon dioxide emissions are about 0.6 tons per MW hour. Add-on pollution-control systems for nitrogen oxides will add an incremental 10,000 tons of increased carbon dioxide emissions annually to the atmosphere.

When pollutants from the flue gas of fossil fuel-fired boilers are removed, the by-products may be marketable or require disposal. For example, in removing sulfur dioxide from a boiler burning four-percent sulfur coal using a wet limestone scrubber with only settling for sludge dewatering, as much as 1200 pounds of waste material per ton of coal burned is produced. These by-products usually undergo additional processing to meet end-use specifications or disposal regulations.

Sulfur Dioxide Emission-Control Technology

Sulfur dioxide emissions are a major source of acid rain. The Clean Air Act Amendments call for a nationwide annual sulfur dioxide emission reduction of 10 million tons, using 1980 baseline emissions, by 2000. All coal- and oil-fired plants will be obligated to control sulfur dioxide emissions below 1.2 pounds/million Btu heat input by 2000.

Utilities that consider switching to fuels lower in sulfur to meet emission regulations will probably have higher fuel costs and fewer competitive suppliers. An alternative to fuel switching is flue-gas scrubbing, which may be economical at some locations, to control sulfur dioxide emissions. Flue-gas scrubbing can be used with coal oil-fueled boilers.

Flue-gas scrubbing sulfur dioxide-control systems broadly include three types:

(1) wet limestone with landfill disposal or upgrading a sludge or dewatered by-product for commercial use;
(2) dry lime that produces a dry by-product for landfill disposal or commercial use; and
(3) regenerative processes that regenerate and reuse scrubbing reagents to produce a concentrated sulfur dioxide, sulfuric acid, or elemental sulfur by-product.

Several wet-limestone desulfurization process with sludge dewatering and landfill disposal are commercially proven. Many second-generation, energy-efficient processes of this type are under development, or in the demonstration phase. A discussion of three energy-efficient processes follows.

The New York State Electric and Gas Corporation is installing a Saarberg-Holter-Umwelttechnik wet-limestone system at its 300-MW Milliken Station as part of the United States Department of Energy (DOE) Clean Coal Technology IV Program. This technology combines co-current/countercurrent scrubber design to improve flue-gas and limestone-slurry contacting. This innovative system will use organic acid additives to increase limestone reagent use and to suppress scale formation that could lead to operating problems. A split-module open-spray tower absorber will be located at the base of a new flue-gas stack. The system includes equipment for producing marketable commercial-grade gypsum,

calcium chloride, and fly ash to minimize solid-waste disposal. This space-saving sulfur dioxide scrubbing system is expected to reduce parasitic power consumption by one percent compared to baseline wet limestone process. For the 300 MW Milliken Station, a one percent reduction in parasitic power consumption is equivalent to three MW.

The Chiyoda-Thoroughbred 121 (CT-121) process' jet-bubbling reactor/ absorber design injects flue gas below the surface of the limestone-reagent scrubbing slurry. Flue-gas/reagent-slurry contacting is enhanced in the jet-bubbling zone. While the pressure-drop across the absorber is higher than in an open-spray tower, the design eliminates the need for energy-consuming slurry injection and recycle pumps. Moreover, sulfur dioxide absorption, sulfite oxidation, and gypsum precipitation occur in the scrubber vessel, eliminating the need for additional pumping capacity. The process produces large, readily dewatered gypsum crystals. Parasitic energy consumption is expected to be lower than with conventional wet-limestone scrubbing.

The Pure Air process uses a co-current, downflow absorber with a single level of grid packing for contacting sulfur dioxide with limestone slurry. The co-current absorber permits higher gas velocities and therefore a compact design. Grid packing increases flue-gas/limestone slurry contacting, enhancing sulfur dioxide removal. An Air Rotary Sparger system at the base of the absorber provides slurry agitation and forced oxidation to produce a gypsum sludge for dewatering and disposal. Open-grid packing scaling and plugging problems are resolved by using additives. Parasitic energy is expected to be lower than with conventional wet limestone scrubbing.

These three advanced wet limestone scrubbing systems illustrate how the penalties associated with sulfur dioxide removal can be substantially reduced. An alternative approach, dry-scrubbing technology, produces a solid waste that does not require dewatering, and is easier to dispose of. Most dry processes, with the exception of spray drying, are designed for retrofit installation where sulfur removal rates from 40 to 70 percent are targeted. The increased flue-gas solids loadings from injected lime solids are removed by existing or add-on electrostatic precipitator or fabric filter particulate-collection devices.

Finally, regenerative flue-gas scrubbing processes recover the scrubbing reagent while producing a marketable sulfur-containing by-product. These processes tend to be more complex and somewhat more costly to construct and operate than wet-limestone processes, but they have the advantage of minimizing solid or slurry waste disposal, and of generating revenue from the sale of elemental sulfur, concentrated sulfur dioxide, or sulfuric acid by-products.

The Wellman-Lord process is the major commercial regenerative sulfur dioxide scrubbing system. Although widely used abroad, only two plants in the U.S. use the technology due to its cost and complexity.

Two new regenerative flue-gas desulfurization processes are in the development stages. The Energy Authority is co-funding two three-MW pilot-scale demonstrations of the Tung and SOXAL processes at Niagara Mohawk Power Corporation's Dunkirk Plant. Evaluations of the two processes estimate that Tung and SOXAL are more energy-efficient and less costly than the Wellman-Lord process. While both these new processes use sodium sulfite as the absorber reagent, they differ in how they regenerate spent reagent.

The Tung process uses an organic solution in a liquid/liquid extraction operation followed by low-temperature steam stripping to regenerate sodium sulfite from the sodium bisulfite absorber effluent. The SOXAL process uses standard polymeric electrodialysis membranes and proprietary polymeric bipolar membranes to regenerate the sodium sulfite reagent. In both processes, concentrated sulfur dioxide gas is produced that can be further processed into sulfuric acid or elemental sulfur. It is estimated that capital and operating costs are competitive with wet-limestone desulfurization technology. The pilot-plant demonstrations will establish process performance with flue-gas that contains fly ash from a coal-fired boiler, and will verify process economics to the extent possible with these pilot-scale demonstrations.

Operating characteristics for a number of sulfur dioxide emission control systems are outlined in Table 1. The costs for new plant construction are estimated in Table 2. Retrofit systems generally cost more than grassroots installations. Cost premiums for retrofit systems are site-specific and difficult to quantify.

Nitrogen Oxide Emission-Control Technology

Nitric oxide and nitrogen dioxide pollutants are combustion products of all fossil fuels. These nitrogen oxide compounds, commonly called NOx, lead to ground-level smog and ozone formation, and contribute to acid precipitation.

NOx forms from the nitrogen present in the fuel (fuel NOx), and from the reaction of nitrogen and oxygen in air at high combustion temperatures (thermal NOx). Coal combustion produces the most and natural gas the least NOx pollutants per unit of energy released. Intense combustion processes with high flame temperatures result in good fuel use and low carbon monoxide emissions, but high NOx emissions. Low-intensity combustion processes tend to be low NOx sources, but may have poor fuel use

and higher levels of carbon monoxide emissions.

There are several technologies to control NOx emissions that apply to all fossil fuels. These technologies modify the combustion process to minimize initial NOx formation, or use reagents and/or add-on catalytic converters to reduce NOx in the flue-gas to nitrogen and water. Combustion modifications can reduce NOx emissions by 20 to 50 percent. Reagent-based systems can reduce NOx emissions from 40 percent to more than 80 percent.

Combustion modification technologies are available to control NOx emissions by reducing combustion intensity and temperature, and by controlling combustion air injection and mixing with fossil fuel. Some examples of such technologies include low-NOx, staged-air admission burners, flue-gas recirculation into the combustion zone of a boiler, overfire air ports to complete combustion above the burners in a boiler, and shutting down a number of burners in a boiler. Combustion modifications tending to be low cost, are usually easily retrofit, and do not significantly reduce plant efficiencies. However, plant capacity may be reduced. NOx removal is limited, and the combustion process must be carefully monitored to assure complete fuel combustion, and to warn of operating conditions that may accelerate boiler ash deposition and corrosion.

NOx control systems that use reagents injected into the furnace or boiler flue gas are either catalytic or non-catalytic. Both systems use a reagent to reduce NOx present in the flue gas to nitrogen and water. Non-catalytic processes inject reagent into the boiler or flue gas where temperatures range from 1600^{0}F to 2100^{0}F. Catalytic processes operate in the 600^{0}F to 750^{0}F range, and inject reagent into a separate reactor vessel.

Non-catalytic processes, called selective non-catalytic reduction (SNCR) in the literature, inject ammonia or urea into regions of the boiler where flue gas temperatures are optimal for the NOx reduction reaction to occur. Optimum temperature for ammonia is around 1700^{0}F, while 1900^{0}F is best for urea. As boiler load changes, the optimum reaction temperature location changes in the boiler, which requires installing multiple reagent injection grids or injection nozzles. Flue-gas composition, specifically carbon monoxide and hydrogen, and flue-gas flow distribution in the boiler affect the NOx reduction reaction.

Experience with SNCR is somewhat mixed. Some boilers have achieved NOx reductions as high as 80 percent, and others only 20 percent. This performance range indicates that detailed, specific injection grid design and location in the boiler is critical. The reagent injection control system must be designed to efficiently follow boiler load and inject reagent at the optimum temperature injection nozzles. Care must also be taken to assure that unreacted ammonia, or ammonia produced by the

decomposition of urea, does not react with sulfur compounds in the flue gas to form ammonium sulfate or bisulfate that can deposit and plug the air heater. Unreacted ammonia emissions from the boiler stack must be below a permit level. Also, nitrous oxide or laughing gas, an identified greenhouse gas, is a product of SNCR processes. Currently nitrous oxide emissions are not regulated in the United States. Extensive testing of SNCR installations at a number of fossil fuel-fired plants is presently under way to evaluate operating problems, and to refine process economics. The Energy Authority is co-funding the demonstration of urea injection SNCR on a 185-MW oil-fired boiler at Long Island Lighting Company's Port Jefferson Station. Commercial urea injection SNCR systems are operating on two 85-MW, and one 160-MW coal-fired boilers at the Salem Harbor Station of New England Power Company.

In catalytic, or selective catalytic reduction (SCR) processes, ammonia is injected into the flue-gas as it enters a catalytic reactor vessel that can be installed in the flue-gas path at different locations. The most cost-effective location is site-specific, and depends on fuel composition, boiler design, and other parameters. The SCR reactor is installed where normal flue-gas temperatures are around 650^{0}F. If the reactor is located upstream of the combustion air heater and/or flue-gas-desulfurization system it is hot-side SCR. Since flue-gas temperature changes with boiler load, temperature control is achieved by bypassing flue-gas from the boiler around the economizer. Catalysts that function efficiently at flue-gas temperatures encountered at low boiler loads also can be used.

In hot-side installations, the SCR reactor can be installed before or after an electrostatic precipitator (ESP). If the reactor is upstream of the ESP, the catalyst ceramic support must have larger openings to prevent ash-plugging problems. Sootblowers also help to avoid reactor plugging. Care must be exercised in operating this reactor, especially during plant startup and shutdown when acid dewpoint temperatures are reached that could lead to deposition of alkali sulfate salts in the catalyst support openings. Catalyst poisoning and plugging may result. A reactor downstream of the ESP makes smaller catalyst support openings and a more compact reactor design possible.

Cold-side SCR installations avoid reactor deposition problems entirely because the reactor is installed in a low-particulate and low-sulfur-concentration environment. The downside to this seemingly best alternative is that energy is required to reheat saturated flue gas from the scrubber to the 650^{0}F SCR reactor temperature, which reduces plant efficiency. The additional energy penalties must be compared to the advantages of improved operations and longer catalyst life when choosing an SCR configuration. The Energy Authority is co-funding a one-MW pilot-scale demonstration of cold-side SCR that uses a novel

heat-pipe heat exchanger to heat flue gas to reactor temperature at New York State Electric and Gas Corporation's Kintigh Station. The demonstration project is evaluating the performance of a number of catalysts supplied by different manufacturers. Results to date indicate that catalyst performance in removing nitrogen oxides from flue gas, and the amount of unreacted ammonia that passes through the catalyst, depends on catalyst chemical formulation and on the design of the catalyst support.

Table 3 summarizes operating characteristics of NOx emission control options. Cost estimates appear in Table 4.

A new technology for exclusively natural gas-fired boilers is being evaluated at Southern California Edison's Mandalay Station. The technology uses an SCR catalyst that is spray-applied to the regenerative Ljungstrom combustion air-heater baskets. Pressure drop and heat transfer characteristics are not appreciably affected by the catalyst coating on the convoluted metallic heat transfer surfaces. Ammonia is injected upstream of the air heater as in a conventional SCR reactor to avoid the expense of adding a separate catalytic reactor vessel, and the additional induced-draft fan power for overcoming reactor pressure drop. The effect of the shorter gas residence time in the catalytic air heater process compared to a conventional SCR reactor on NOx removal is a major unknown. If successful, this technology may be a low-cost way to control NOx emissions from the combustion of low-ash fuels.

Particulate Emission-Control Technology

Particulate emissions are a combination of fuel ash and unburned carbon that is transported with the flue gas to the boiler flue gas stack. Initial concerns about health effects led to regulations that limit total particulate emissions. The realization that respirable-size fine particles less than 10 microns are a more serious health hazard has increased legislative interest in limiting their emission. The 1990 Clean Air Act Amendments specify that new regulations be established to address these concerns.

Traditionally, electrostatic precipitators (ESPs) removed particulate matter from the flue gas of coal-fired and oil-fired plants. With ESPs which have low pressure drop and low energy consumption, the power plant can continue to operate if the ESPs have operating problems. However, ESP performance is affected by the electrical resistivity, cohesivity of the collected material, and particle size. Collection efficiency for fine particles less than 10 microns is lower than for larger particles, and this may necessitate extremely large ESP designs or other techniques if increased removal of particles in this size range is required.

Using baghouses for collecting fly ash from coal-fired boilers is increasing because these devices are insensitive to ash composition and characteristics, and because they collect very fine particulate more efficiently than ESPs. The availability of new, durable fabric-filter materials makes baghouses economically competitive with ESPs, particularly for the collection of high-resistivity and/or very fine particle-size fly ash. Their chief disadvantage is high flue-gas pressure drop, which consumes more energy than ESPs.

Anticipating Clean Air Act Amendments regulations, utilities are considering using compact pulse-jet baghouses downstream of existing ESPs to capture respirable-size particulates that are not removed from the flue gas by the ESP. This may be an economical option to comply with projected regulations.

Collected fly ash from ESPs and baghouses is usually sent to a landfill for disposal. Efforts to find appropriate end uses, depending on composition and physical properties, include cement manufacture, concrete blending, grouting, landfill cover, soil conditioner, and flowable fill material.

Table 5 summarizes operating characteristics of particulate emission-control systems. Table 6 presents estimated costs.

CONCLUSIONS

Current utility pollution control systems often reduce plant operating efficiency by five percent or more. In New York State, total statewide utility fossil-fuel expenditures in 1992 were about $2 billion. The power losses translate into additional fuel costs approaching $100 million dollars per year to replace lost electric-generating capacity.

Estimated energy consumption for emission control systems relative to a plant's gross generating capacity is:

* 3 to 5 percent for reducing up to 90 percent sulfur dioxide emissions from coal-fired plants;
* 0.5 to 2.5 percent for reducing nitrogen oxide emissions by up to 80 percent from all fossil fuel-fired plants; and
* 0.5 to 1.5 percent for controlling particulate emissions from oil- and coal-fired plants.

The emission-control systems also result in increased carbon dioxide emissions per unit of electric energy generated. Significant plant efficiency gains with reduced cost and environmental impacts may be achieved, however, by the use of emerging emission-control technologies such as those identified in this paper.

Although sulfur dioxide scrubber chemistry is still not completely understood, sufficient knowledge is available to improve the performance of existing scrubbers, and to design more energy-efficient new scrubbers. One result of this new knowledge is that additives are used at existing facilities to enhance lime and limestone reactivity, while avoiding scaling, plugging, and sludge dewatering and disposal difficulties. The Electric Power Research Institute's High-Sulfur Test Center in Somerset, New York, operated with Energy Authority support, provides a convenient facility to investigate specific scrubber problems.

Emission-control systems either minimize the formation of nitrogen oxide and nitrogen dioxide, or reduce gaseous nitrogen oxides to molecular nitrogen gas, the main constituent of air, and water vapor. Except for the possibility of unreacted ammonia emissions, and spent catalyst disposal, nitrogen oxide control systems do not produce by-products for disposal or reuse. In the future, research will undoubtedly focus on reducing cost and increasing the performance of nitrogen oxide reduction catalysts.

Particulate control technology will be affected by regulations requiring increased removal of respirable-size particulates. These collection systems will consume more energy than current systems. Many techniques, such as improved flue-gas flow distribution, pulse energization, special discharge electric designs, modern electronic voltage control systems, reverse polarity operation, and precharging, will be evaluated to improve ESP performance. Using chemical additives such as sulfur trioxide and ammonia to condition the flue gas also appears to be promising to bring existing ESPs into particulate emission compliance.

While some of the advanced emission-control technologies discussed in this paper are commercially available today, many more are at the development/demonstration stage. It is critical, therefore, that support for such research be maintained if the benefits these technologies offer are to be realized.

Table 1

Operating Characteristics
Sulfur Dioxide Emission-Control Technologies

	Status	Parasitic Power (% Generation)	By-products
Wet Limestone	Commercial	4	Sludge or dewatered gypsum for landfill or wallboard manufacture
CT-121	Commercial overseas, US demonstration	3.5	Dewatered gypsum for landfill or wallboard manufacture
Pure Air	Commercial overseas, US demonstration	3.5	Dewatered gypsum for landfill or wallboard manufacture
Saarberg-Holter	Commercial overseas	3	Dewatered, marketable gypsum and calcium chloride
HYPAS	Pilot demonstration	1	Dry calcium sulfite and sulfate solids for landfill
Lime Spray-Drying	Commercial for low-sulfur coal	3	Dry fly ash and calcium sulfite and sulfate solids for landfill
Wellman-Lord	Commercial	5	Sulfur, sulfur dioxide, or sulfuric acid
SOXAL	Pilot demonstration	3	Sulfur, sulfur dioxide, or sulfuric acid
Tung	Pilot demonstration	4	Sulfur, sulfur dioxide, or sulfuric acid

Table 2

Estimated Costs
Sulfur Dioxide Emission-Control Technologies

	Capital ($/kW)	Levelized ($/Ton SO2)
Wet Limestone	150-180	350-450
CT-121	150	350
Pure Air	150	380
Saarberg-Holter	145	380
HYPAS	130	1000
Lime Spray-Drying	135	500
Wellman-Lord	217	470
SOXAL	185	500
Tung	200	300

Table 3

Operating Characteristics
Nitrogen Oxide Emission-Control Technologies

	Status	Parasitic Power (% Generation)	Environmental Impacts
Combustion Control	Commercial	Negligible	Potential for increased unburned carbon and carbon monoxide emissions
Low-NOx Burners	Commercial	Negligible	Potential for increased unburned carbon and carbon monoxide emissions
SNCR	Commercial	0.5 - 2	Ammonia reagent Unreacted ammonia emissions Formation and emission of nitrous oxide
SCR Hot-side	Commercial overseas, US demonstrations	1 - 1.5	Ammonia reagent Unreacted ammonia emissions Spent catalyst disposal
SCR Cold-side	Commercial overseas, US demonstrations	2.5	Ammonia reagent Unreacted ammonia emissions Spent catalyst disposal

Table 4

Estimated Costs
Nitrogen Oxide Emission-Control Technologies

	Capital ($/kW)	Levelized ($/Ton NOx)
Combustion Control		250 - 1800
Low-NOx Burners	5 - 50	250 - 1,800
SNCR	5 - 16	500 - 1,800
SCR Cold-side	100 - 120	2,850 - 4,200
SCR Hot-side	78 - 93	3,300 - 3,800

Table 5

Operating Characteristics
Particulate Emission-Control Systems

	Status	Parasitic Power (% Generation)	Advantages	Disadvantages
ESP	Commercial	0.25	Low pressure drop Low energy consumption Malfunction will not cause boiler shut-down	Low collection efficiency for fine particles Sensitive to fly-ash chemical composition
Reverse-air Baghouse	Commercial	0.35	Not sensitive to fly-ash composition High collection efficiency for fine particles	High pressure drop Large space requirement Filter bags can plug and cause boiler shut-down
Pulse-jet Baghouse	Commercial	0.35	Space requirement same as ESP High collection efficiency for fine particles	Expensive filter material High pressure drop Filter bags can plug and cause boiler shut-down

Table 6

Estimated Costs
Particulate Emission-Control Systems

	Capital ($/kW)	Levelized ($/kW-yr)
ESP	65	5
Reverse-air Baghouse	75	6
Pulse-jet Baghouse	50	6 - 7

COAL TECHNOLOGY AND ENVIRONMENT

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COAL PRODUCTION IN INDIA

According to a survey made by the year 2020 India will probably have an annual production rate and annual production growth rate which will be 4th and 2nd respectively in the world. If we find environmentally safer ways to mine, transport and burn coal it would be the best bet for the next several hundred years.

Coal Mining In India :

Mining of coal is among the most arduous labours that man is called upon to perform. The condition in coal mines are generally extremely difficult, the working places being several hundred metres below the ground, surrounded by poisonous and dangerous gases with week roofs and unstable working areas. The growth of Indian coal industry has achieved very high rate since independence, especially after nationalization and this is accompanied by production of large volumes of hazardous solid, liquid and gaseous material during various miniming and related activities, polluting the otherwise clear environment. If these are not properly handled, adequately treated and carefully disposed of the effect could be disastrous to man kind and detrimental to aquatic and terrestrial flora and fauna.

Environmental disturbances due to coal mining :

Increasing the nation's output of coal at faster rate is possible only with giant open cast projects. The O.C. mining results in a constant decline of cultivated or afforested areas as it involves the removal of overburden to exploit the underlying valuable coal deposits. Stripping of the overburden from the coal seam is devasting to the environment at the surface area of the digging side. Vegetation is removed, microflora and micro-organism are destroyed, soil, sub-soil and

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underlying strata are ruptured and displaced, wild life scatter or die, air quality is temporarily degraded, surface is exposed to meteorological alteration, weather and general topography changes. Thus surface mining process in general disturbs the ecological balance which is a part of our environment. This eco-system is changed due to excavation and deforestation resulting soil erosion, land slip, land subsidence and flooding etc. Various problems such as, water, air noise pollution and land degradation etc. are also associated with it. Thus potential impacts generated by mining activities includes (1) Impacts on landscape, (2) Impacts on land use, (3) Impacts on flora and existing vegetation, (6) Impacts on water quality, (7) Impacts on micro meterlogical paramters, (8) Acoustic impacts, (9) Impacts on Socio-economical structure of community.

Environmental protection measures in coal industry :

Of late, there has been an increasing awareness for protecting and restoring the mine environment in the coal industry. Every mining project at its conceptual stage now introduce a requisite environmental assessment and management plan (EMP) EMP for every new and old mines will include the impact assessment of mining activities on environment. In addition to this mining industry is regulated by mine development and reclamation act so as to ensure land restoration.

Purpose of assessment

The basic reason for such assessment is to allow an informed public and professionals to make intelligent choices among alternative courses of action. That is, an environmental assessment is intended to present a clear and concise picture of the benefits and costs in terms of natural and cultural assets, as well as social values associated with various alternative course of action. Environmental assessment is a valuable tool in eliminating or mitigating undesirable effects on the environment that arise from contemplated actions.

National Environmental Policy Act and EIS :

In January 1970 the National Environmental policy act (NEPA) became public law in United States of America. Though they have a number of legislations for controlling pollution of water, air etc. and for different kinds of pollution, e.g. noise pollution hazard etc. in many countries there was no act for protecting the environment in totality. NEPA necessitated the preparation of environmental impact statement (EIS) to ensure that all environmental indices have been considered. Procedurally an environmental impact statement is a detailed written statement that provides discussion of significant environmental impact associated with a proposed mining project and informs decision makers and public, of reasonable alternatives that would avoid or minimize adverse impacts or enhance the quality of human environment.

Legislation for Indian Coal mining :

Every coal project implementation in various of environmental protection is regulated by central and state legislation through a series of mandated permits, approvals, notifications and coordination agreements which are based on loosely coordinated family of environmental legislation acts. The requirement under these acts are to be followed strictly while preparing frame work of EMP and EIS. potential impact of project development on the natural development is constrained by legislation as illustrated in Fig.1

Frame work for environmental management plan (EMP)

For preparing environmental impact statement for proposed mining activities, the assessment of impacts of individual action is required which in turn will be based on systematic reproducible and interdisciplinary approaches. Systematic denotes an all inclusive, orderlay and scientific consideration of potential impacts on the physical, biological, cultural and socio-economic aspects of the environment. The result of an assessment should be reproducible by other group of investigators.Finally inputs are required from many disciplines to ensure that a complete analysis has been accomplished. Environmental assessment for coal mining projects requires to perform five activities as illustrated in Fig.2

1. Description of Environmental setting

A proper description of the environmental setting can provide base line information necessary to assess the predicted imparts associated with the various alternatives under consideration. In addition to this it will provide sufficient information so that decision makers and reviewers unfamiliar with the general location can develop an under standing of the project need as well as the environmental characteristics of the proposed miniming project. EIS sent for approval receives many review comments if description/data of environmental setting is inadequate.

No single approach for developing a list of environmental factors should be used to the exclusion of other approaches. The most effective means of preparing a list of environmental factors is to be employ a combination of approaches specifically tailored for individual project need for alternatives under consideration. There are many agencies which identify the environmental factors that should be included in a description of the environmental setting but for a particular mining project these informations may be inadequate and uneconomical. The environmental factors associated with describing the environmental setting for proposed mining plan include detail survey of Topography, Geology, Demography, Meteorology, Hydrology, Ecology and Scio-economical consideration of mining area, which are directly or indirectly affected. As is evident from Fig.2 a description of the characteristics for each of these potential impact factors would represent good approach for describing the environmental setting for proposed mining project. The information can be obtained from the relevant officers of public institutions which are enlisted in Table.1 Baseline informations are often found to be inadequate with regard to environmental statement preparation from the agencies enlisted in Table.1. As time progress, data inadequacies will be overcome as a result of manifold information gathering by the private/public institutions. Modest efforts are correctly being made to describe the environmental setting through the use of information storage and retrieval techniques; in some instances remote or computer mapping approaches are utilized.

2. Impact Prediction and Assessment

After description of environmental setting for the proposed project, the major step in environmental assessment process which requires highest degree of scientific application of technology is impact prediction and assessment. This particular step involves projecting the environmental setting into the further without the proposed action and then performing the necessary calculations or studying the approaches for actually predicting the impact of the proposed action and assessing the consequences. Prediction and assessment of the impact of each

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alternative on the physical, chemical, ecological, cultural and socioeconomic environment require many scientific approach and models that can be used to predict the air water, noise and biological environment. The prediction of impacts on the cultural environment is largely associated with the determination of the geographic distribution of cultural resources in the project area. Since this determination requires on site survey work, this impact prediction is perhaps the most precise one that can be accomplished. Finally, prediction of impacts on the socioeconomic environment does have technological bases. However, most of the projections for socioeconomic consideration, such as pollution and polutation distribution are largely based on historical trends. Assessment of the consequences of predicted impacts is approached in different ways depending upon the environmental compartment. For example, predicted changes in air and water quality can be assessed against environmental quality standard, whereas predicted changes in land use and the resultant consequences on floral and fauna species are more difficult to access. Steps for prediction and assessment of air, water, noise, biological, cultural and socioeconomical environment due to coal mining are briefed in Table- 2, and will be useful for decision makers in preparing EMP. Various methodologies available for impact analysis involve the concept of an impact scale and impact importance. However, professional judgment is useful in the absence of any standard or formalized assessment methodologies, Fig.3 illustrates the coal mining activities and their impact on environment and also possible mitigating efforts to minimize the impact. With regard to assessment or interpretation of predicted impacts, standards are available for may parameters within the physical, chemical and socioeconomic environments. Less qualitative standards are available for other areas of concern. Research and Development activities outside and in- house may be developed enabling inter-disciplinary team to interpret more properly the consequences of project implementation.

3. Selection of proposed action

In any model environment assessment, the selection of proposed action should be accomplished only after consideration with each alternative for meeting the project need. In many coal mine projects, the environmental assessment made for previous similar activities can be used in predicting for the proposed project. Now - a - day the guidelines provided by National Environmental Council are useful for selection of proposed action. The first step for selecting the proposed action is aggregation and display of the comparative environmental impacts as briefed in Table-2. Various techniques are available for aggregating the information including multiplication of scaling and importance values in some technique and use of professional judgment in others. In coal industry particularly, professional judgment would be the best selection criteria of proposed action. Before the selection of proposed action, technical difficulties associated, economic analysis based on benefit cost ratio or excess benefits minus costs and general public preference for each alternative are taken into consideration.

4. Preparation of Environmental impact statement

The last step in the working for EMP involves are preparation of EIS. EIS preparation includes :

i) 4 Draft preparation - Based on the study of environmental setting, impact assessment and selection of proposed action, draft of EIS is prepared which will include in brief a. The description of proposed action, project purpose and environmental setting,

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b.relationship of the proposed action on land use, plans, policies and control for the affected land, c. Probable impact of the proposed action on environment, d. alternatives to the proposed action especially reclamation activities in detail, e. any probable adverse environmental effect that can not be avoided as evident in Fig.3 relationship between local short term uses of the human environment and maintenance and enhancement of long term productivity, g. any irreversible and irretrievable commitments of resources that would be involved in the proposed action should be implemented, h. any indication of what other interests and considerations are thought to offset the adverse environmental effects of the proposed action.

ii) 4 Circulation of EIS draft for review of federal, state local agencies and public institutions.

iii) 4 Preparation of final EIS after incorporating review comments of groups discussed above and send for approval from National Environmental Council.

Environmental Planning

Coal mining and related activities are the process whereby ideas, concepts and program development plans are transformed into terrain alteration resulting into climate change and disturb the total ecosystem. Environmental planning can and should be applied systematically as an integral part of project completion. Environmental planning for coal industry includes the analysis of environmental quality indices relevant to all mining related activities, and implementation of alternatives resulting mitigating the adverse environmental effects and maximizing the environmental benefits associated with project development. From the foregoing paragraphs it reveals that environmental planning is an interdisciplinary efforts evolving physical, biological, chemical, socioeconomic and cultural realms and also includes preparation of environmental impacts statements under the sphere of environmental legislation.

Need for Separate Organization of Environmental Quality Management

Better environmental quality management could be achieved by creating a unified organization to handle air, noise, and water pollution and land degradation. The body should have power to impose standards as detailed in legislation, set target standards for implementation and enforce regulations.

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approach for describing the environmental setting for proposed mining project. The information can be obtained from the relevant officers or public institutions which are enlisted in Table 1. Baseline informations are often found to be inadequate with regard to environmental [illegible] preparation from the agencies enlisted in Table 1. [illegible] progressive data [illegible] manifold information [illegible] institutions. Modus operandi [illegible] describe the environmental [illegible] information storage and retrieval [illegible] balances remote or computer [illegible] utilized.

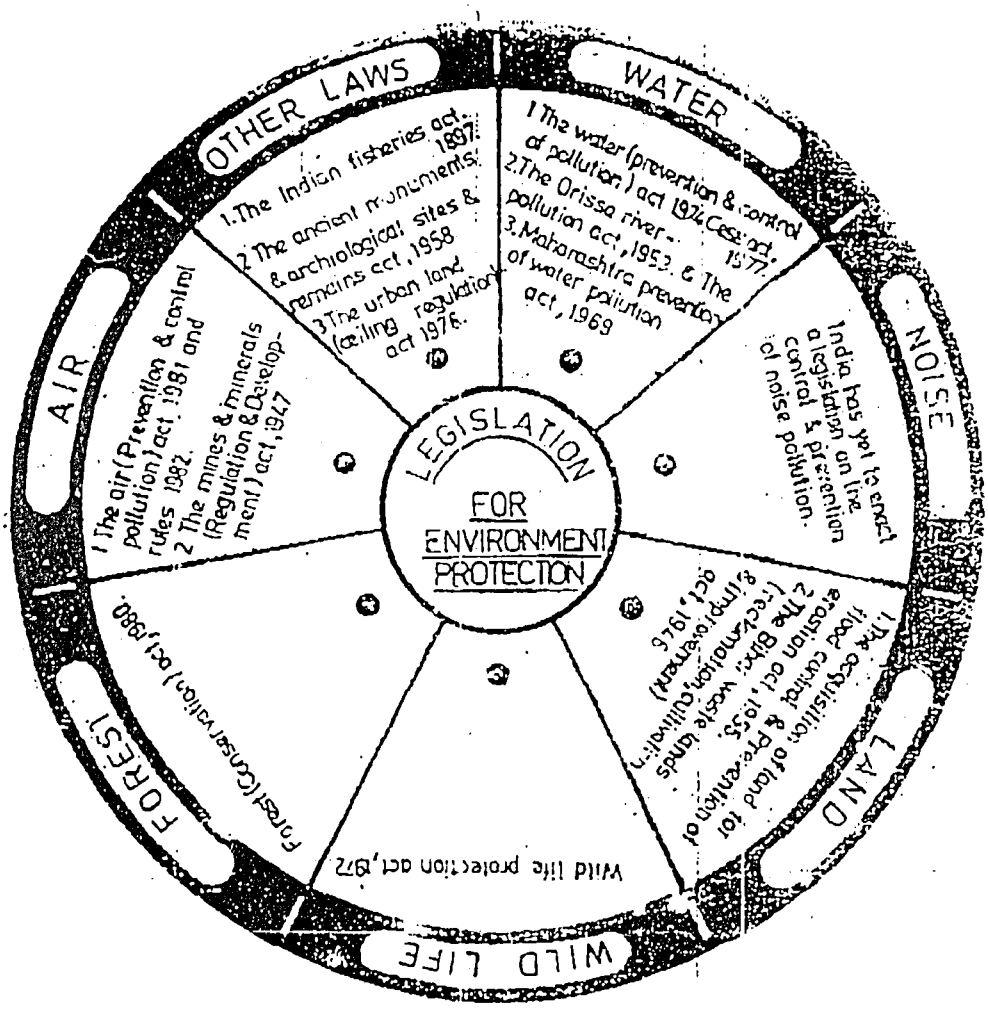

FIG.1 FRAMEWORK OF LEGISLATION FOR ENVIRONMENTAL PROTECTION FOR COAL MINING INDUSTRY

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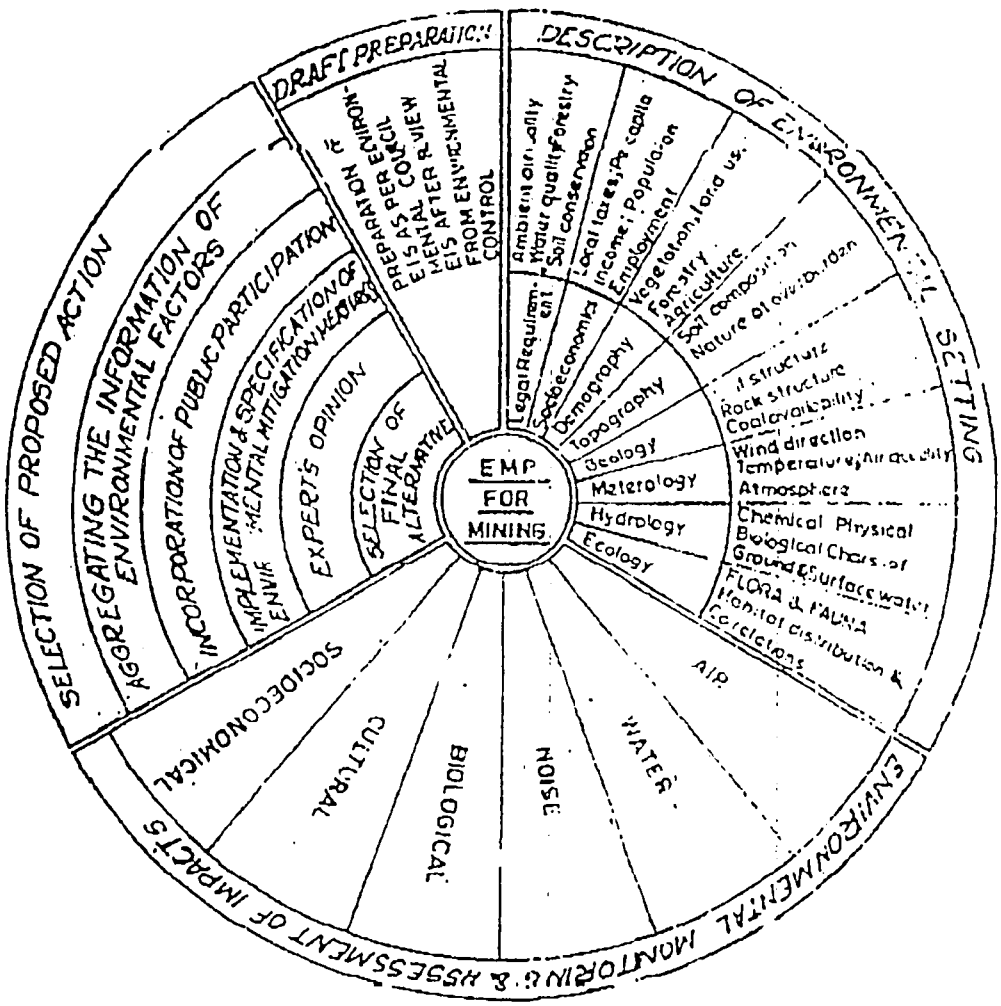

FIG 2:—FRAME WORK FOR PREPARING ENVIRONMENTAL MANAGEMENT PLAN (E.M.P.) FOR COAL INDUSTRY

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THE ROLE OF CLEAN AND EIFFICIENT USE OF COAL IN THE FUTURE ENERGY AND ENVIRONMENT OF CHINA

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Abstract

China is the developing country that posses near 1200 million population. Coal is the main energy of china, which has provided and continue to provide about 70 percent of the energy for China. However, the efficiency of coal use is very low and the coal pollution is revere in China. Clean and efficient use of coal, therefore, will play an important role in the future energy and environment of China.

In this paper, We firstly review the current situation of energy environment of China. Secondly the importance of the measures is analysed which are raising the proportion of coal used in electric power industry, improving the industrial boilers, increasing the rate of washed coal, and ete. Finally, We put forward three strategic stages that China should reach step by step for achieving the goal of clean and efficient use of coal.

In addition, We state that the environmential improvement of China has to be on the basis of the economic development of China.

Keywords: Coal, clean and efficient, energy environment.

1. Current Situation

China is not only the largest energy producer and consumer but also a revere energy pollution country. The fact of the the low economic developmental level in company with the heavy energy pollution of China is the basis for us to understand China´ s energy environment situation and its developing trend.

1. 1 Basic characters

In China the main environmental issue is energy environment, and the main energy environmental issue is the coal environment. Coal is the major energy of China. China´ s coal production as well as the consumption has been accounting for above 70 percent of total energy production and consumption (Table 1). This ratio is much higher than that of the developed countries. According to statistics for 1991, in China 96 percent of total waste substances of the burnt fuels were from the burnt coal. So the major issue of China´ s environment is the coal environment.

The another character of China´ s energy environment is the low efficient use of energy. The efficiency of energy use is only 30 percent, which is much lower than the 57 percent of Japan, the 51 percent of American and the 40 percent of Britain. This is just the one of main reasons of resulting in revere energy pollution of China.

China posses about 1200 million population, which nearly equals to the one fifth of the world population. As a result, the difficulty of China to improve the energy environment is greater than that of any other country.

Besides, as a developing country, China can not afford too much to decrease the environmental pollution in the near future. This is major obstacle for China to care for her environment.

1. 2 Current Energy Environment

In China, more and more attention has been payed to the environmental issue since 1980. A lot of achievement of improving key polluters have been done. However the energy environmental pollution is still very revere for various reasons. Table 2 shows the statistical figures of China environmental pollution in 1991. With reference to table 2, we can see that 80 percent of total ash and 90 percent of total surlpur dioxide (SO_2) came from the burnt coal. In addition, the substance area resulted from coal producing has been near 90,000 hectare by far. Thus, we can conclude that the situation of China´ s energy environment is revere.

2. Potential and role

As a developing country with coal as main energy, China´ s energy pollution is revere and the potential of saving energy is great. For this reason, clean and efficient use of coal is of vital importance for the energy and environment of China in the future.

2. 1 Coal for generating electricity

In China coal used in electric power industry amounted to about 200 million tons per year, but that was only a quarter of total consumed energy. Inspection of table 3, we can see that the proportion is only half of that of developed countries in the world.

On the basis of the real situation of China, the first thing for China to do is to raise the ratio of coal used for electric power. If so, the coal consumption construction will be improved, the efficiency of coal raised, coal pollution decreased and the difficulty of coal transportion overcomed partly. Besides, it will be easier to gather the coal-fired boilers to be improved if the ratio of coal for electrity is raised. And as a result, the coal pollution will be reduced a lot. At present, the ratio of coal used for power supply is 427 g/KWH in China while the ratio is only about 330 g/KWH in developed countries. So if the ratio can be

lowered by 50 or 60 g/KWH then China will save coal by 5 or 6 million tons in this respect, in the meantime the environment pollution will be decreased.

2. 2 Industrial Boilers

There are 400,000 small industrial boilers in China which consume 300 million tons coal per year. The heat efficiency of the boilers is only 55-60 percent. The efficiency is 15-20 percent lower than that of the developed countries. Potential reduction in coal use by improved efficiency could be over 50 million tons per year. This is an important way to enhance coal efficiency and to reduce pollution for China.

2. 3 Washed Coal Industry

At present, the clean coal yield accounts for only 18 percent of total output of coal in China. Developing washed coal industry has a direct benefit in both respects of energy and environment. In 1990 only the consumed coal for power was 310 million tons in China in which there was 86 million tons ash. If the ash content is reduced by 10 percent then the rate of coal for power will be decreased by 3 g/KWH. That mean that coal will be saved at least 10 million tons and the coal pollution will be reduced greatly.

2. 4 Domestic Coal Use

Improved domestic usage of coal is potentially important in China not only because of energy efficiency gains but also because of the contribution to easing heath problems associated with polluted air.

In 1991 the rate of coal gasification was only 42 percent of China's domestic coal. The rate must be increased so that the residential living conditions and environmental quality could be upgraded.

The saved coal of the above terms totalled up to over 100 million tons per year. The total amount almost equals to total production of thirty large coal mines. The coal pollution would be reduced by 10 percent.

It can be seen from above analysis that how important for china´ s energy and environment to use coal cleanly and efficiently.

3. Strategic Steps

In view of the facts that in China the population is great, the level of economic develepment is low and the energy pollution is revere, China must step three paces to the goal of using coal cleanly and efficiently.

In my opinion, the three steps may be as follows.

First of all, in the short run efforts should be concentrated on saving coal. For this, it is essential to raise the coal proportion for electricty and the ratio of washed coal. The both ratios should have been enhanced up to the average level of the world by the end of the century. It can be forecasted that the China´ s coal pollution will continue increasing during this period.

Secondly the key issue is how to use coal efficiently in China. Effective measures must be adopted to improve all industrial boilers and to introduce advanced technology for generating electricity. The wide application of circulating sulpurigation bed boilers will be useful to improve coal efficiency and to reduce the pollution. This objective is expected to be achieved in 15 years after the first step. The coal pollution will be smoothed down during this period.

The third strategic objective is to use coal cleanly and efficiently. To achieve this, the useful ways may be to improve the technology of coal chemical industry, to develop the comprehensive utilization of coal, and to change waste into useful substance. Main efforts must be made to minimize the coal pollution in order to make the China´ s energy environment better and to establish a clean and beautiful living environment for China in the middle of next century. The achievement will also be a great contribution to the world environment.

4. Conclusion

China is a largest coal producer and consumer. In China, the major environment issue is the coal pollution.

The potential of saving coal is immense. potential reduction in coal use by enhancing the efficiercy to the average level of the world could be over 100 million tons per year.

At present, as a developing country, China should get to the overall target " clean and efficient use of coal" step by step. The first step may be to save coal, the second to enhance coal efficiency and the third to use coal cleanly and efficiently.

For the low economic level, China must go all out to develop economy so as to get rid of poverty and to increase the capacity of preserving environment.

Also the improvement of China´ s energy environment will play an important role in improving the world environment. China will accelerate cooperation with foreign companies and encourage more foreign capital investment; import more advanced technologies and equipment; and welcome more foreign specialists to work in China.

We believe that the China´ s energy and environment future are full of promise.

Table 1. Primary Energy output, consumption and Mix (1981-1990)

year	Total output (Mtce)	percentage of each sector				total consumption (Mtce)	percentage of each sector			
		Raw coal	Crude oil	Natural Gas	Hydoopower		Raw coal	Crude oil	Natural Gas	Hydropower
1981	63 227	70.2	22.9	2.7	4.2	59447	72.7	20.0	2.8	4.5
1982	66 778	71.3	21.8	2.4	4.5	62067	73.7	18.9	2.5	4.9
1983	71 270	71.6	21.3	2.3	4.8	66040	74.2	18.1	2.4	5.3
1984	77 855	72.4	21.0	2.1	4.5	70904	75.3	17.4	2.4	4.9
1985	85 546	72.8	20.9	2.0	4.3	76682	75.8	17.1	2.2	4.9
1986	88 124	72.4	21.2	2.1	4.3	80850	75.8	17.2	2.3	4.7
1987	91 266	72.6	21.0	2.0	4.4	86632	76.2	17.0	2.1	4.7
1988	95 801	73.1	20.4	2.0	4.5	92997	76.2	17.0	2.1	4.7
1989	10 1639	74.1	19.3	2.0	4.6	96934	76.0	17.1	2.0	4.9
1990	10 3922	74.2	19.0	2.0	4.8	98000	75.6	17.0	2.1	5.3

Source: Statistical yearbook of China 1991, Statistical press of China, 1991.

Table 2. The Environmental Pollution of China in 1991

Air		Water	Solid Waste
Soot	SO_2	Industrial Waste	Industrial solid Waste
13.14Mt	16.22 Mt	23577 Mt	590 Mt

Source: Introductory News paper of World Energy (in Chinese), June 15, 1993.

Table. 3. World Coal Use

World	Highly Developed countries	Europe	India	China	others
54.25%	82.78%	37.85%	54.31%	26.12%	71.41%

Source: S. William Gouse and others, The Long Term Outlook for Coal to the Year 2100, Proceedings of the Second World Coal Institute Conference, London, 1993.

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Merging Process Control and Environmental Compliance Systems

Environmentally Sound Facilities Management

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Over the last century, facilities management responsibilities in the United States primarily focused on safe and efficient operations. Each new iteration of automated process control employed by management to increase industrial productivity brought with it enhanced safety measures as well as cost-effective automated production methods. Over time, many facilities were considered to be well run industrial centers where the production cost per unit of product was competitive, the quality of the product was high and the operating conditions relatively safe and employee friendly. Concerns about a facility's impact on the local environment and human health issues were not, for the most part, a visible or pressing concern to plant owners, managers, or employees. As long as the facility continued to produce in accordance with its planned production objectives, avoiding serious mishap to human life, company management and the local community seemed content to continue business as usual.

Business as usual was acceptable then because there was little or no environmental legislation which regulated a facility's operations. This is not to say facility managers were taking advantage of the situation by overtly abusing the environment. On the contrary, most facility managers by and large were conscientious, law abiding citizens who did their best to avoid hazardous waste emissions, spills and leaks. However, their problem now, as opposed to then, is that they must maneuver through a veritable regulatory obstacle course in order to address the broad spectrum of complex environmental issues which govern the operations of their facilities.

Today, a facility manager faces a staggering load when it comes to environmental compliance. Not only must he manage the operations of his facility, he must also be able to access, evaluate, process and act upon thousands of pages of constantly evolving and varying environmental legislation. As shown in Figure 1, in the United States, federal statutes alone have grown from approximately 400 pages in the Code of Federal Regulations (CFR) during the early 1920's to well over 10,000 pages today.

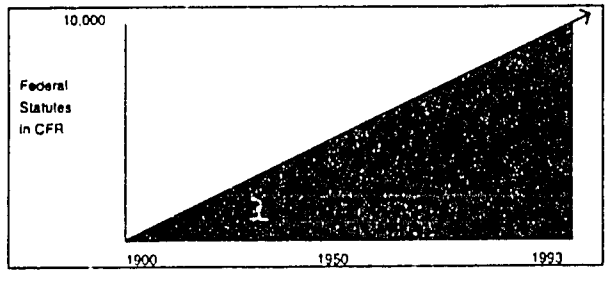

Figure 1. Growing Federal Statutes

On top of this, every state and local government has added to this legislative nightmare by introducing their own stricter-than-federal or conflicting requirements. In the United States, a typical facility manager today must be able to address and fully understand Superfund Amendment Reauthorization Act (SARA) reporting, Comprehensive Environmental Recovery Compensation and Liability Act (CERCLA) remediation, Resource Conservation and Recovery Act (RCRA) compliance, Toxic Substance Control Act (TSCA) regulations, Occupational Safety and Health Act (OSHA) requirements, National Institute of Occupational Safety and Health (NIOSH) recommendations, National Pollution Discharge Elimination System (NPDES) permitting issues, Clean Air Act (CAA), and Clean Water Act (CWA) compliance, American Conference of Government Industrial Hygienists (ACGIH) limits, - and the list continues ad infinitum - to perform his job as an environmentally sound facilities manager. In addition, his duties include Material Safety Data Sheet (MSDS) tracking, generation, and distribution; chemical inventory tracking; regulatory reporting; illness and injury tracking; employee medical and training tracking; hazardous waste tracking; incident/spill reporting; emergency planning; sample tracking; permit tracking; manifest generation and much more. Becoming more than familiar with the application and implementation of these responsibilities is, to say the least, a perplexing and, at times, a frustrating and overwhelming task. Staying abreast of the latest changes to these requirements requires a continuous and vigilant review process involving hundreds of documents and literally thousands of pages. For example, a new "Worst-Case" accidental release regulation under the proposed Clean Air Act rule will force companies to publicly report on the predicted off-site consequences of a catastrophic release of any of about 170 hazardous chemicals. It is estimated that to comply with this new rule, companies will have to expend $150,000 annually to ensure the voluminous data and administrative documentation requirements are met. These requirements include, as a minimum, developing worst-case scenarios and emergency plans with the residents of their local communities for each hazardous chemical in inventory. If a facility maintains 100 hazardous chemicals - 100 scenarios and emergency plans will have to be developed, coordinated and approved.

Coming to grips with establishing an environmentally sound facilities management program means more than an after the fact attempt to avoid fines and citations for non-compliance with reporting and recordkeeping requirements. It also means more than purchasing an off-the-shelf environmental software program to track hazardous wastes and generate required environmental reporting documentation. What it does mean is developing a system which will provide the business with a competitive edge in today's marketplace which is made up of an environmentally conscious public and cost-minded competition. An environmentally sound facilities management system will provide the business entity a number of quantifiable benefits such as liability reduction, operating cost reduction, improving investor relations, increasing customer loyalty and increasing employee morale and motivation. Companies can benefit directly from good environmental recordkeeping by reduced operating costs and a

lower likelihood of liability - including time in jail for accountable managers - from chemical incidents, employee exposure risks, and private citizen lawsuits. Examples include: proper inventory control can reduce raw material losses, inefficient processes can be pinpointed to minimize excessive waste production, extremely dangerous chemicals can be replaced with benign alternatives, equipment maintenance histories can indicate potential failures, permit exceedance trends can be noted - the list is almost endless.

To achieve these benefits, an environmental tracking and reporting system as shown in Figure 2 must be fully integrated into the company's facility management/process control system. Environmental software, referred to these days as E-software, provides a good starting point for electronic/automated waste and materials tracking and reporting. However, because most are standalone software packages, they are not easily able to interface with other existing process control systems such as purchasing and production which, if tied together, could create real waste minimization and pollution prevention savings.

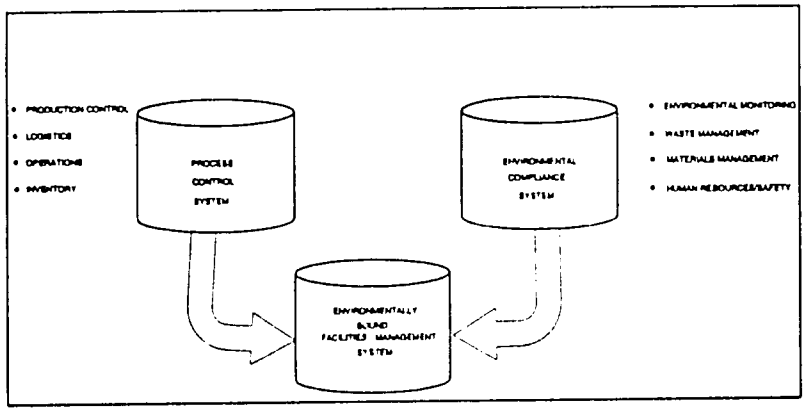

Figure 2 - Integration of Process Control and Environmental Compliance Systems

Most facility software systems on the market today are either process oriented or environmental compliance driven. Much effort is being expended by the developers of these systems to make them a complete system capable of both process control as well as achieving environmental compliance. Approaches taken by these developers include:

- Modification of their existing system to incorporate the additional functional requirements.
- Development of software to bridge the two systems together.
- Development of completely new software which incorporates the features of both systems into one.

The predominant approach being used today involves modification of a company's existing process control software to add environmental compliance functions. Manufacturers and industrial concerns are utilizing this approach because of the tremendous investment they already made in their process control software. Thus, they are not eager to approve an additional large budget outlay to attain a fully integrated system. Moreover, there is no clear leader/provider of this capability on the market today.

The merger between process control and E-software has many implications. Some of the bigger hurdles that will have to be overcome by the facility manager include:

- Training and cross-training of existing industrial and environmental employees to indoctrinate them to the additional requirements/responsibilities that they will incur operating and implementing the system. For example, industrial employees will have to become more aware of hazardous materials including their proper handling, storage and disposition. Industrial management will be held responsible for interpreting, evaluating, and developing environmental compliance reports. Environmental managers will have to become familiar with warehousing, purchasing, research, production and logistics functions - all of which either procure, store, use, or dispose of hazardous materials.

- New job categories will be created specifically to address the new responsibilities associated with incorporating waste minimization and pollution prevention throughout the entire facility. As companies are forced to comply with new environmental regulations and rules, more and more focus will be applied to prevention and planning rather than remedial waste cleanup. These new labor classifications could include such titles as Chief Environmental Officer, Environmental Audit Manager, Community Coordinator for Environmental Issues, and Environmental Quality Engineer, to name a few.

- By far the biggest hurdle to jump will be the sheer magnitude of complying with every environmental act, law, regulation, rule, citation, ordinance and ruling out or due out in the next several years. In order to feel confident that one has put in place a system that will address compliance as well as future requirements, it would be wise to consider a software development company that provides as a minimum, the following:
  - System installation and hook-up
  - Implementation consulting
  - Basic and advanced training
  - System updates and enhancements
  - Hotline Support
  - Newsletters
  - Access to other user groups.

  It is important to select a software vendor that makes available the above services - especially access to other user groups who are confronted with similar issues which you are facing or will face.

The system which you are installing and/or interfacing with your process control software should address four primary environmental compliance areas, plus a general system interface requirement. These include:

- Materials Management
- Waste Management
- Environmental Monitoring
- Human Resources/Safety
- Integration with Other Systems

Each of these areas plus the interface requirement is described below.

Materials Management

This area should include the ability to provide MSDS tracking, generation and distribution for organizations which are required to generate and distribute MSDS in accordance with OSHA 174 guidelines. It also should include inventory tracking, materials approval and control which includes purchase unit conversions, shelf-life limitations and materials selection, and hazardous materials labeling. Specifically, the software should provide:

- Relationships between manufacturers, suppliers, product codes, materials, and inventories.

- Ability to track all material streams - receipts, storage transfers, internal disbursements, process consumption, product output, releases, leaks, evaporation, customer shipments, waste generation - at all internal facility locations.

- Mass balance capabilities for any location at any time interval.

- Information concerning inventory reconciliations, processes, engineering controls, storage tanks, PCBs, and equipment inspection, maintenance and calibration.

Waste Management

This area should include the ability to provide cradle-to-grave tracking of all wastes. It should provide storage area monitoring, container tracking, and waste profile/approval tracking. It should provide Transportation, Storage and Disposal Facility (TSDF) qualification, manifest generation and control and provide cost and schedule tracking for all waste streams. Specifically, the software should provide the ability to:

- Categorize waste streams and maintain detailed information concerning their sources, contents, and destinies.

- Develop waste profiles based upon analytical samples.

- Generate the Uniform Hazardous Waste Manifest. The software should be capable of tracking manifests from their point of departure to transporters and TSDF, until a certificate of disposal is returned. It should also be capable of listing noted discrepancies.

- Manage information for annual waste generator reports.

- Detail waste minimization procedures and results.

Environmental Monitoring

This area should included the ability to perform emission monitoring, permit tracking, SARA reporting and Discharge Monitoring Reports (DMRs). It should generate spill/incident reports, provide regulatory queries, environmental auditing and groundwater sampling. It should also provide DOT references and source materials. Specifically, the software should let you:

- Log information about samples from any type of environmental media including air, water, soil, waste and biological samples.

- Manage complete descriptive information concerning any type of release source, including air stacks, outfalls, and surface impoundments.

- Track samples from collection through results reporting. The software should also allow you to annotate collection conditions, sample preparation, chain of custody, and laboratory information and analyses.

- Generate a DMR using monitoring results to determine compliance with mandated permit limits.

- Log basic, descriptive information for each permit.

- Maintain comprehensive data concerning regulated parameter limits, including whole effluent toxicity. The software should also allow you to log minimum, maximum, and average values according to permit, regulatory, and/or corporate specifications.

- Provide notification of expiration dates and the status of the renewal process.

- Maintain federal and state chemical "list" information such as SARA Extremely Hazardous Substances, SARA Toxic Chemicals.

- Generate Tier I and II and Form R reports in standard Environmental Protection Agency (EPA) formats. The software should be capable of electronically submitting Form R reports and performing calculations to reduce chemical commodities to their component ingredients.

- Manage information to notify emergency planning groups of unplanned releases.

Human Resources/Safety

This area includes the ability to determine and perform training scheduling/requirements, to provide a respirator management program, to conduct and track medical examinations, to report workplace illnesses and injuries, to perform workplace sampling and to conduct HazCom reporting. Specifically, the software should let you:

- Achieve and maintain Environmental, Health, and Safety (EHS) regulatory compliance.

- Track and monitor EHS data over a broad range of EHS activities at the plant, division and corporate levels

- Prepare regulatory filings associated with EHS data.
- Evaluate EHS data in regards to your specific facility.

Integration with Other Systems
This area should include the E-software's ability to interface with other company department systems such as warehousing, personnel, payroll, purchasing, and your geographical information system.

These interfaces should allow the manufacturer the ability to:

- Link sales, waste approval, transportation, treatment and disposal activities.
- Prevent business transactions beyond approved credit limits.
- Monitor treatment costs.
- Schedule receipt of waste.
- Compare waste approval requirements to fingerprint analysis.
- Monitor and control analytical work for each waste stream.
- Provide multi-facility tracking, with corporate roll-ups.

In the United States as elsewhere in the world, the age of environmental compliance is upon us. Environmental compliance strategies and manufacturing processes must now go hand in hand to minimize or eliminate harmful byproducts and hazardous wastes. No longer can American industry ignore the growing expanse of environmental control regulations and still remain a viable, competitive concern. Companies that wish to operate successfully in the 1990s and beyond must embrace with vigor the development and adoption of an integrated total environmentally sound facilities management system.

In much the same manner as American industry has had to find ways to remain competitive in an ever increasing global market, they now must again re-engineer their operations to remain competitive in an increasingly environmentally conscious economy. Facility managers must face this challenge with a well thought out game plan for success. Success in this instance is defined as the ability to completely respond to environmental regulations at all levels of authority while still remaining an on-going competitive business. To many companies, this is an unachievable objective. Full and continuing compliance with regulators,

they say, will require enormous financial resources which they don't have. On the other hand, failure to comply will result in large fines upon the company. Just recently the United States Environmental Protection Agency levied over $45 million in fines to American companies for alleged TSCA and permit violations and for failure to meet complex environmental reporting requirements. In one startling example, Chevron Chemical was fined $17 million due to "alleged paperwork violations" regarding TSCA reporting. Companies caught up in this difficult situation see no easy or timely solution. But as difficult as their predicament may be, there really is only one choice - to comply. Given this realization, the earlier a company embarks upon integrating their process control and environmental compliance systems, the greater the chance that they will achieve success in the long run.

At Ogden Environmental and Energy Services, we are presently integrating into our Ogden*FM Facilities Management System a full service environmental compliance program capable of addressing materials and waste management, environmental monitoring and environmental health and safety issues. Once completed, our Environmentally Sound Facilities Management System will allow facility managers to operate their facilities in a cost-effective manner while complying with all environmental regulatory laws. It is our intention to implement and utilize this system on all of our large private and government facilities management contracts.

CQE: Bringing New Dimensions to Fuel Decisions

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THE GROWING NEED

Growing competition among power producers, increasingly stringent emissions regulations, and advances in power generation technology are complicating the power generation industry worldwide. Such pressures will impact the many varied and important fuel purchase decisions which account for 30 to 70 percent of a utility's annual expenditures. Unfortunately, understanding coal quality and its impacts on plant performance, emissions, and production costs is a difficult proposition.

Coal quality impacts nearly every system in a power plant. Measuring or quantifying such impacts requires a comprehensive analysis of the power plant's performance. The very complexity of coal, its combustion, and the resulting relationships to performance, emissions, and costs, continue to provide impetus to R&D programs active throughout the world and many computer products, current and future.

The diversity of fuel decisions further complicates the situation. Coal quality concerns span many areas of the utility organization, with each area having specific, yet very different, needs:

- Fuel Supply and Procurement--Rapid evaluation of alternative coal suppliers and coal specifications, with emphasis on determining least-cost, acceptable coal sources.
- Engineering--Detailed analysis of coal quality/performance relationships and analysis of potential plant retrofit projects.
- Production--Understanding of how adjustments to operating practices influence impacts of coal quality.
- Environmental--Relationships between fuel sources and emissions, both short- and long-term.
- System Planning--Influence of fuel sourcing on system-wide production cost, unit dispatch, and annual emission rates.
- Management--Influence of fuel sourcing options on production costs and flexibility of utility to adapt to changing market influences.

Utilities need a consistent, timely means of evaluating coal quality impacts, as well as a means for integrating such information into their day-to-day decision processes.

THE VISION, THE CHALLENGE, AND THE STRATEGY

Ongoing and past research efforts at the Electric Power Research Institute (EPRI), other international research organizations, and equipment manufacturers have focused on the many difficult coal quality issues. During the last decade, EPRI has been directing efforts to translate the results of its research into viable computer-based analytical solutions. The CQE™ (Coal Quality Expert) is a key part of this strategy.

The CQE, under development as part of a $21.7 million Clean Coal Technology project sponsored by the US Department of Energy and EPRI, will offer unparalleled advancements in technical capability, flexibility, and integration. Scheduled for initial release in late 1994, the CQE will bring a new level of sophistication to fuel

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decisions by seamlessly integrating the system-wide effects of fuel purchase decisions on power plant performance, emissions, and power generation costs. The CQE will feature both seamless integration of already proven and extensively used computer programs, such as the EPRI Coal Quality Impact Model (CQIM™) and new relationships derived from the project's comprehensive full-, pilot-, and bench-scale testing programs.

The CQE will be composed of technical models to evaluate performance issues; environmental models to examine environmental and regulatory issues; and cost estimating models to predict costs for installation of new and retrofit coal cleaning processes, power production equipment, and emissions control systems. Also evaluated will be other productions costs such as consumables (fuel, scrubber additive, etc.), waste disposal, operating and maintenance, and replacement energy costs. The foundation for the CQE's calculation power begins with the CQIM. CQIM enjoys worldwide acceptance and is currently used by over 100 utilities and coal companies. A better understanding of the CQE's capabilities relative to those of the CQIM can be more clearly described by using the analogy of a gear train. New CQE technology couples with the existing CQIM to increase both the power and scope of analytical capabilities, as shown on Figures 1 through 4.

The CQE extends the state of the art in coal quality impact modeling in three dimensions:

- Redefining Flexibility.
- Advanced Technical Models and Performance Correlations.
- Advanced User Interface and Network Awareness.

The First Dimension: Redefining Flexibility

The CQE's architecture and program structure is designed to promote ***FLEXIBILITY*** to the greatest extent practical:

- ***FLEXIBILITY*** to address the engineering and analytical needs of fuel purchasing specialists, engineers, operation support staff, and planners.
- ***FLEXIBILITY*** to perform its many calculations tailored to the needs of the specific audience and specific problem in question.

New ***FLEXIBILITY*** is largely a function of two factors, use of object-oriented programming techniques and the CQE's innovative Application framework.

Object-Oriented Programming Techniques. The CQE will be coded entirely in the C++ language, enabling the program to take advantage of the language's inherent strengths for managing large, complex analytical processes. Object-oriented programming also allows the CQE to be easily expanded as user demand grows. An object-oriented CQE can simulate real-world objects, such as boilers, pulverizers, coals, and plants. By altering order, type, and content of queries between objects, different problems can be solved. Thus, the objects can be reused to handle different situations. Unlike other methods, object-oriented techniques result in a design that interconnects data objects and processing, rather than isolating processing from data.

The CQE has been designed such that future modifications can be easily made to enhance or replace current models. This objective will be accomplished by judicious application of object-oriented programming and maintaining an eye toward current or future related R&D efforts. The object-oriented approach is ideally suited to handling such future modifications; once the interface between objects has been determined, the internal contents of each object can be improved without altering the rest of the system. Thus, future advancements in coal quality analysis or models can be rapidly assimilated, as follows:

- As technologies advance, existing models can be refined without disrupting or overhauling the entire system. For example, when EPRI work on coal handleability is computed, it will be a straightforward matter to incorporate improved estimates of power station derates due to poor handling quality of coal in question.

- As new technologies are incorporated into power plant design and operation, new models such as for Selective Catalytic Reduction (SCR) for a fluidized-bed combuster, can be dropped into CQE to work seamlessly with existing ones.
- As the most commonly used equipment and system configurations are identified and built, users may share these pre-built systems, adding to their set of software models representing their individual systems.
- As new relationships between cost, emissions, and performance are proven, new CQE applications can be built.

CQE Application Framework. An Application is the highest level of interface with the CQE system. As shown on Figure 5, available Applications are prominently displayed in CQE's user interface.

- A toolbox displays each of the 10 specialized applications available to the user.
- As each application is selected, the CQE will display a log of prior and current analyses (analogous to a computer "run" or "data file") in the window at the lower right corner of the screen.
- Additional information about either the application itself or a specific analysis is shown in the window in the upper right corner of the screen.

Applications facilitate sharing of data and knowledge between users and various analyses by using a consistent set of tools and data to perform different types of analyses. Applications contain the intelligence necessary to guide the user through an analysis by providing instructions regarding the order in which things should be performed and what data or information are needed to successfully complete the analysis. In addition to providing the control logic for an analysis, the Application will provide a visual roadmap through on-screen diagrams. Additional roadmaps can be displayed for any step warranting further explanation. Figures 6 and 7 show top-level roadmaps for two principal CQE applications, the Fuel Evaluator and the Plant Engineer, respectively. Figure 8 employs the Fuel Evaluator application to illustrate CQE's ability to "expand" displayed roadmaps to describe the analytical process on a step-by-step basis.

Different applications allow CQE to support a cross section of users with very specific, yet very different, needs. Fuel buyers, for instance, can use the CQE to rank spot market fuel options, while environmental engineers can use the CQE to evaluate different emissions compliance strategies. CQE streamlines analyses by matching software presentation to the specific task at hand. In addition to the Fuel Evaluator and Plant Engineer applications, other major applications that will be available as a part of the CQE program include the following:

- New Plant Designer.
- Coal Cleaning Expert.
- Environmental Planner.
- Fuel Purchase Manager.
- Coal Specification Analyst.
- Environmental Expert.
- Coal Contracts Assistant.
- Capital vs. O&M Tradeoff Analyst.

The CQE offers other sources of flexibility. It accommodates either individual or networked PCs and can employ English or metric units, different monetary systems, and international power plant technologies. Reports can be tailored to meet company- or project-specific needs and to tailor language/terminology as appropriate.

The Second Dimension: Advanced Technical Models and Performance Correlations

The CQE marks a significant advance in the sophistication of technical models available within a single, integrated environment. The CQE builds on and integrates existing models to support broader and more detailed analyses of fuel decisions.

The CQE builds on existing correlations from worldwide R&D on the impacts of coal quality for specific parts of the total power generation system. In addition to CQIM, CQE interfaces with other industry-leading computer models. Southern Research Institute's SoRI™ model addresses electrostatic precipitation. EPRI's Coal Quality Information System (CQIS™) provides a database of coal quality information. Similarly, capital costs and performance assumptions for flue gas desulfurization (FGD) installations and NO_x retrofits are developed from EPRI's FGDCOST™ and NOxPERT model results.

The CQE allows the user to customize software to further enhance the accuracy of analyses. CQE permits the user to graphically configure system, plant, and unit equipment systems to match actual configurations. The CQE will also configure equipment models for users based on limited information, enabling them to begin applying the software immediately.

This groundwork of established models is complemented by new and enhanced models derived from bench-, pilot-, and full-scale test programs. These test programs, which allow coal-related effects to be distinguished from operational or design impacts, are among the most extensive of their kind ever conducted to relate power plant performance and emissions to coal quality. Six full-scale power plant test burns supplied important data to verify and expand the CQE models.

Slagging and fouling phenomena have been extensively investigated in the program to allow the CQE to predict their occurrence in boilers and convection passes and how such deposits affect unit performance and load capability. The CQE's innovative slagging and fouling model evaluates the effects of unit load, operation, and coal quality to predict heat transfer and ash deposit growth, strength, and removal.

CQE users can establish coal ash behavior by using conventional American Society of Testing and Materials (ASTM) analyses or a new approach based on Computer Controlled Scanning Electron Microscopy (CCSEM). CCSEM provides additional, specific information on coal and mineral size, associations, and abundance not obtained through ASTM analyses.

The Third Dimension: Advanced User Interface and Network Awareness

Because the CQE will be dealing with a large amount of data and trying to satisfy a variety of specialized users, it is important that the interface to the program be very user-friendly, yet sophisticated enough to address each user's needs.

As discussed previously, CQE's application framework navigates users through an analysis, making the CQE's user interface fundamentally different from interfaces found on traditional engineering, environmental, and fuel purchase models. By applying different visual roadmaps to different analyses, the CQE meets the specific needs of diverse users in the following ways:

- Prompting the user to select or enter appropriate data about plant or equipment configurations, coals, and generation requirements.
- Displaying additional, more detailed roadmaps for subsequent steps, as needed.
- Managing the sequence in which data are entered and calculations performed.
- Seamlessly sharing plant, equipment, coal, and performance data among CQE users.
- Allowing users to build on results of previous analyses.
- Providing interactive displays of results that allow users to better understand results.

The CQE's graphical user interface will employ all screen elements currently found in modern windowing environments such as windows, menus, and dialogue boxes. Icons, bitmaps, and other graphical elements will be used to further enhance the CQE interface. In addition, the CQE will take advantage of OS/2 notebooks to organize data and feature custom elements to manage international units and traceback explanations for key calculations. These will enable a vast amount of information to be displayed in a logical, consistent manner. Tables, graphs, and other professional business graphics will round out the user interface. For example, as shown on Figure 9, business graphics will allow the user to compare economics of alternative fuel strategies, expand graphic objects to break out cost components, or display other pertinent supporting data such as key plant performance parameters.

The CQE's ability to manage and integrate information allows users to efficiently share pertinent data and knowledge. Even though fuel decisions affect nearly every aspect of power generation, the complexity and diversity of fuel analyses have traditionally forced utilities to perform various evaluations without adequate information sharing and integration. Fuel buyers handle transportation issues and coal sourcing; plant engineers evaluate how individual coals behave in a unit; ad-hoc teams assess key fuel strategic issues; and environmental engineers address compliance and disposal issues. Typically, each expert uses an individual set of assumptions, data, and tools to complete an evaluation, resulting in one-dimensional pictures of fuel-related costs.

The CQE integrates these assumptions, data, and tools, creating a unique environment within which experts can efficiently and effectively share their knowledge and results in a consistent, timely, and accurate manner.

The power of this environment is twofold. It not only efficiently manages all relevant information but also makes that information available to all other experts as appropriate. The end result of integrating a set of previously isolated analyses is a new capability that provides a complete picture of fuel-related impacts and costs.

This sharing of data and operations among all the different CQE applications will be made possible through the use of the object database (ODBMS). The ODBMS will handle the storage, management, and retrieval of all objects in the system. It will guarantee the persistence and integrity of the objects. It will also handle the concurrent transactions that will occur as CQE objects are shared not only among different applications, but also among different users on a network. Consequently, the CQE user need not be concerned with the complexity of managing all data in the CQE program.

MOVING FORWARD: A CLOSER LOOK AT THE CQE PROJECT AND OTHER RELATED EPRI ACTIVITIES

The CQE Project

The CQE is a product of an extensive coal quality R&D initiative. The CQE project includes testing, analysis, and software development. The overall CQE project is managed by CQ Inc., a subsidiary of EPRI; Black & Veatch is the project's primary software developer and manager of all software development efforts. In this role, B&V is responsible for supervising, coordinating, and planning all software development efforts. Decision Focus Inc. is responsible for software development efforts related to the fuel supply portion of the program, which deals with retrieval/storage of coal data, transportation costs, feasibility of cleaning processes, and cost predictions for cleaning facilities.

Testing and data analysis portions of the project are supported by a number of recognized industry specialists. Electric Power Technologies leads the full-scale testing program; ABB Combustion Engineering leads pilot and bench-scale testing, analysis, and algorithm development activities. Other project participants are listed below:

- Alabama Power Company.
- Babcock & Wilcox.
- Duquesne Light Company.
- Energy and Environmental Research Corporation.
- Fossil Energy Research Corporation.
- Mississippi Power Company.
- New York State Electric & Gas Corporation.
- Northern States Power.
- Pennsylvania Electric Company.
- Physical Sciences Incorporated Technology.
- Public Service Company of Oklahoma.
- Southern Company Services.
- Southern Research Institute.
- University of North Dakota Energy & Environmental Research Center.

The software will be available to EPRI members as part of membership. The world commercialization of CQE is handled by Black & Veatch and CQ Inc.

CQIM

Since its introduction in 1989, the CQIM has demonstrated wide application in a number of fuel purchase assessment areas. It has been used by over 100 utilities, engineering firms, and coal companies in the United States, as well as by a growing number of international users for a variety of applications, including the following:

- Fuel Procurement Decisions and Negotiations.
- Clean Air Act Compliance Strategies.
- Fuel Switching Analyses.
- Coal Contract Specifications and Pricing Clauses.
- Coal Beneficiation Analyses.
- Test Burn Planning and Analysis.
- Engineering Analyses.
- Technology Screening.

As more and more utilities refine coal procurement procedures to meet the challenges presented by the increasingly competitive nature of the power industry and fuel-cost reduction pressures, the CQIM is frequently incorporated into day-to-day purchase and planning procedures.

The CQIM's capabilities and usage continue to grow. EPRI is currently working with the Gas Research Institute to expand the CQIM to model gas co-firing concerns; EPRI and Black & Veatch are currently working with both US and international users to define and develop additional extensions to the CQIM and to improve its ability to model international equipment and coal concerns. Black & Veatch is responsible for its continued development and commercialization.

Coal Quality Evaluator (C-QUEL)

EPRI's efforts in delivering coal quality tools to the industry are not limited to the CQE and CQIM; EPRI is also developing a real-time advisory and diagnostic system, the Coal Quality Evaluator (C-QUEL), for use at power plants. C-QUEL™ will allow power plant operators to better manage day-to-day coal quality, performance, and cost issues.

Applying coal quality impact analysis to a specific station or unit must first begin with a thorough understanding of how coal affects performance, irrespective of the actual nature of the analysis. As in the case of the CQE, C-QUEL will base its performance analysis calculations on the proven foundation of the CQIM. By combining the CQIM calculational capabilities with other hardware and software, C-QUEL employs on-line coal analysis to provide actual coal quality being fed to the unit and recommend specific operator actions to improve plant operation and reduce costs. The C-QUEL is scheduled for initial release in Spring 1994; Black & Veatch and Praxis Engineers are responsible for C-QUEL development and commercialization.

CONCLUSIONS

The CQE is designed for the future in mind. Its architecture is oriented toward customization, integration, and future expansion. By building on the capabilities of the CQIM, incorporating other industry-standard tools, working directly during development with the international community, using the strengths of object-oriented design and programming, and employing other state-of-the-art computer tools, the CQE is expected to become the new international industry standard when it is initially released in late 1994.

The CQE is a key product offering in EPRI's fuel impact analysis arena and a key ingredient of future strategies. Its design demonstrates EPRI commitment to developing practical, easy-to-use, and integrated computer products. Today, the CQE and C-QUEL are able to work directly with the CQIM and other EPRI computer products. In the future, the CQE will be an important part of even larger, more encompassing fuel management systems.

FUELS ASSESSMENT

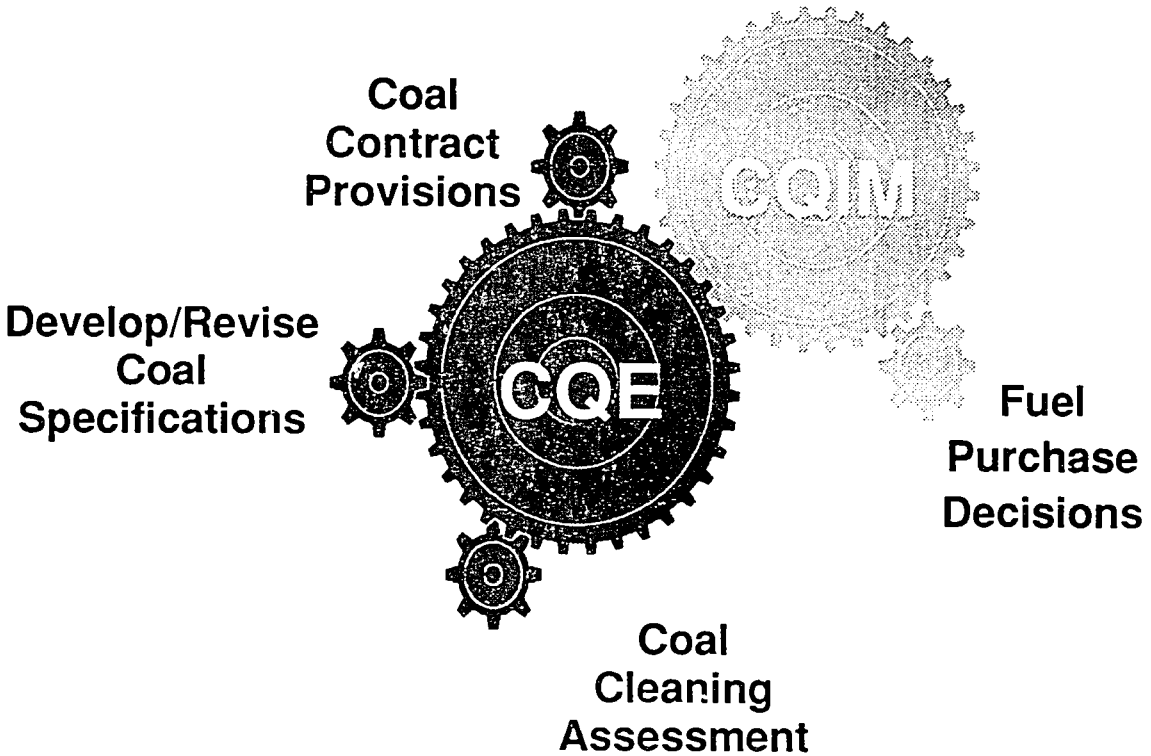

Figure 1. CQE Extends Fuel Purchase Analysis Capabilities

ENGINEERING ASSESSMENT

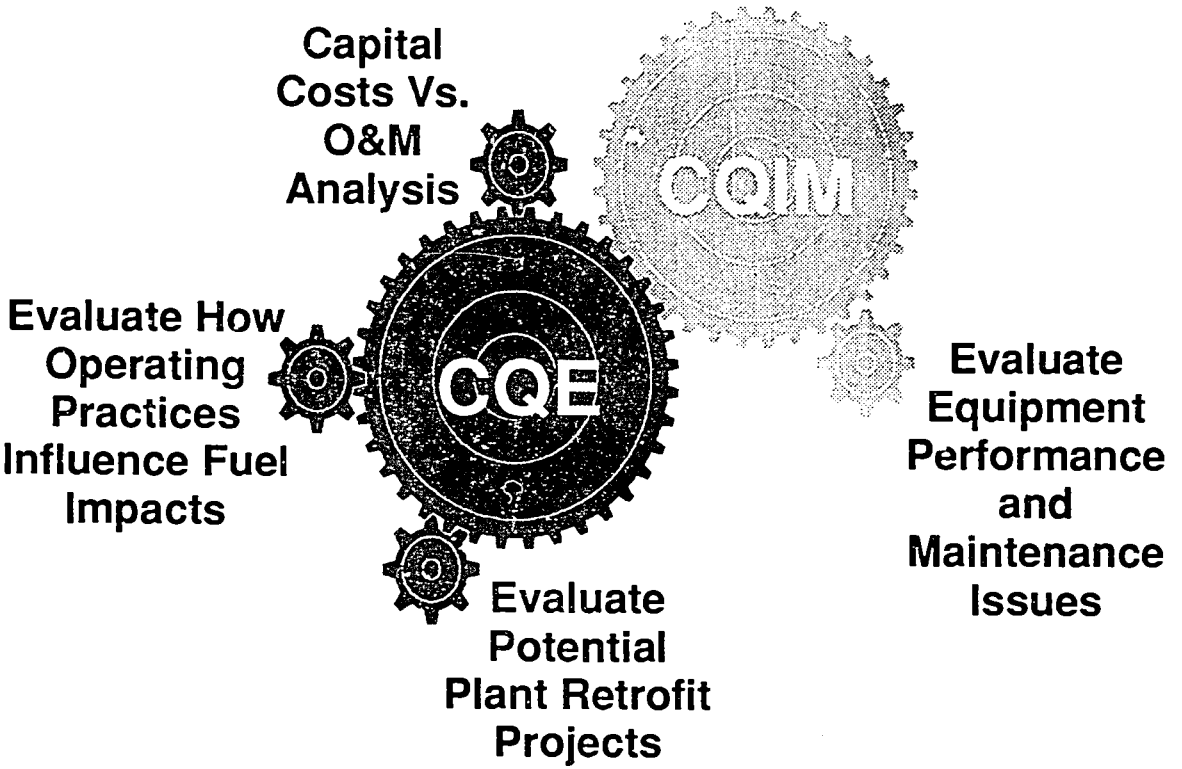

Figure 2. CQE Extends Engineering Analysis

ENVIRONMENTAL IMPACT ASSESSMENT

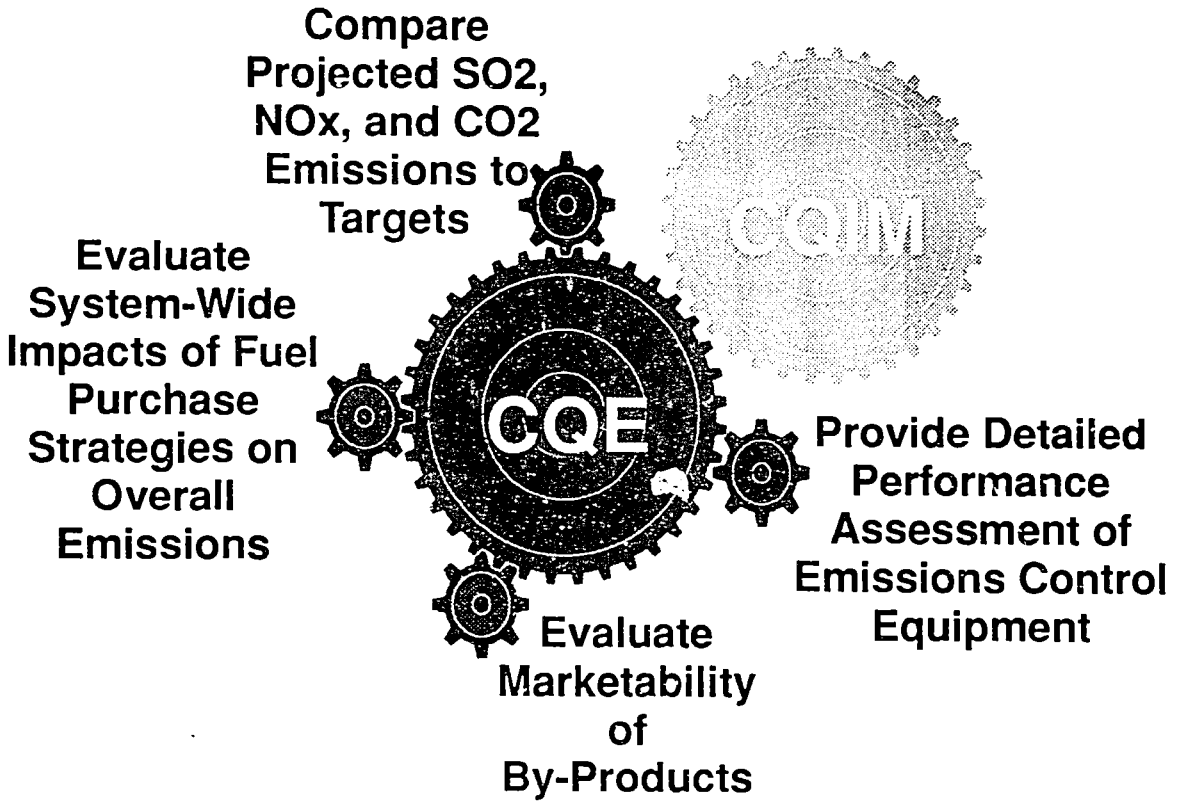

Figure 3. CQE Offers Extensive Environmental Analysis Capabilities

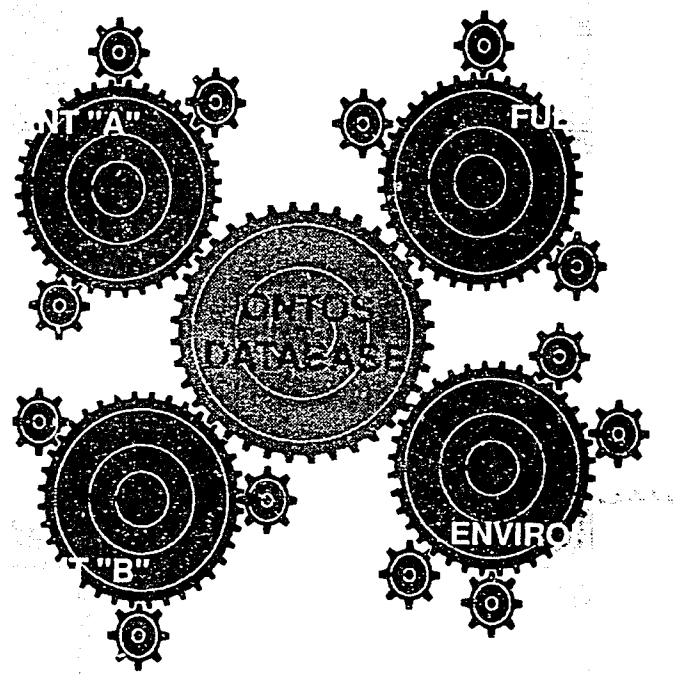

Figure 4. CQE Design Targets Effective Sharing of Data Between Various Users and Needs

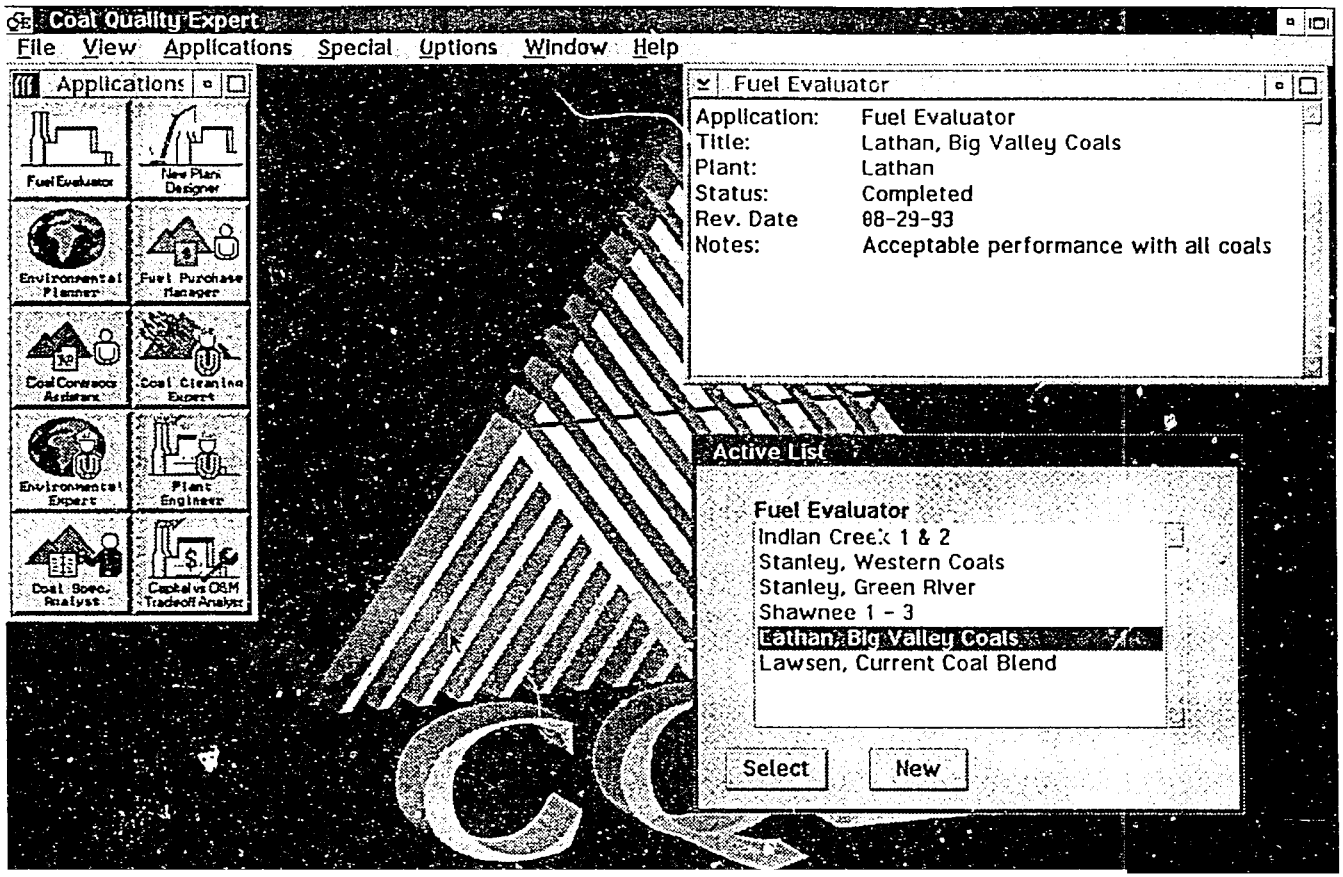

Figure 5. CQE Main Screen Display

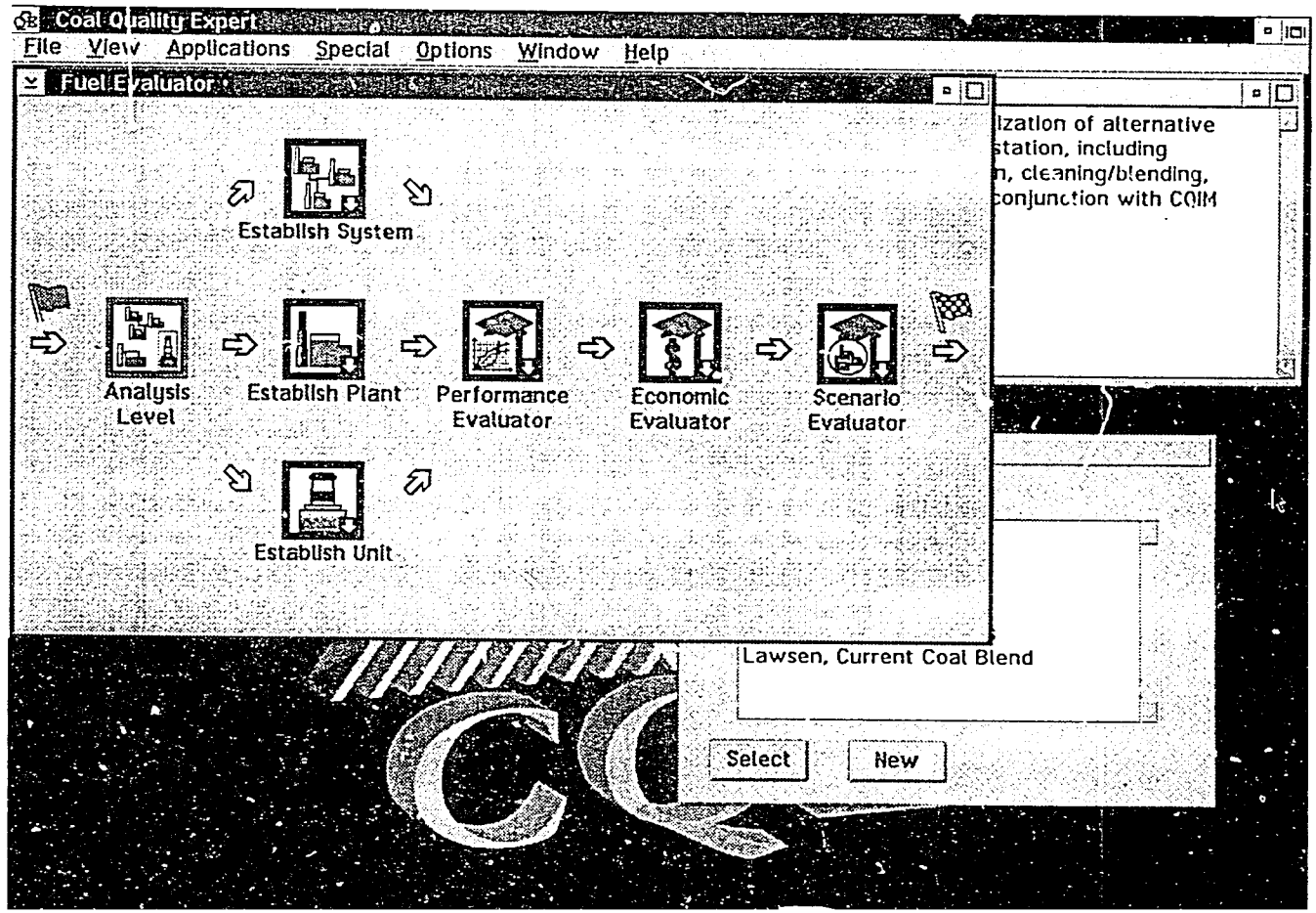

Figure 6. Fuel Evaluator Main Application Roadmap

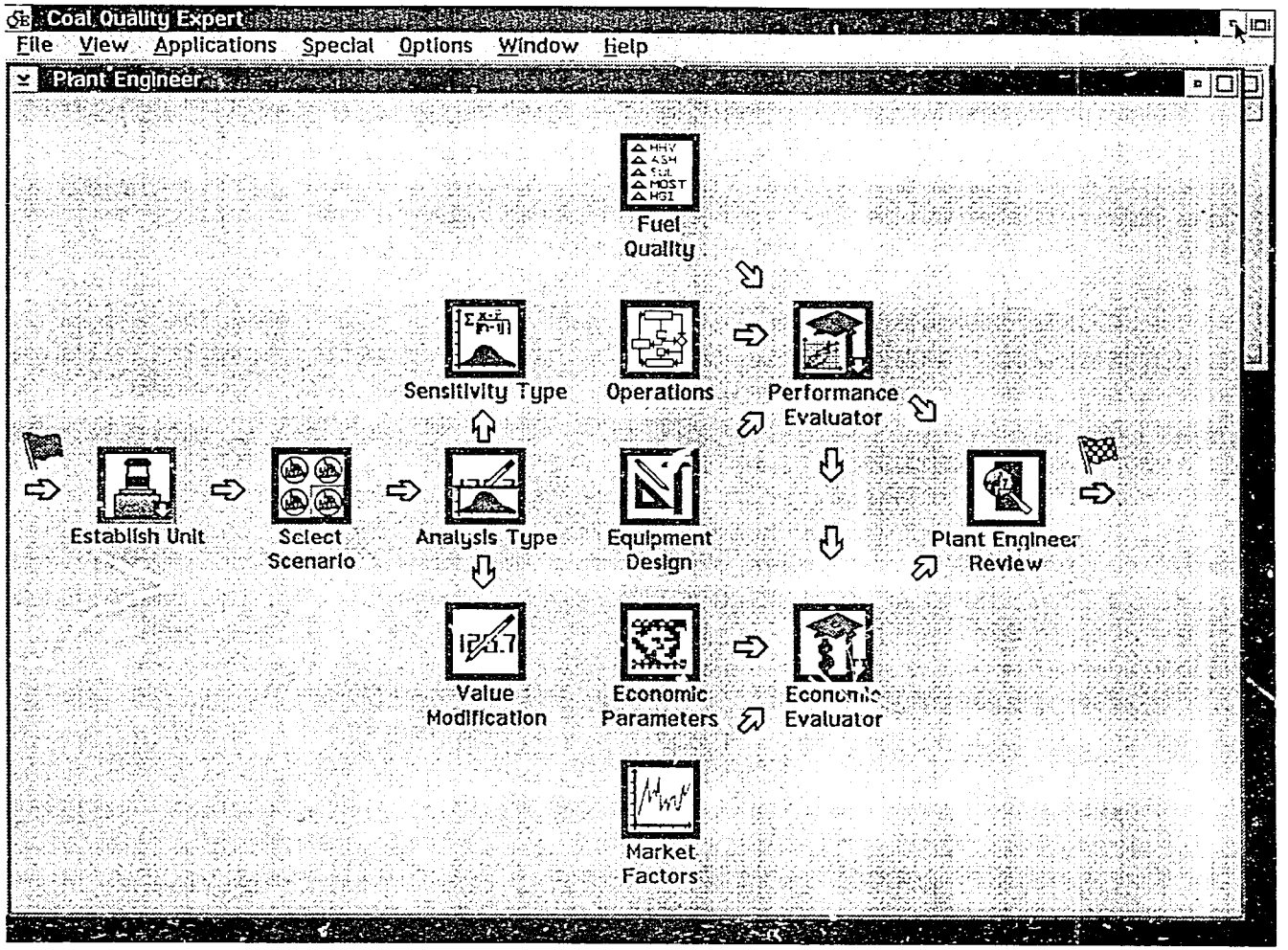

Figure 7. Plant Engineer Main Application Roadmap

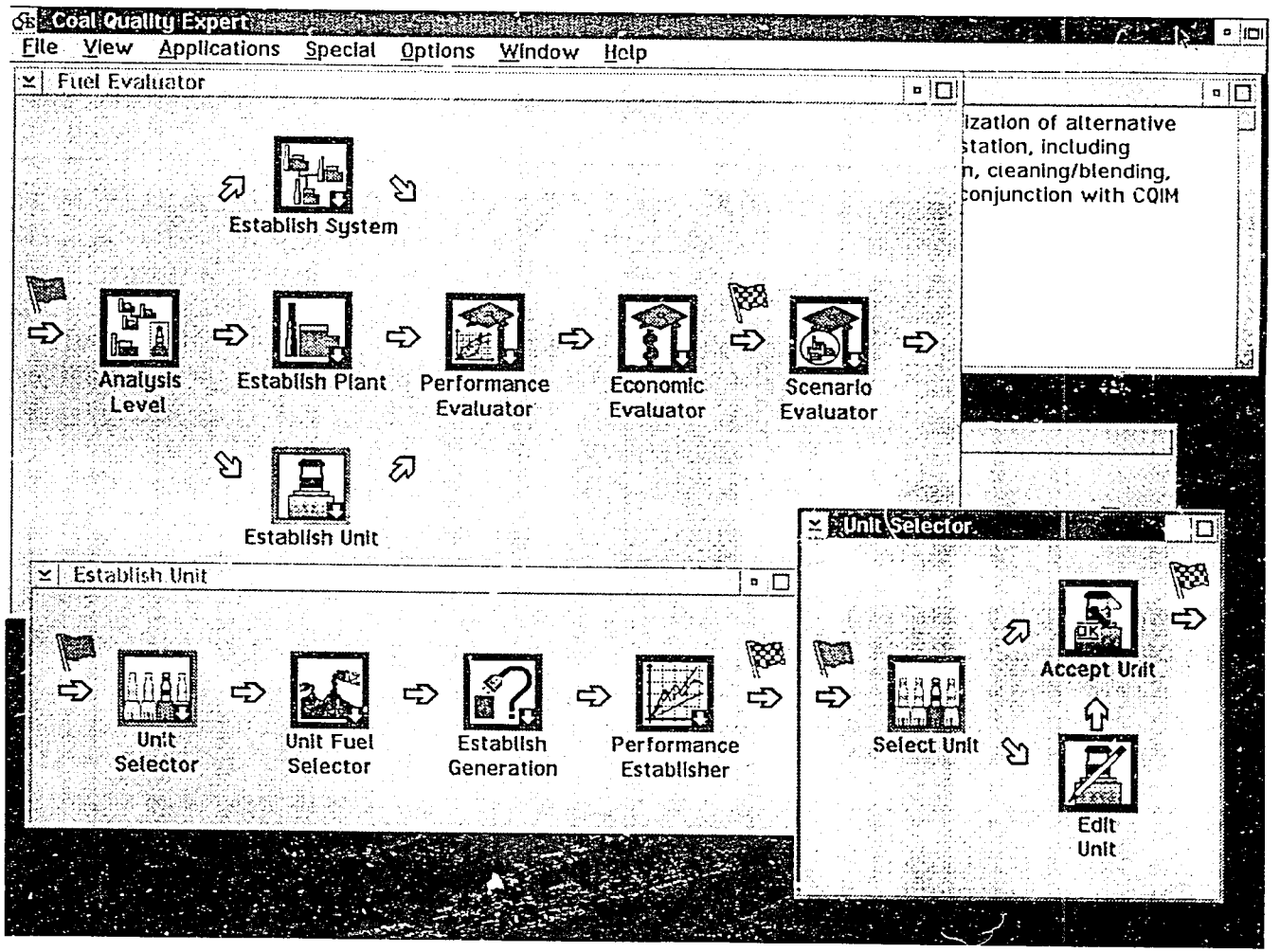

Figure 8. Expanding Application Roadmaps for Key Steps

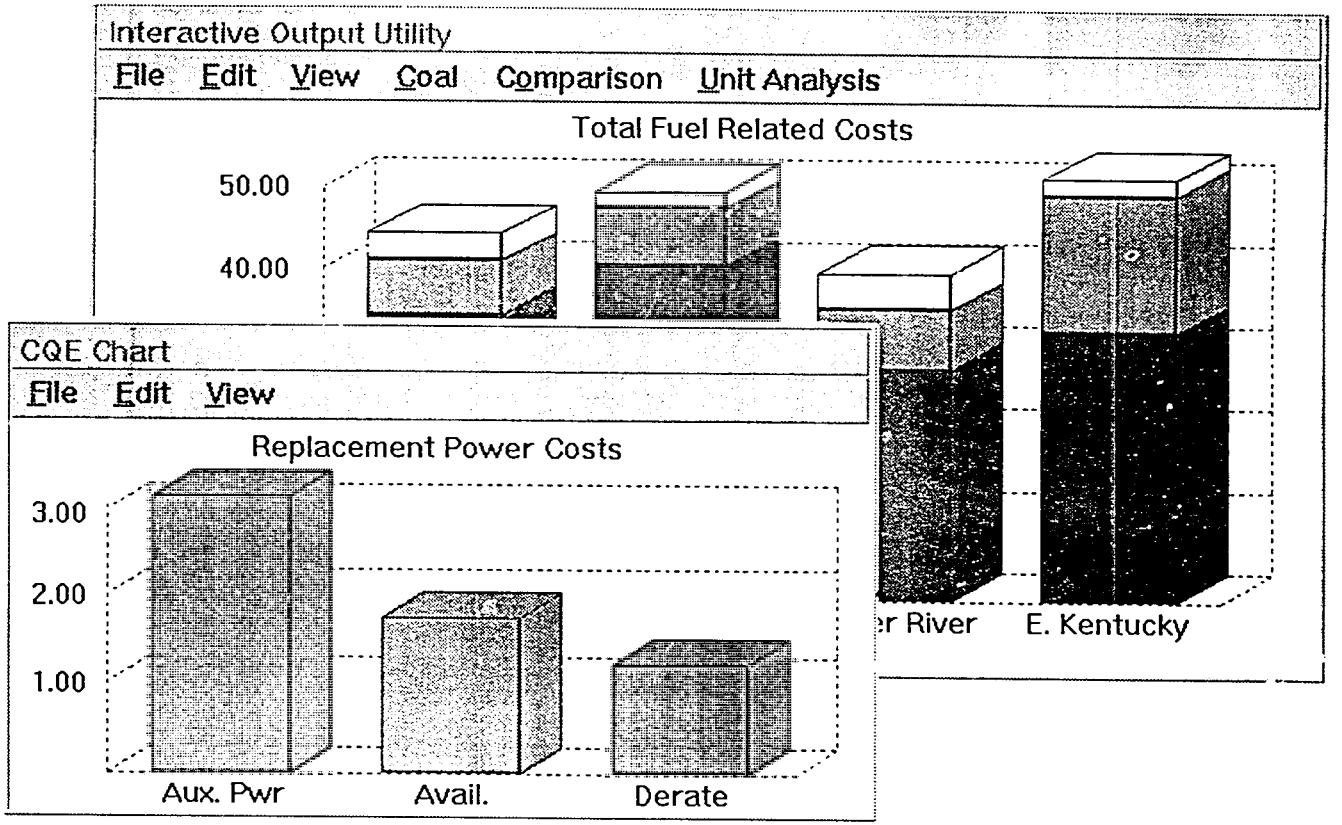

Figure 9. Business Graphics Explain Cost Differences Between Fuels

SESSION III

ENVIRONMENTAL CHALLENGES & OPPORTUNITIES

PLENARY SESSION III: ENVIRONMENTAL CHALLENGES & OPPORTUNITIES

Five distinguished Panelists participated in this discussion of the environmental challenges facing coal-based energy development in the Asia-Pacific region, and the opportunities for managing the economic/energy/environment issue. They were:

Alan Burrell, Manager, Power Division East
Asia Development Bank, Manila, Philippines

Robert Crick, Assistant Secretary
Resource Industries Policy Branch, Canberra, Australia

Akira Kinoshita, Assistant to the President
Electric Power Development Company, Tokyo, Japan

Kitti Kumpeera, Chief of Environmental Resources Division
Electricity Generating Authority (EGAT), Thailand

Isao Kurihara, General Manager
Tokyo Electric Power Company, Japan

They were asked to address the following six questions:

1. What are the environmental priorities for action by emerging economies of the Asia-Pacific Region regarding coal-based energy development?

2. How is the cost-benefit balance for environmental protection determined in an emerging economy with limited capital resources? What can it afford to do, and what can it NOT afford NOT to do, in protecting environmental quality?

3. Is electrification the most effective way to reduce pollution from small-scale coal combustion in developing countries (residential, commercial or small industrial furnaces)? Does electrification open up new avenues for different, more environmentally compatible, kinds of economic development - if so, what would be the major opportunities?

4. If there is a global effort to mitigate emissions of greenhouse gases, what types of "win-win" situations can be envisaged involving international cooperation to achieve the most cost-effective results?

5. How can emerging economies obtain access to the most current, reliable and unbiased information on technologies for clean, coal-based energy development? What type of information is most needed, and what are the most promising means of making it available?

6. How can foreign investment in coal-based energy respond to the environmental challenge in emerging economies, while maintaining the prospect of an attractive return? How important is the environmental issue relative to other barriers to this investment?

Responses from four of the Panelists follow.

Alan Burrell, Manager, Power Division East
Asia Development Bank, Manila, Philippines

1. Environmental Priorities

The Bank's developing member countries (DMCs) endeavor to find a compromise path between the pressing need to fill the demand-supply gap and simultaneously steadily improve environmental control of thermal power stations in response to public pressures. While highly advanced coal technologies like pressurized fluidized bed generation and integrated gasification combined cycle will not be available commercially until the beginning of the next century, a number of advanced coal technologies are rapidly coming onto the commercial market. These include fluidized bed boilers and high efficiency supercritical once-through boilers: the former enable DMCs to take advantage of technology which allows low quality, high ash and high sulphur coals to be burned cleanly at reasonably efficient levels of up to 37% (fluidized bed boilers); the latter provide access to the higher efficiencies (and consequent CO_2 reduction) becoming available pulverized coal boilers. There is a need for DMCs to approach the matter of legislating for stringent environmental conditionalities on thermal power plants with caution. Flue gas desulfurization is very expensive at about 15-20% of total project cost. The cost of FGD for a typical 1,000 MW coal-fired plant could cost about $150-200 million. If coal-fired power plants are burning low sulfur coal, and are located in low population/remote areas, it is clear that investments of this considerable magnitude would be better spent improving environment elsewhere in the country, say, in the cities and inland and coastal waterways. While it is not easy to make an across-the-board judgment on such issues, environmental improvement should be addressed on a "whole country" basis, rather than the singling out one particular aspect like thermal power generating stations.

2. Environmental Cost-Benefit Balance with Limited Capital Resources

The Asian Development Bank maintains continuous dialogue with the government authorities responsible for environment in its developing member countries. The environmental regulations of each country are compared with others both in Asia-Pacific and in developing countries, and also with internationally accepted standards (e.g. World Bank Environmental Guidelines). Appropriate environmental safeguards are agreed for projects to be financed by the Bank and the costs of these safeguards, (including appropriate resettlement procedures, particular design characteristics, etc.) to meet agreed environmental standards are added to the cost of the project. These in turn are included in the least-cost analysis undertaken for project selection, and the project would be eligible for financing if still remains the "least-cost solution". It is quite possible that because of falling oil prices, the least-cost solution of a power expansion program with strict environmental requirements could favor continued oil-fired generation rather than coal-fired with FGD.

3. Electrification

The average efficiency of power generation in the Bank's DMCs is only about 25-30 per cent. Since 70 per cent of the effective heat is wasted (unless used for cogeneration, district heating, etc.) it would appear wasteful to use electricity for domestic cooking or for small industrial or commercial furnaces. These are normally better fired with LPG or natural gas, if available. In particular instances, particularly if there is a severe risk of deforestation, or extreme urban pollution from open coal fires, then use of electricity would be justified. It would be hoped that the price mechanism would guide consumers in the right direction.

Electrification particularly opens up rural development, and in this regard rural electrification should be encouraged. Many countries are well advanced in this area; however, others including Sri Lanka and Indonesia have relatively low household electrification ratios, and while steps are being taken to correct this, it is necessary to place higher emphasis on slowing the urban drift of population, enabling higher efficiencies of food production and conservation, and avoiding deforestation.

4. International Cooperation

The Bank together with other multilateral institutions has adopted the "no regrets" policy with regard to emissions of green house gases. The Bank is encouraging adoption of advanced coal technology in developing countries as it becomes commercially available (for example, several countries have adopted fluidized bed combustion and India, Korea, China and others have adopted supercritical boilers for high efficiency power generation in their countries). A particular area which needs much more attention in Asia concerns supply side system losses, wherein many developing countries have distribution loss of over 25 per cent. It is the Bank's experience that the cheapest form of capacity addition to many developing countries is distribution reinforcement which effectively "releases" megawatts at a cost of only 15-40 per cent of the incremental cost of adding generating capacity. Energy efficiency and loss reduction components have become substantial parts of most Bank-financed power projects.

5. Technology Information Transfer

The Asian Development Bank encourages seminars and public awareness campaigns on all aspects of power conservation and efficiency. Prior to financing any capacity expansion project, extensive dialogue is held with governments and power utilities to establish if higher technologies than initially proposed would be appropriate for the country. Terms of reference for project design consultants are carefully written to ensure that commercially available clean coal technology is adopted wherever feasible. Initiatives by the International Energy Agency (IEA), EPRI, World Coal Institute and others with regard to advanced coal technology are firmly supported by the Bank.

6. Investment Climate

It is clear that the "image" of coal, and coal-fired thermal generation needs to be considerably improved. Populations generally perceive thermal power stations to be unsightly, dangerous from a health standpoint, and belching black smoke! This image must be improved by awareness campaigns, primarily from manufacturers. From the standpoint of the Bank, it is seen to be necessary that coal-fired power stations must be planned and designed many years ahead of their commissioning date. Sites should be identified; purchased and prepared far ahead of construction commencement. Such preparation would include protecting the area from squatter encroachment, the building of embankments to provide screening (together with trees, etc.) from external view, and public awareness campaigns in the area to enable proper resettlement to be accomplished with generous compensation, model resettlement villages, and livelihood programs for those affected by the project. The relatively minor investment in this aspect can pale to insignificance compared with the very high economic costs of such thermal plants being delayed by strong action from environmentalists and social objectors. The Masinloc 600 MW thermal power plant in the Philippines is a prime example in this regard, having been delayed at least four years from its original construction schedule at enormous economic cost to the country particularly during the severe load shedding periods in 1992 and 1993.

Robert Crick, Assistant Secretary
Resource Industries Policy Branch, Canberra, Australia

1. Environmental Priorities

At the present time I think the reality is that emerging economies of the Asia-Pacific Region are very much preoccupied with the need to meet the extremely fast growing energy demands being made upon their economics. This means that by and large the sorts of sophisticated environmental protection measures which have been and are being incorporated into coal based energy development in developed countries are not necessarily practicable for emerging economics in the Asia-Pacific Region.

Against this background it is important to stress the economic and environmental advantages of improved efficiency in coal burning. This will both improve the pace of economic development and facilitate meeting energy demands as well as improving the environmental conditions under which coal based energy programs can develop.

2. Environmental Cost-Benefit Balance with Limited Capital Resources

In very general terms the cost benefit balance must be determined by getting maximum energy output from minimum capital input. While this is undoubtedly a starting point it can be a very risky one. Each country will need to examine the implications of such an approach in order to make adjustments that can offset any particular environmental problems that might be contrary to a cost benefit balance.

Emerging economies should be able to afford to improve the efficiency of operations even at some additional capital cost because of the longer term savings in pure economic terms that this will bring about depending on location and quality of coal being used. Emerging economies, at least in some situations, will not be able to afford to take some additional environmental protection measures. This would apply for example if indigenous high sulphur coal were causing particularly excessive air pollution situations. Other situations might be that high moisture content coal would need to be subjected to additional capital infrastructure for drying in order to maintain basic efficiency. Highly industrialised countries may need to take other measures to ensure minimum air standards which if not implemented would cause severe health problems and ultimately slow down the very economic development that is being sought.

3. Electrification

While there is little doubt that electrification is a highly effective way of reducing such pollution and indeed of facilitating general economic development as well as improving living standards, there could be many situations in rural parts of Asia-Pacific emerging economics where electrification may not be the most immediate practicable answer. In such situations there are other effective means of reducing such pollution by providing improvements to household burning equipment and to the quality of the product being burned. Coal bricketing is a solution already being explored in such situations.

4. International Cooperation

The answer to this question relates to the issue raised under the first question above and one that was raised in much of the discussion at the conference. It is energy efficiency.

In the context of a global effort to mitigate emissions of greenhouse gases it must be remembered that the enhanced greenhouse effect if proven is a global problem. Effective solutions must be on a global scale. While recognising the particular problems and needs of developing countries there is no avoiding the reality that efforts made only by developed countries will do relatively little to alleviate any problems that might be caused to the environment by an enhanced greenhouse effect.

The best "win-win" situation is this context would be for developed countries to be encouraged to assist developing countries to mitigate emissions of greenhouse gases in ways which not only did not impede their economic development but actually assisted it through improved energy efficiency and other so called "no regrets" activities.

In due course there may be additional actions that may be taken to mitigate greenhouse gases which may be appropriate or even necessary in particular circumstances.

The crucial key to such a development is to provide methodologies particularly in the context of the framework convention on climate change for developed and developing countries to work together and to share the acknowledgment of their efforts to reduce greenhouse gases.

5. Technology Information Transfer

This conference itself is an important stage in identifying the sort of information that is needed and the ways in which it can be accessed. Hopefully the IEA will have recognised from this conference that if it is to provide real assistance to emerging economies in the Asia-Pacific Region it needs to have a much better tailoring of its approach to the particular needs that have started to be identified at the conference.

The Asia-Pacific Economic Cooperation Forum (APEC) has been addressing these sorts of issues for some time and will be an important forum in which developing countries in the region can work together to solve both economic development and environmental energy problems.

Australia for one is working bilaterally with regional economics in the Asia-Pacific Region in this particular area. There is undoubted scope for other developed countries to work on a similar bilateral basis.

There are also other international organisations that can and should have a role in this regard.

6. Investment Climate

It would seem that the primary answer to this question lies once again in energy efficiency. While it is understandable and obviously acceptable that foreign investors should be looking for an appropriate rate of return there is perhaps an additional onus on them to ensure that plant construction by them entails the most appropriate basic efficiencies. There may also be scope for introducing cost effective other environmental controls through negotiations with the host country. The bottom line will be striking that cost benefit balance we spoke of earlier.

Akira Kinoshita, Assistant to the President
Electric Power Development Company, Tokyo, Japan

1. Environmental Priorities
   a. Institutional Consolidation
   - Clarification of environmental administration
   - Establishment of regulations and transparent assessment procedures
   - Establishment of monitoring systems
   - Ensured recovery of environmental investments
   b. Standardization of plant design for new plants according to the development stage with focus on transfer of available commercial technologies centering on conventional high efficiency, particulate control, deSOx, waste water control, extensive use of ash in cement mixture and road filling, improved boilers and low-NOx burners.
   c. Intensification of review processes on the comprehensive urban/regional development planning including land use and transport systems for the purpose of reduction of total emissions.
   d. Introduction of integrated heat management requirements in formation of industrial complexes/parks.
   e. Intensified propagation of co-generation and CHP in any feasible level.
   f. Promotion of forestation programs.
   g. Encouraged commercial utilization of coal bed methane.

2. Environmental Cost-Benefit Balance with Limited Capital Resources
- We need to think beyond national borders. The "Joint Implementation" concept is useful even though much remains to be specified as to its mechanisms.
- A wide-ranging strategy mix is better than concentrating on limited options; this should center on energy efficiency improvement integrated with general strategies beneficial for reasons other than environmental protection and justifiable in their own right.
- It is also important to develop innovative financing in order to alleviate capital constraints to realize the genuine cost-effectiveness.
- Within capital availability, retrofitting is likely, but in general greater benefits would be realized by giving priority to new additions, given high growth of electricity demand. Coal cleaning could be an alternative depending on environmental requirements.
- It is, first of all, needed to study and establish assessment criteria prior to identification of cost-benefit balance. It should imply the context of total inputs vs. total outputs involving whole processes throughout inter-industrial linkages on the global basis.
- It is quite difficult to conclude larger cost-benefit balance in small scale decentralized units compared with integrated power systems. Of course, it depends on dynamics of size of demand.
- Many of the new energy sources regarded clean and fitting for the developing countries are not necessarily beneficial in the total context above.

3. Electrification

- Electrification has been driven by a growing needs for energy services uniquely provided by electricity for information technology including office innovation, automation, sophisticated control and cleanness in addition to the conventional use for lighting, heating, cooling and motive power. We have to recognize new dimensions of electricity as a strategic means for efficient development in the developing countries. No one denies the tremendous effects of TV as a most effective media for dissemination of information and knowledge to lead efficient sound development. Various versions of some Expert Systems may supplement planning and operating capacity. Wide-range Data Bases are sure to increase efficiency and effectiveness in development planning. Automation can supplement unskilled labor. Modern technology systems, in which sophisticated controls based on computer-monitored and automatic systems are embodied, can increase not only precision in manufacturing but also energy efficiency through technology progress.
- We have to accelerate the total analysis, including consideration of the fact that appropriate switching from fossil fuels to electricity saves energy and cuts emissions even when the fuels used to make the electricity are considered.
- Illustration of energy saving through switching to electricity.
  - Electric Mill/Blast Furnace: 50%
  - UV Drier/Gas Oven: 90%
  - Induction Melting/Gas Oven: 40%
  - Electric Vehicle/Gasoline Car: 30%
  - Microwave Oven/Gas Oven: 90%
  - Electric Heat Pump/Oil Furnace: 40%

4. International Cooperation

- We should recognize the potential benefits of efficiency improvement in the developing countries taking into account the existence of a large gap in energy efficiency between the developed and developing countries as well as faster and larger growth of their energy requirements. We can realize cost-effectiveness of investment in the developing countries on the world basis.
- Joint Implementation will contribute to promotion of wider-range and flexible technology cooperation to the developing countries.
- Any carbon tax mainly imposed in the industrial countries may accelerate carbon "leakage" to the developing countries,
- In order to realize the total efficiency in use of resources and to minimize emissions, increased attention should be paid to system-oriented integrated strategies involving comprehensive fusion of the supply and demand sides consolidated on the comprehensive regional and urban planning based on efficient space management. In this connection, we realize the beneficial opportunities in the developing countries abundant in flexibility in infrastructure planning. It is strongly suggested to develop comprehensive demonstration projects which practice technology cooperation as a package involving both hardware and software with focus on the particular region to realize a concept of the system-oriented total energy system integrated with regional and urban planning.
- Development of policy science research should be intensified on the international informal basis for the purpose of study of cooperation strategies in line with a new paradigm of sound development.

5. Technology Information Transfer

At this initial stage, priority should be given to information services on the institutional framework related to environmental management in the developing countries in order to meet needs of the technology suppliers. Given the actual limits in assessment capacity of the users in the developing countries, intensification of information on the side of the developing countries is considered more useful.

6. Investment Climate

- Voluntary technical standards, developed internationally, present an important means through which industries, governments, and institutions cooperate to define modes of environmental technology management. In this manner, promotion of voluntary international standardization of environmental management which involves specification of technology cooperation and related investments will enhance more specific business action initiative without bringing about frictions on trade.
- Prior to transfer of hard technology, consolidation of the institutional framework related to environmental and development management, including policy, measures, regulations, assessment procedures, monitoring and observance facilities is an critically important factor along with economic soundness, technical capacity and transparency of the decision-making system. In the meantime, it is required to facilitate international standardization related to costing, accounting and other appraisal criteria.
- The assurance of industry's autonomy is regarded as a basis for industrial activities centering on recovery of investment or immediate internalization of environmental costs. In particular in the developing countries, the market mechanism works imperfectly where price distortions derived from the considerable level of subsidies are common.

Isao Kurihara, General Manager
Tokyo Electric Power Company, Japan

1. Environmental Priorities

The pace of economic growth of the developing countries will be accompanied by growth in the field of electricity generation. An increase in the standard of living depends on the ability of the country to provide a reliable electricity network; however, a balance between socio-economic development and impacts on the environment must be found, and it will not be easy.

The environmental priorities are local pollution, acid rain, and CO_2. Authorities must concentrate on maximizing efficiency and reliability of existing and new generation to help maximize the output from a limited fuel supply and maximize the effectiveness of the capital investment. With regards to the transfer of technology, the appropriate technology must be recommended, taking into consideration the countries economic situation and future electricity demand.

As many deficiencies in the system are a result of inadequate attention to operating disciplines and maintenance practices, the developing countries must focus on:

- an educated, trained, stable work force
- standardized plant designs
- improved plant coal and water/steam quality
- plant assets life management
- plant sizing for flexibility and staff capability
- advanced equipment especially controls
- in-plant efficiency and reliability program

2. Environmental Cost-Benefit Balance with Limited Capital Resources

Socio-economic development and impacts on the environment are usually at odds with each other. To increase the standard of living, as well as the economic growth of the country, improving the electricity network is necessary. Unfortunately, any reductions in costs achieved due to increased capacity or improved efficiency are offset by increased costs due to pollution control.

A developing country cannot afford to do nothing. Through the implementation of basic, proven pollution technology, pollution control can be achieved with a minimum of costs, using the intelligent transfer of technology form the industrialized countries. The simple technology can allow the utility to improve the capacity and efficiency, to stabilize the work force, and ideally raise profits to further improve pollution control.

The role of the international banks must not be underestimated. The World Bank and the Asian Development Bank fund many types of development projects in developing countries. Projects dealing with improvements in the energy sector have not always been successful, because although the Bank supplies the financial capital, they cannot always supply the necessary unbiased technical expertise. The E7 Network is prepared to offer their expertise, to allow these financial institutions make the best environmental choice for their clients.

3. Electrification

Electrification can have an important impact, especially in heavily populated areas, like India or China. Mini-hydroelectric dams can be installed almost anywhere, and remote areas can profit from the new renewables - photovoltaics and wind power. Hydroelectric is a well proven technology, and can create jobs in the local economy, using local expertise alongside industrialized expertise. The role that the E7 Network is prepared to play is to analyze a region's situation, with the help of local authorities, and offer our advice to the decision makers regarding the best balance between electrification and environmental priorities.

4. International Cooperation

One of the main conclusions of the 1992 World Energy Conference in Madrid was that the developed countries must take the leading role in facilitating the transfer of energy technologies to the developing countries. Utilities in developing countries should have access to the technological expertise which has been accumulating in the developed countries for decades. If simple, effective, cheap, clean coal technologies can be implemented in a heavily populated area, like China, this will make a global impact on the environment. We will all profit from better air quality. That is why, in terms of the environmental transfer of technologies, the E7 network is ready to give, rather than sell, its unbiased advice.

5. Technology Information Transfer

The transfer of technology from industrialized countries to developing countries has great potential. The E7 Network of Expertise for the Global Environment is currently involved in accomplishing this transfer. The E7 has seen the need for global cooperation and has responded to it. Our Network has prepared a seminar on Clean Coal Technology, to present to the Chinese, in a seminar arranged by the E7, UNESCO and the Chinese government. A second seminar is still in the planning stage with another Chinese group, the China Council. The E7 is dedicated to using efficient and environmentally sound generation methods, but we may not always clearly recognize the needs of a developing nation. E7 assistance must be used to develop and encourage local expertise alongside the transfer of appropriate technology.

The type of technology that needs to be transferred must be already proven clean coal technology, rather than the sophisticated processes, which are complex, and at the moment, less cost effective. The "know-how" involved in a process should be emphasized, rather than the technology itself, and the training of engineers and technicians.

6. Investment Climate

Although each of the companies in the E7 does have its own investment interests, as the Chairman of the E7 Network I do not wish to answer this question as stated. With respect to the importance of environmental issues versus this investment, I can only say the E7 was so convinced that preventative measures are necessary at a world level in order to avoid the deterioration of the climate and the environment that they created the E7 Network of Expertise, in order to offer its advice to its clients, at a conceptual assessment level, free of charge. We do not intend, as a group of partners, to make any E7 investments on a commercial basis.

CLOSING SESSION

"COAL AND LIGNITE: THEIR ROLE IN ENERGY AND THE ENVIRONMENT"

MR. JOHN P. FERRITER
Deputy Executive Director
International Energy Agency

INTRODUCTION

Good Afternoon, Ladies and Gentlemen.

I am particularly pleased to be here in Hong Kong to address this *Second International Energy Agency Conference on the Clean and Efficient Use of Coal and Lignite*. The first Conference, in Budapest two years ago, had as a major theme the difficulties Central and Eastern Europe countries were having in restructuring their coal and electricity sectors. They faced major environmental problems and a declining energy market as energy intensive industries were confronted with the realities of competition and realistic input prices. Here in Asia, the context is different. Here there is steadily increasing energy demand, but existing and future use of coal and lignite are also meeting increasing environmental pressures. At the same time there are major opportunities for the introduction of cleaner and more efficient technologies which can bring substantial economic and environmental benefits. And that is what bring us together in Hong Kong.

I would like to thank the other sponsors of this conference (the American, Australian and Japanese Governments and the United Nations) together with the supporting organisations for having made this conference possible.

THE INTERNATIONAL ENERGY AGENCY

I would like to begin with a few words about the International Energy Agency, for the benefit of those not already familiar with the Organisation. The International Energy Agency was created in 1974, in response to the first oil shock to ensure its Members' collective energy security. At that time, the essence of energy security was seen as an uninterrupted oil supply. Attention focused primarily on developing emergency preparedness measures to respond to a major disruption in the international flow of crude oil, and on promoting long-term co-operation and research and development activities among Members to reduce their dependence on imported oil. While these activities continue today as fundamental elements of the Agency's work, events of the last several years, in particular the end of the Cold War, have dramatically altered the world political and economic scene, and thus changed the basic context in which world energy markets function:

- The economic restructuring under way worldwide, most notably in Central and Eastern Europe and the Newly Independent States of the former Soviet Union, coupled with the expected continuation of strong incremental energy demand growth in non-OECD Asia and elsewhere in the developing world, will have significant effects upon both the supply and demand sides of international energy markets -- these are now becoming truly "global".

- The resulting world energy balance is shifting, with the OECD now accounting for only half of global energy consumption.

- Energy markets generally have evolved, with deregulation and liberalisation resulting in their being driven more by market forces than through government intervention, although government involvement is clearly still required in certain instances.

- Environmental effects associated with the energy sector, from production through to consumption, have become increasingly vexing and compel innovative approaches to energy policy.

The challenge for energy policy makers in this evolving world will be to respond to aspirations for energy security, environmental protection, and sustainable economic growth -- what is frequently referred to as the 3 E's. Coal and Lignite can contribute to meeting these aspirations:

- First, coal is one of the world's most important and abundant fossil fuels; its share of many countries' energy mix and the wide distribution of reserves around the world enhance diversity, and thus increase energy security.

- Second, there is major scope for improving the efficiency with which it is used and for mitigating the pollution and other emissions that its production and use can cause.

- Third, coal and lignite are cheap compared with oil or gas, perhaps between a quarter and half the price for the same primary energy content. Many countries have economically viable domestic resources of coal or lignite. So coal and lignite can make a major contribution to providing the energy supplies needed to support sustainable economic development.

PROSPECTS FOR COAL

Against this background, what is the IEA's assessment of the prospects for coal? Earlier this year, the International Energy Agency published its ***World Energy Outlook*** to the year 2010. We forecast that total world energy demand could increase by almost 50 per cent, with OECD energy demand rising rather more slowly.

In this projection, we predict coal and other solid fuels will continue to have almost 30 per cent of world primary energy demand in 2010, roughly the same figure as in 1990. Worldwide, we expect an increase of almost 50 per cent in primary demand for solid fuels between 1990 and 2010.

Some parts of the world will see faster growth in coal demand than others. If we look just at this part of the world, namely East and South Asia (including China, but not Japan) use of solid fuels was almost 1000 million tons of coal equivalent in 1990, some 30 per cent of worldwide use. By 2010, we expect solid fuel use in this region to more than double to over 2000 million tons of coal equivalent, representing close to half of worldwide use of solid fuels. Put another way, we expect three-quarters of the worldwide increase in solid fuel use

over the two decades to occur in East and South Asia.

These numbers, more than anything else, show why addressing the issue of the clean and efficient use of coal and lignite is so important in this region, and why holding this conference in Hong Kong is so significant.

EFFICIENCY AND THE ENVIRONMENT

There is an essential need to improve the efficiency of coal and lignite use throughout the world. This will contribute significantly to sustainable economic growth and energy security, as well as reduce the environmental impacts. Electricity generation is the example most often quoted, though it is important to remember that more than 40% of coal use world wide does **not** go into power production.

Early in this century, no fossil fuelled power station anywhere could achieve a thermal efficiency above 10 per cent. Today, typical average efficiencies for pulverised fuel plants currently operating in the IEA countries are around 33 per cent, and the best new plants are capable of 40 per cent or more. New advanced technologies should be able to reach even higher figures.

These numbers make incredible differences. Taking just one country, China, our World Energy Outlook forecast assumes that thermal efficiency in power stations will rise from around 25 per cent in 1990 to around 33 per cent, i.e. the current IEA level, in 2010. This means that the fuel input required in 2010 will only be about three-quarters of that which would have been required for the same amount of electricity output at current levels of thermal efficiency in China.

In fact Chinese electricity demand is rising rapidly. And, if this efficiency improvement fails to occur, China would need to use an extra 180 million tons of coal equivalent, producing substantially increased emissions of carbon dioxide and other pollutants, as well as increasing fuel costs and thus hindering economic growth. The impact on the global environment of a 180 million tons of coal equivalent saving would be a reduction in emissions of around half a billion tons of carbon dioxide. This would more than offset the annual CO_2 emissions from all energy sources in Italy (or in France, or in Canada, or in Australia). In financial terms, the expected efficiency improvement by 2010 might be worth on the order of five billion US dollars a year in saved fuel costs.

Although Chinese use of solid fuels for electricity production is likely to be only a ninth of total world wide solid fuel use, the expected efficiency improvement will save 4 per cent of worldwide use. Scale up the numbers to include all countries where current efficiencies are below the best available technologies, and to include all industries and uses of coal and lignite, and the environmental and economic benefits of increased efficiencies become enormous.

Technologies which can achieve these efficiency improvements and other methods of mitigating the environmental impacts of coal and lignite production and use already exist. More are being developed and deployed each year, and you have discussed these in detail in

the workshops earlier this week. The value of the deployment of these technologies is substantial, whether it is measured in terms of fuel savings through efficiency, or through avoiding environmental damage.

TECHNOLOGY CO-OPERATION

The prospect of increasing energy demand means that further technology improvements are needed throughout the world. Energy research and technology is one of the major areas of international co-operation within the IEA. The development and adoption of improved technologies can significantly reduce and influence the nature of future energy requirements. Promotion of technology development and deployment by government can contribute significantly to mitigating and solving environmental problems. Intensified energy technology co-operation among IEA Member countries and with non-Member countries is an indispensable means to accelerate technology advances and to enhance long-term energy security and environmental protection.

Our co-operation on research and technology takes a number of forms. One involves representatives of the Member Governments meeting to review and discuss their policies and experiences. A second involves conferences such as this and its predecessor in Budapest. A third is through direct co-operation between Governments (or participants nominated by them) to undertake specific projects.

The largest and longest standing project of IEA technology collaboration is *IEA Coal Research*, originally established in 1975. With 14 countries and the Commission of the European Communities participating, it collates and disseminates information about coal, and undertakes technical and economic analyses. It provides easy low cost access to the most comprehensive information about coal available anywhere in the world.

Five other IEA collaborative projects are also focused on coal, namely: *Coal Combustion Sciences, Coal/Liquid Mixtures, Fluidised Bed Combustion, Testing of High-Temperature High-Pressure Filters,* and *Multiphase Flow Sciences.* In 1991 we established a project on Technologies related to Greenhouse Gases derived from Fossil Fuel Use, investigating abatement and control of Greenhouse Gas emissions and related issues. This year we established GREENTIE, a technology information exchange designed to facilitate access to information on energy and environment related technologies to players both from IEA Member countries and from the rest of the world. And we are currently setting up an Electric Power Technology Information Centre.

These projects and agreements are open to all IEA Member countries. There is also the possibility of associate participation by non-IEA countries. If you are interested in more information about these projects and how to participate, whether you come from an IEA Member country or not, many of the officials responsible for their establishment and operation are here at this Conference and would be happy to discuss them with you.

THE ROLE OF GOVERNMENTS

The workshops at this conference have covered a wide range of issues, from the

financing of clean coal projects to environmental strategies for governments. I am particularly pleased that you have had an opportunity to discuss strategies for financing clean coal projects, as the capital costs are often a major hurdle in the deployment of these technologies.

If one point is clear, it is that the role of government is to facilitate commercial activities, rather than replace them. Companies, not governments, produce and transport energy, and they do this more efficiently in markets where they face commercial pressures and rewards. Key aspects of government policy should include the following points:

- Prices should not be held below costs and, to the extent necessary and practicable, the environmental costs of energy production and use should be reflected in prices. This will create an automatic balance for decisions to invest in new supply against decisions on end use efficiency and conservation. Without proper pricing at all stages of the energy chain, new initiatives are less attractive and project financing becomes almost impossible.

- Free and open trade and a secure framework for investment are needed to contribute to efficient energy markets and energy security. Barriers and distortions to energy trade and investment should be avoided. If there is a lesson for the rest of the world from the IEA experience, it is that such protection is rarely justified in the longer term, and merely prolongs the pain and cost of the inevitable adjustment.

- The environmentally sustainable provision and use of energy are central to the achievement of energy policy. Governments need to aim to minimise the adverse environmental impacts of energy activities, just as environmental decisions should take account of the energy consequences.

- Government support for research, development and market deployment of new and improved energy technologies can make a critical contribution to achieving energy and environment objectives. Energy technology policies should complement broader energy policies. International co-operation in the development and dissemination of energy technologies, including industry participation and co-operation with other governments, should be encouraged.

In summary, governments need to set the stage and, in some areas, set out the rules of the game for energy market participants, so that companies can operate competitively and efficiently, and thus produce results which are satisfactory in terms of energy, environment and economic objectives.

CONCLUSION

In conclusion, we at the IEA believe that coal and lignite will continue to play a vital role in national and international energy markets. Their use can aid energy security and economic development. Producing and using coal and lignite more cleanly and more efficiently will mitigate the environmental impacts of increased energy demand, and will help lead to sustainable economic development. Deployment of new and improved coal related technologies will play a critical part in meeting the growing world demand for energy. And that is why we are here today and why this Conference has been so topical and important.

Closing Remarks of Jack Siegel

The conference was a great success for several reasons:

(1) It was very substantive as summarized by the Workshop session chairs and Sergio Garribba in his closing statement.

(2) Because it was a collaborative effort with the UN, the World Energy Council and individual countries which enabled

- a pooling of resources
- a pooling of expertise, and
- cross fertilization among organizations with common interests but different charters

(3) Because of the conference planning process which reached out to stakeholders throughout the world to obtain ideas on the context and format of the conference.

(4) Because of the opportunities, created by the conference design, for informal discussions among participants.

However, the full value of the conference will not be realized without follow-up. Therefore, it is the intention of the IEA to develop a program for follow-up. Your input is desired and needed.

Finally, the conference could not have succeeded without the hard work of a lot of people and organizations. Of special note are:

- The conference sponsors

  - the United Nations
  - the World Energy Council and its' U.S. affiliate the U.S. Energy Association
  - The U.S. AID and the U.S./Asia Environmental Partnership
  - and the Governments of the U.S, Japan and Australia.

- The Host country, Hong Kong and Mr. Gordon Siu, Secretary for Economic Development.

- Hong Kong Electric and China Light and Power Companies.

- The session chairs, co-chairs, speakers and conferences participants.

And, a special note of thanks to Barbara McKee, without whose attention to details the conference would not have been as successful.

KEY FINDINGS AND OPPORTUNITIES FOR ACTION

by Sergio F. Garribba
Director
Energy Technology and R&D
International Energy Agency

Ladies and gentlemen, distinguished speakers and guests, good afternoon. This has been, I believe, a great Conference. Most of the countries of South and East Asia with interests in coal use and activity were represented here as well as all the Member countries of the IEA which have significant coal technology expertise and programmes. We also had the six elements of the coal equation all present: governments, coal producers and users, constructors and technology developers, financing organisations, and regulators.

The Conference was timely and unique. In the announcement it was stated that the Conference had four main themes and leading objectives: first, to gain better understanding about the coal outlook towards the next century and the corresponding coal supply and demand trends; second, to assess the status of coal and lignite technologies and their development prospects; third, to analyse the conditions that may determine the adoption of efficient and environmentally clean coal technologies, with a view to the special needs of the countries of the Asia-Pacific region; and fourth, to identify means and opportunities for better government-industry interaction and enhanced international co-operation.

I believe that all these objectives were met. With regard to the first objective, the coal outlook, it was clear from the presentations of the IEA, the World Energy Council, the World Coal Institute and others, that during the next 20 years or so the largest part of the incremental coal demand, let us say more or less three fourths of this demand, will concentrate in the countries of South and East Asia, and China. Clearly, the exact figure will depend upon a number exogenous variables that refer to trends in the world price of oil, economic growth and the possible impact of new environmental policies. But the aspect which is worthy recalling is that the Asia-Pacific region will be the source of most of the new coal in the years in front of us. Different data and projections all indicate that by the year 2010 the new coal demand and supply in the Asia-Pacific region will be in the range of one billion tons per year.

Correspondingly, there will be an enormous investment in new power plants, coal production and transport infrastructures. We can make a rough guess and assume that the total investment, excluding coal plant operation, could vary between 0.5 and 1.0 trillion US dollars to be compared with much less money that will flow into the coal system of other regions of the world. We know that two major driving forces in technology progress are investment and market, so it is easy to predict a continuing and even more pronounced shift in coal technology innovation from OECD Europe and the Atlantic region towards the Pacific Basin.

Coal Technology Prospects

The second objective of the Conference was to analyse coal technology status and its prospects for further evolution. Again, I think that this Conference did a tremendous job. Of course, it was not amongst the goals of a Conference like the one we had to reach consensus. There was agreement however, on one important point: coal cannot be conceived as a physical commodity, rather it represents a service embodying a complex technological chain and organisational network. Along this view, if countries are to benefit in the future from the enormous, low-cost coal reserves, a variety of efforts are necessary: to develop and demonstrate new "clean coal" technologies; to reduce uncertainty over environmental regulation and allow users maximum flexibility in their actions to comply with the goals of environmental protection; to provide regulatory incentives to offset financial risks in the commercial deployment of new clean coal technology; to reduce the cost, investment risk, and environmental impact of converting coal into other fuels; and to confront head-on the need to reduce carbon dioxide emissions.

In the electricity sector, clean coal technologies can substantially improve efficiency and contain emissions from power plants. In recent years the thrust toward utility applications of these systems has become much stronger. The new coal technologies are entering the large-scale demonstration phase of development and could be ready for commercial deployment by the end of the 1990s. Advanced technologies such as integrated gasification combined cycle, circulating and pressurised fluidised bed combustion, hybrid combined cycles have been under development for many years but there have been few applications to commercial utility power generation to date. Coal gasification is well established for commercial service in other industries, while fluidised combustion has been growing in importance for industrial boiler applications. However, it has been noted during the Conference that electric utilities of IEA countries have been hesitant to move away from the familiar pulverised coal-fired boiler and steam turbine combination, which has served the electric industry so well for many years. With the addition of flue gas desulphurisation and some form of NO_x control, the pulverised coal-fired boiler has

maintained its position as the norm for utility undertakings in industrialised countries. Several utility representatives noted that the clean coal technologies still have to show their competitiveness in the absence of proven track records from which the operational reliability and overall performance could be established. A number of Conference speakers also remarked that few baseload power plants of any kind are being built in IEA countries and such a construction gap provides a narrow window of opportunity for commercialising the new generation of coal technologies.

As a result, I can say that a largely shared view in this audience, was that the commercial deployment of advanced coal technologies would require the sustained commitment by governments and others to build further demonstration facilities necessary to resolve the remaining technical and economic issues facing each of the new coal technologies. These conclusions parallel very much the results of a recent enquiry conducted by the Global Climate Committee of the IEA's Coal Industry Advisory Board. Most of the respondents believed that clean coal technology is currently too expensive, and a vastly different type of technology involving chemical processes and gas turbines. Because clean coal technology systems were not yet commercially proven, it was perceived that the investment risk was just to high, particularly if no national or international support was forthcoming. This is a point which is also included in the communiqué issued by the IEA's Energy Ministers on 4th June 1993 where Ministers "call upon the IEA to expand international co-operation, information exchange and technology dissemination to provide incentives for and eliminate barriers to clean coal technology deployment".

The need to identify and differentiate among global, regional and local environmental problems was mentioned in the context of gaining a better understanding of the issues involved, as well as formulating and prioritising viable solutions to such problems. The existence of contrasting perceptions and priorities of countries at different levels of economic and technological development was highlighted. Technologies transferred from one country to another can not always be expected to perform in the same way, it has been said. Performance would vary according to the local level of expertise and the education of workers, as well as the type of infrastructure and other social and cultural factors.

Compared with IEA countries, the developing countries of the Asia-Pacific region show significant differences in the use of coal in the type of environmental concerns they have to face and in the local conditions. It has been said for instance, that in China about two thirds of coal demand are in the non-power sector. Coal fires were recalled as a major problem in one of the inland provinces. There is an apparent paradox here, the general trend is towards the

globalisation of the technologies and the markets, yet quite a few local situations require the development of site-specific and context-specific solutions such as more efficient ovens, burners and small boilers, technologies for coal briquetting and beneficiation. Particularly, there is the need to attach high priority to technology and management systems that use cleaner production approaches to environmental protection and management practices such as coal benefication, as opposed to end-of-pipe solutions, such as SO_2 and NO_x removal from stack gas. Cleaner and more efficient coal production and use technologies reduce both the utilisation of material and energy and the production of waste and environmentally harmful releases.

Barriers and Incentives to Effective Coal Technology

With regard to the conduct of and the barriers to the deployment of effective coal technology, the attention of Conference participants focussed on the general context and on problems that may affect and determine the capacity of absorb technologies in the developing and newly industrialising countries. In the post-Rio context renewed efforts are being made with a view to moving beyond broad political statements and towards formulating effective policy responses in the area of technology that will avoid further ecological degradation, particularly in the developing countries and in countries undergoing the process of transition to market economy. Environmental concerns should be an integral part of coal technology transactions, proceeding from the development and adaptation of the coal technology, through its acquisition, use, and operation and maintenance.

The necessity to identify specific environmental needs was reiterated numerous times. It was agreed that many of these needs vary from country to country. Moreover, distinct domestic conditions are likely to lead to differing emphasis on regulating environmental impacts. The potential for conflict between environmental concerns and international trade is increasing it has been said, as it became an issue in the current Uruguay Round of the General Agreement on Tariffs and Trade. The conflict also reflects the sharp contrast between developed and developing countries over the responsibilities towards regional and global environment. Although no country wishes to be seen as a pollution haven, many developing countries seem reluctant to take the lead in raising their environmental standards and adopt environmentally clean coal technologies for fear of jeopardising what might provide a comparative economic advantage or attraction for new investment. However, as numerous experts highlighted during the Conference, there is the emerging recognition in developing nations that environmental and development objectives must become more compatible if a sustainable future is to be forged. Speakers reported on the Technical Seminar of the APEC Experts' Group on Clean Coal Technology which was held in Chiang Mai, Thailand on 6th-10th September and expressed the

view that the Asia Pacific Economic Co-operation Forum can perhaps become the best platform to debate and possibly resolve these conflicts at a regional level.

It was argued that liberalised trade and investment will produce the financial resources that developing countries and countries in transition towards market economy might use for environmental improvements. Quite a few Conference participants said that this will not happen unless a country has incentives and a supportive infrastructure in place for an effective environmental management.

Governments of developing countries and countries in transition towards market economy are increasingly showing the desire to attract foreign direct investments for environmentally sound technologies through a number of policy instruments, such as tax holidays, grants, subsidising a portion of pollution control expenses and assisting in waste disposal. Yet, foreign direct investments are purely commercial ventures and are therefore undertaken only when the political, economic and technical climates are considered suitable for long-term profitability. I believe this Conference made clear that open markets, a stable and trasparent economic climate, including predictable environmental regulation, constitute the best enabling conditions for fruitful coal technology co-operation and involvement. As a consequence, modernising government structures provides an important starting point from which to enhance environmental performance. These reform measures should extend to the important area of government R&D activities, where a refocus on improving the commercialisation of clean coal technologies is essential. Other important factors that may facilitate coal technology co-operation would be full cost pricing, the availability of skilled personnel and good governance. In cases involving several players, co-ordination would also improve the process.

Opportunities and Means for International Co-operation

Regarding international collaboration on clean coal and lignite technology with developing countries and countries in transition towards market economy, it has been said by several experts in the course of the Conference that successful experiences of coal technology adoption and adaptation show that there is no mechanical transfer of technology, rather there should be a co-operative relation that may develop into a fully-fledged joint venture and partnership. Any coal technology "transplant" would be bound to fail unless there is a parallel and joint work between the parties on a number of preconditions relating to the context, such as: public and private institutional capacity building; policy and fiscal regulatory reform; and strengthening of the financial framework.

Conference participants remarked that this co-operative approach may receive added momentum because of the implementation process of the UN Framework Convention on Climate Change. Although no concrete targets with timetables for greenhouse gas emissions stabilisation were included in the Framework Convention, OECD countries agreed in essence to adopt national policies and take measures consistent with the objective of returning their anthropogenic emissions of carbon dioxide and other greenhouse gases to the 1990 levels by the end of this decade. But a few countries, in analysing their forecasted emissions vis-à-vis their announced targets have acknowledged that meeting them might be harder (or more costly) than originally expected. Policy makers are finding attractive the idea of investing in emissions reduction projects in other countries where such projects would be more cost-effective than trying to achieve an equivalent reduction within their own countries. This is a derivative of the idea of emissions trading which is being variously called "clearinghouse for projects", "joint implementation" or "compensation measures", and which might greatly affect technology co-operation in the coal area.

Very many suggestions and proposals have been put forward during this Conference on how to adapt coal technologies to specific contexts and uses, on how to cope with environmental concerns and requirements of good performance and economic efficiency while integrating the environmental concerns. Quite a few of these suggestions and proposals appear to ask for enhanced or new international co-operation mechanisms and in this respect, the IEA intends to do its part.

I do not need to repeat that in the coal and clean coal technology area there are strong players and the predominant work takes place in industry and utilities. But governments have a long-standing commitment to clean coal technology development, and the problems encountered in the developing countries should be in the forefront. Governments can affect the direction of investments, technical leadership, environmental standards and regulations, and the adoption of an integrated energy, economic and environmental policy approach.

The existing international co-operation on energy technology amongst IEA Member countries appears to offer firm ground to further initiatives. The IEA's Implementing Agreements are multilateral contracts drawn up to suit the requirements of individual participants or contracting parties representing government interests. As it has been explained in the course of the Conference, these Implementing Agreements set down the commitments of the contracting parties and establish a management structure to ground the international co-operation. Private organisations and industrial entities may be willing to become contracting parties because they can ease the financial risk and take advantage of ventures involving several countries, or

produce more effective results with wider commercial applications than can be achieved by one industrial entity going it alone. Non-Member countries may also wish to participate as associate contracting parties and share the benefits of the international co-operation on an equitable ground.

I would like to invite the representatives of those countries which are not a contracting party to the IEA's Implementing Agreements in the coal technology area to consider joining. The scope and interest of the IEA Coal Research centre has been variously recalled. IEA Coal Research is an international collaborative project for the exchange of technical, economic and environmental information about the coal and related industries. Review and assessment reports are prepared and specialised data bases which are unique in their detail and breadth of coverage. The IEA Coal Research centre was established in 1975 and is supported by the governments of fourteen IEA Member countries and the European Commission. The participation of countries from South and East Asia, all international organisations and national coal producers and users groups is encouraged.

I will then quote a few amongst the several means which have been suggested and discussed for facilitating international co-operation on environmentally sound coal and lignite technology. Five inter-related means are as in the following.

First, Conference participants said that demonstration projects are needed to show the effectiveness and appropriateness of clean coal technologies to specific country applications. Demonstrations can be designed to display an individual technique or technology and disseminate systems where know-how is shared, so that users can make an educated decision on the type of equipment to purchase. Two or three advanced large-scale coal technology demonstation plants were described during this Conference, as they are being proposed for construction in the Asia-Pacific region. I assume that practical ways to exchange information and better co-ordinate the initiatives may be worthy consideration and some debate.

Second, is coal technology training. Conference participants stressed the fact that many technology skills could not be easily transferred but must be developed through hands-on experience. Consequently, the importance of skill formation and know-how accumulation appear to be necessary conditions for successful adoption and adaptation of clean coal technology. Training should be provided to all employees at all technical and managerial levels, aiming at continuously enhancing environmental awareness. Particular attention would be needed at the management level, where policies are set, as well as in the coal plant, where the activity takes place. To this purpose, coal technology supply contracts should include relevant result-oriented

skill development and training programmes. These would, in turn, increase absorptive capacities in developing countries and countries in transition towards market economy.

Third, the establishment of interutility centres or other mechanisms has been advocated to disseminate and share information about successful applications and adaptation of environmentally sound coal technologies. The interutility centres should appraise the needs of potential users, evaluate technology options and projects, promote joint coal and lignite R&D programmes. Teaming could also be considered between electric utilities to exchange operational experience and technology.

Fourth, developing countries may wish to consider the creation of "one-stop shops" which could assist potential coal investors obtain all required information on investment conditions from one source. These "shops" would centralise the information available within the country on all aspects of national conditions related to the transfer of technology. They would act as a referral mechanism to provide data, assistance on regulatory and institutional aspects, consulting and other services relevant to coal technology deployment.

Fifth, is the new financial means to promote the diffusion of environmentally sound coal technologies. Overseas development aid, although desirable, is not enough it was said. Rather, a more entrepreneurial approach is required in searching for future projects with environmental and economic pay-offs. One possible suggestion for consideration by national and intergovernmental bodies, has been the creation of an "environmentally sound technology rights bank" as an intermediary that would acquire patent rights to clean coal technologies and make them available to developing countries under favourable terms. Other suggestions referred to joint venture coal technology development and commercialisation involving enterprises from developed and developing countries. A hallmark of this apparoch is that developing countries participate directly in the preparation and adaptation of innovative coal technologies, and thus are able to influence the outcome. Next, there would be the build-operate-transfer arrangements, especially for the construction and operation of big coal facilities and infrastructures. In these arrangements a private company would build the coal project, operate it long enough to pay back its debt and to achieve a return on equity, and then transfer the project to the host country.

Final Remark

Finally, on behalf of the IEA, I would like to thank once more, those organisations that contributed to the success of this Conference and wanted to sponsor or co-sponsor this event.

I should mention the Conference Steering and Organising Committees and their individual members who defined the goals of the Conference. The concept which was originally formulated in the IEA's Committee on Energy Research and Technology and the Working Party on Fossil Fuels, was eventually provided with structure, programme and action. In particular, our thanks should go to Dr. Jack Siegel, Chairman of the Working Party on Fossil Fuels who contributed with support, enthusiasm and thrust. It was an extraordinary experience to share views and engagements with him. Then there is the commitment and extraordinary work performed by Dr. John Tilley, IEA's Head for Energy Technology Collaboration, by Mr Henry Bottomley, IEA's Principal Administrator, by Mrs Barbara Mc Kee, Director for International Programme Co-ordination, Office of Coal Technology of the US Department of Energy, and by Dr Roger Le Gassie, Chairman of the Committee on Technology Collaboration of the US Energy Association. I believe they deserve a warm applause. But the success of the Confeence is mostly due to the continuing work of those who followed its oganisation day by day, and to the Chairmen, Co-Chairmen, Rapporteurs, speakers and participants, who gave ideas, activated discussion and presented new and practical proposals for future action. I think that some of us will have the opportunity to meet again and share our accumulated experience.

It is the intention of the IEA to keep the Conferences that we organise or co-organise as practical as we can and to provide these Conferences with adequate follow-up. Proceedings will be published and the proposals for international collaboration that you made, or quite a few of them, will be brought to the attention of governments and policy-makers through the IEA Working Party and Committee system. I hope we will be able to tell policy and decision makers, and the general public that clean coal technology is plenty of options for coping with the three big "ees" and challenges that were mentioned so many times during these three days, energy security, economic development towards sustainability and environmental protection. Perhaps we will recall this event in Hong Kong as the begnning of a new thinking and course of action. Let us therefore say that we will continue to work in our respective countries and organisations and together towards achieving a common agenda for coal and lignite technology progress in this region of the world.

Thank you ladies and gentlemen for your attention, have a safe return to your respective homelands and countries.

CONFERENCE PROGRAMME AND COMMITTEES

CONFERENCE PROGRAMME

MONDAY
29 NOVEMBER

REGISTRATION

6:00 p.m. - 9:00 p.m.

TUESDAY
30 NOVEMBER

REGISTRATION

7:30 a.m. - 10:00 a.m.
4:00 p.m. - 8:00 p.m.

SITE VISIT

Castle Peak Power Station - departing 8.30 a.m. from the JW Marriott and returning at approximately 2:00 p.m.

Lamma Power Station - departing 9:30 a.m. from Queen's Pier and returning at approximately 2:00 p.m.

WEDNESDAY
1 DECEMBER

8:00 a.m. - 12:15 p.m.
OPENING SESSION

Co-Chairs
S. Garribba, Dir., Energy Technology, Research and Development, IEA - Paris
J. Siegel, Acting Asst. Sec. for Fossil Energy, USDOE, U.S.

8:00 a.m. - 10:00 p.m.

FORMAL OPENING OF CONFERENCE
S. Garribba

WELCOME TO THE CONFERENCE PARTICIPANTS
G. Siu, Secretary for Economic Services, Hong Kong Governor's Office

REMARKS AND INTRODUCTION OF KEYNOTE SPEECHES
J. Sullivan, Dir., Office of Energy and Infrastructure, USAID, U.S.

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REMARKS AND INTRODUCTION OF KEYNOTE SPEECHES
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KEYNOTE SPEECHES - I

- World Energy Outlook and Technology Challenges
  ***S. Garribba**, Dir., Energy Technology, Research and Development, IEA - Paris*
- Coal and Lignite: The Needs and Concerns of Developing
  and Industrialising Nations
  ***C. Ji**, Under Sec. Gen., UN*
- The World Energy Council and the Findings of Its Commission
  ***I. Lindsay**, Sec. Gen., World Energy Council*
- Perspectives of the People's Republic of China
  ***Minister S. Wang**, Ministry of Coal Industry, PRC*
- Perspectives of the Government of India
  ***Minister N.K.P. Salve**, Ministry of Power, India*

10:00 a.m. - 10:30 a.m.—*Coffee Break*

10:30 a.m. - 12:15 p.m.

KEYNOTE SPEECHES - II

- The Perspectives of Coal Suppliers and Users
  ***J. Williams**, Managing Director, Shell Coal International, Ltd., U.K.*
- The Reality of Coal and Coal Technology
  ***A.C. Toohey**, Chief Executive, World Coal Institute*
- The Technological Pathway for Coal
  ***J. Siegel**, Acting Asst. Sec. for Fossil Energy, USDOE, U.S.*
- Coal in the 21st Century
  ***R. Higgins**, Exec. Dir., Minerals and Fisheries Group, Dept. of Primary Industries and Energy, Australia*
- Coal Technology Options, International Cooperation and Partnership
  ***M. Ichikawa**, Dir. Gen., Coal Dept., Agency of Natural Resources and Energy, Japan*

12:15 p.m. - 2:15 p.m.—*Lunch*

2:15 p.m. - 4:00 p.m.
PLENARY SESSION I
Asia Pacific Coal Use Strategies: Needs, Plans and Opportunities

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Co-Chairs

***J. Wilcox**, Deputy Chairman of ACTT, Australia*

***I.M. Sahai**, Chairman and Managing Dir., Power Finance Corp. Ltd., India*

OPENING REMARKS OF THE CO-CHAIRS

OVERVIEW THEME ADDRESSES

- Strategies for Financing Coal Technology Deployment
  K. Jechoutek, Division Chief, Industry and Energy, World Bank, U.S.
- Development and Demonstration of Superior and Sound Coal Use Technologies
  A. Kunito, Managing Dir., Electric Power Development Co., Japan
- Integrating Improved Coal Technologies Into Regional Energy Systems
  S. Boedihardjo, Dir., Engineering Service Center, PLN, Indonesia
- International Collaboration and Partnering for Effective Selection, Demonstration and On-going Use of Clean Coal Technologies
  A.M. Ferrer, Vice Pres., Stone & Webster Engineering Corp., U.S.

DISCUSSION

4:00 p.m. - 4:30 p.m. *Coffee Break*

4:30 p.m. - 6:00 p.m.
REGIONAL FORUMS
Opportunities for International Collaboration

Moderators

K. Jechoutek, Division Chief, Industry and Energy, World Bank, U.S.

S. Sadiq, Director, Energy and Industry Department, Asian Development Bank, Philippines

PEOPLE'S REPUBLIC OF CHINA

A. Tan, Dir., Dept. of International Cooperation, Ministry of Electric Power

F. Zhou, Dir., Energy Research Institute

INDIA

R.K. Sachdev, Advisor, Ministry of Coal

P. Ghosh, Senior Fellow, Tata Energy Research Institute

REGIONAL FORUMS (continued)

INDONESIA

K. Samadikun, Dir., General Planning, PLN
B. Purnomo, Head, Bureau for Electric Power and Energy, BAPPNAS

REPUBLIC OF KOREA

Representatives from Korea

MALAYSIA

M. Nor, Dir. Gen., Dept. of Electricity Supply, Ministry of Energy

PHILIPPINES

D. Peralta, Vice Pres., Planning Services, National Power Corp.
R. Bomasang, Under Sec., Dept. of Energy

THAILAND

K. Kumpeera, Division Chief, EGAT
S. Tridech, Deputy Sec. Gen., Ministry of Science, Technology and Environment

VIETNAM

L. Le, Vice Minister of Energy, Ministry of Energy
Q. Tran, Director, Institute of Energy

7:00 p.m. - 9:00 p.m.
OPENING RECEPTION
Sponsored by Australia

THURSDAY 2 DECEMBER

8:00 a.m. - 11:45 a.m.
PLENARY SESSION II
Asia Pacific Coal Use Strategies: An Integrated Approach

Co-Chairs - Session 1
S. Chun, Dir., Pittsburgh Energy Technology Center, Office of Fossil Energy, USDOE, U.S.
K. Zheng, State Science and Technology Commission, PRC

8:00 a.m. - 9:45 a.m.
OPENING REMARKS OF THE CO-CHAIRS

PLENARY ADDRESSES

- Environmentally Sound Technologies for Sustainable Development
  ***J. Sullivan**, Dir., Office of Energy and Infrastructure, USAID, U.S.*
- Strategies for Financing Coal Technology Transfer, Centering on Build-Own-Transfer
  ***D. Hutchinson**, Operating Mgr., Hopewell, Hong Kong*
- Improved Coal Technologies for the Asia Pacific 21st Century Economic Development
  ***G. Preston**, Vice Pres., Generation & Storage Div., EPRI, U.S.*
- Integrating Coal Use into Korean Energy Systems
  ***H. S. Moon**, Chairman of the Board, Korea Electric Power Corp., Korea*

DISCUSSION

9:45 a.m. - 10:15 a.m.—*Coffee Break*

10:15 a.m. - 11:45 a.m.

PLENARY ADDRESSES *(continued)*

Co-Chairs - Session 2

***K. Yokobori**, Exec. Dir., Organizing Committee, World Energy Council, Japan*

***K. Kumpeera**, Div. Chief, EGAT, Thailand*

OPENING REMARKS OF THE CO-CHAIRS

PLENARY ADDRESSES *(continued)*

- Coal in Power Generation: How the E7 Looks at Technology Transfer to the Developing Countries
  ***D. Kallmeyer**, Dir. Head of Fossil Fired Power Plants RWE Energie, Germany*
- Environmentally Aware Technologies: Challenges, Opportunities and Strategies
  ***J. Rackley**, Vice Pres., R&D, Babcock & Wilcox, U.S.*
- Clean Coal Technology Development, Dissemination and Cooperation Through CCT Center of Japan
  ***H. Okamoto**, Dir., Project Promotion, New Energy Development Organization, Japan*
- International Cooperation in Addressing Coal Technology Transfer and Public Perceptions on the Reality of Coal
  ***G. Gallizioli**, Dep. Dir. Gen., ENEL, Italy*
- The Reality of Coal Technology for Today and Tomorrow
  ***D. Pai**, Chair. and Pres., Foster Wheeler Development Corp., U.S.*

DISCUSSION

11:45 a.m. - 1:45 p.m.—*Lunch*

1:45 p.m. - 5:30 p.m.
PARALLEL WORKSHOPS - PART A

A(1) FINANCING
A(2) TECHNOLOGY OPTIONS/OVERVIEW
A(3) TECHNOLOGY OPTIONS/EMISSIONS CONTROL, COAL PREPARATION AND CLM FUELS
A(4) REGIONAL NEEDS
A(5) ENVIRONMENTAL STRATEGIES

(For the complete listing of workshop papers, see workshop schedule on the following pages.)

6:15 p.m. - 7:30 p.m.
PANEL: Perspectives from the Press

Panel Moderator
R. LeGassie, Chair, Committee on Technology Collaboration, USEA; Vice Pres., TMS, Inc., U.S.

The panel will comprise various members of the press. Confirmed panelists include:

C. Goldstein, Chinese Affairs Correspondent, Far Eastern Economic Review, Hong Kong
J. Higgins, Editorial Dir., Coal Publications, U.S.

7:30 p.m. - 9:00 p.m.
RECEPTION
Sponsored by Exxon Energy, Ltd.

FRIDAY
3 DECEMBER

8:00 a.m. - 11:45 a.m.
PARALLEL WORKSHOPS - PART B

B(1) COOPERATION AND PARTNERSHIP
B(2) TECHNOLOGY OPTIONS/DESULFURISATION AND INTEGRATED GASIFICATION COMBINED CYCLE
B(3) TECHNOLOGY OPTIONS/PYROLYSIS AND FLUID BED COMBUSTION
B(4) REGIONAL NEEDS AND PUBLIC OUTREACH
B(5) ENVIRONMENTAL STRATEGIES

(For the complete listing of workshop papers, see workshop schedule on the following pages.)

1:45 p.m. - 3:30 p.m.
PLENARY SESSION III
Environmental Challenges and Opportunities (Panel)

Panel Moderator
I. Torrens, Dir., Environmental Control Systems, EPRI, U.S.

A. Burrell, Managing, Power Division, Asian Development Bank

A. Kinoshita, Asst. to the Pres., Electric Power Development Co., Japan

I. Kurihara, Gen. Mgr., Office of International Relations, TEPCO, Japan

H. Wang, National Environmental Agency, PRC

3:30 p.m. - 4:00 p.m.—*Coffee Break*

4:00 p.m. - 5:30 p.m.
CLOSING SESSION

Co-Chairs
S. Garribba, Dir., Energy Technology, Research and Development, IEA - Paris
J. Siegel, Acting Asst. Sec. for Fossil Energy, USDOE, U.S.

OPENING REMARKS OF THE CO-CHAIRS

CLOSING KEYNOTE SPEECH

J. Ferriter, Dep. Exec.Dir., IEA - Paris

REPORT OF CHAIRS FROM WORKSHOPS

CONFERENCE SUMMARY

—Key Findings and Opportunities for Action
S. Garribba
J. Siegel

CONCLUDING REMARKS

WORKSHOP A(1)
FINANCING

Co-Chairs
***R. Gentile**, Vice Pres., International Affairs, KFx, Inc., U.S.*
***A. Kinoshita**, Asst. to the Pres., Electric Power Development Co., Japan*
***Rapporteur: K. Langer**, Mgr., Energy and Environment, US-AEP/TR&D, U.S.*

1:45 p.m. - 3:30 p.m.
OPENING REMARKS OF THE CO-CHAIRS

WORKSHOP PAPERS

J. Beardsworth, Hunton & Williams, "Barriers to investment in Emerging Power Markets," U.S.

P. Jezek, Private Power Advisor, Ministry of Mines and Energy, "Project Financial Strategies and Privatisation," Indonesia

R. Sargent, Ahlstrom Development Corp., "Financing of Privatized Power Plants Using Indigenous Fuels," U.S.

M. Agata, Special Advisor to the Governor, The Export-Import Bank of Japan, "Financing Approaches for Asia/Pacific Development," Japan

3:30 p.m. - 4:00 p.m. -- *Coffee Break*

4:00 p.m. - 5:30 p.m.
WORKSHOP PAPERS *(continued)*

F. Denny, Vice Pres., Engineering and Fossil Fuels, Edison Electric Institute, "Process for Encouraging Investment and Technology Cooperation in the Electric Power Industry," U.S.

R. Bibb, President, Bibb and Assoc., Inc., "Assisting Financability Through Rate Structure Design," U.S.

D. Ding, Dep. Chief Engineer, CTIC, "Dealing with Financing Issues," PRC

W. Holland, Partner, LeBoeuf, Lamb, Leiby and MacRae, "Financing Energy Projects and Technology Collaboration," U.S.

WORKSHOP A(2)
TECHNOLOGY OPTIONS/OVERVIEW

Co-Chairs
***S. Jansson**, Mgr., Science and Technology, ABB Carbon AB, Sweden*
***K. Ramakrishnan**, Corp. Dir., Bharat Heavy Electricals, Ltd., India*
***Rapporteur: M. Soliman**, Sr. International Prog. Officer, USDOE, U.S.*

1:45 p.m. - 3:30 p.m.
OPENING REMARKS OF THE CO-CHAIRS

WORKSHOP PAPERS

A. Armor, Dir. Fossil Power Plants, EPRI, "Coal Technology Selection Methods and Tools for New Power Generation and Environment/ Performance Upgrading," U.S.

U. Hauser, Engineering Mgr., ABB Kraftwerke AG, "Highly Efficient Pulverised Coal-Fired Power Plants," Germany

A. M. Ferrer, Vice Pres., Stone & Webster, "Systematic Coal Utilization/ Technology Options Evaluation Process," U.S.

B.C. Misra, Dir., Central Mine Planning & Design, Ltd., "Development of Coal Utilisation Technologies," India

D. Simbeck, Vice President, Technology, SFA Pacific, Inc., "Coal Utilization in China: Technology Options by Sector," U.S.

3:30 p.m. - 4:00 p.m. -- *Coffee Break*

4:00 p.m. - 5:30 p.m.
WORKSHOP PAPERS *(continued)*

G. Moumdjian, Head of Thermal and Nuclear Energy, University of Sofia, "Development and Option of Retrofit and New Technologies for Low-Rank Coal," Bulgaria

B. C. Misra, Dir., Central Mine Planning & Design, Ltd., "Production of Coal-Based Domestic Fuel: An Environmentally Friendly Technology," India

M. Matei, Fuel and Chemical Methods Mgr., ICEMENRG, "Coal Technology for Developing Countries," Romania

J. Topper, Commercial Director, British Coal Corp., "Technology Options for Industrial, Commercial, and Residential Applications," U.K.

F. Emmett, Partner, Sargent & Lundy, "General Overview of Emerging Clean Coal Technology in the U.S. as Applicable to Asian Countries," U.S.

P. Bosak, Senior Geologist, GMS, Czech Republic

WORKSHOP A(3)
TECHNOLOGY OPTIONS/EMISSIONS CONTROL, COAL PREPARATION AND CLM FUELS

Co-Chairs
D. Cain, *Mgr., Environment and Coal Research, Pacific Coal Pty. Ltd., Australia*
M. Nor, *Dir. Gen., Dept. of Electricity Supply, Ministry of Energy, Malaysia*
Rapporteurs: M. Takahashi, *Project Mgr., Energy and Environmental Strategies, Electric Power Development Co., Japan;* ***R. Stuart,*** *Head of Coal & Uranium Dept., Australian Bureau of Agriculture and Resource Economics, Australia*

1:45 p.m. - 3:30 p.m.
OPENING REMARKS OF THE CO-CHAIRS
WORKSHOP PAPERS

I. Webster, GHG Program Director, IEACR Greenhouse Gas R&D Program, "Carbon Dioxide Capture and Disposal as a Greenhouse Gas Abatement Option," U.K.

V. A. Iyengar, Dir., M.S. Iyengar & Assoc., "Clean and Efficient Use of Coal and Lignite Through CO_2 Stabilization," India

K. Sullivan, Global Climate Committee, CIAB, "Improved Coal Utilisation Technology: Potential to Reduce Carbon Dioxide Emissions"

H. Feibus, Chair, IEA/CLM Executive Committee, "CLM: An Integrating Approach to Preparation, Transport and Use of Coal," U.S.

D. Dunlop, Pres., Fuels Management Inc., "Clean Competitive Coal Water Fuels," U.S.

3:30 p.m. - 4:00 p.m.-- *Coffee Break*

4:00 p.m. - 5:30 p.m.
WORKSHOP PAPERS *(continued)*

T. Yamada, Gen. Mgr., Technology/Energy Development Dept., Idemisttsu Kosan, "Clean and Efficient Coal Handling Systems: Development of Coal Cartridge System (CES)," Japan

P. Ling, Senior Preparation Engineer, Ministry of Coal Industry, "New Development of Processing for Coal Beneficiation," PRC

D. Yang, Pres., MTI, "Advanced Flotation: Packed Column Froth Separation for Fine Coal Cleaning," U.S.

T. Hamieh, Professor in Physical Chemistry, CNRS, "Significance of Recent SCI Advances to Future of Coal Liquid Mixtures," France

S. van Hoften, SGI International, "Low Grade Coal Upgrading: Application of the Liquids from Coal (LFC) Technology to Coals in the Pacific Rim," U.S.

WORKSHOP A(4)
REGIONAL NEEDS

Co-Chairs
***F. Remondino**, Dir., North America Office, Italy*
***K. Sridhar**, Dep. Gen. Mgr., National Thermal Power Corp., India*
***Rapporteurs: L. Petrakis**, Chair, Dept. of Applied Science, Brookhaven National Laboratory, U.S.; **M. Tsang**, Mgr., International Affairs, China Light & Power Co., Ltd., Hong Kong*

1:45 p.m. - 3:30 p.m.
OPENING REMARKS OF THE CO-CHAIRS
WORKSHOP PAPERS

D. Boyd, Exec. Gen. Mgr., Coal & Allied Industries, Ltd., "Integrating Improved Coal Technology into Regional Energy Systems," Australia

M. Daniel, Head of Supply Transport and Markets, IEACR, "Asia-Pacific and Europe: Comparison of Coal Prospects/Opportunities," U.K.

W. Gouse, Senior Vice Pres., MITRE, "Regional Analysis and Architecture of the Whole Energy System," U.S.

T. Kashiwagi, Professor, Tokyo University of Agriculture and Technology, "Efficient Use in Integrated Regional Energy Systems," Japan

R. M. Sultan, Chief Inspector of Mines, Dept. of Labour and Manpower, "The Role of Coal in the Development of Pakistan," Pakistan

3:30 p.m. - 4:00 p.m.—*Coffee Break*

4:00 p.m. - 5:30 p.m.
WORKSHOP PAPERS *(continued)*

F. von Bismarck, Head of Lignite Planning Section, Ministry for Environment and Regional Planning, Brandenburg, "Changes in German Lignite Mining: Just the Effects of Reunification," Germany

M. Moubaraki, Engineer, Ministry of Energy and Mines, "Some Considerations on Imported Coal and the Environment in Morocco," Morocco

M. Novak, TE-TOL, "Indonesian Coal for Environmental Value in Slovenia Cogeneration Plants," Slovenia

W. Willson, Senior Research Advisor, Energy Research Center, "Low-Rank Coal Water Fuel (LRCWF's): Commercial Demonstration," U.S.

R. Grundy, Principle Minority Staff, U.S. Senate Committee on Energy and Natural Resources, U.S.

E. Sichome, Mech./Energy Conservation Eng., "Coal Use: An Overview of Southern African Countries with Zambia in Particular," Zambia

WORKSHOP A(5)
ENVIRONMENTAL STRATEGIES

Co-Chairs
***B. Worthington**, Exec. Dir., USEA, World Energy Council, U.S.*
***S. Tridech**, Dep. Sec. Gen., Ministry of Science, Technology and Environment, Thailand*
***Rapporteur: R. Crick**, Asst. Sec., Coal Branch, Dept. of Primary Industries and Energy, Australia*

1:45 p.m. - 3:30 p.m.
OPENING REMARKS OF THE CO-CHAIRS

WORKSHOP PAPERS

G. Schramm, Advisor, World Bank, "Environmental Manual for Power Development," U.S.

A. Tesfai, Project Development Mgr., AES Corp., "Developing Greenfield Clean Coal Technology Plants and Rehabilitating Old Coal Plants with Clean Technology," U.S.

C. Nair, Managing Dir., ERM, "Environmental Impacts," Hong Kong

Y. Yu, Chief, Central Coal Mining Research Institute, "Overview of Coal Use and Efficient Future Technology," PRC

3:30 p.m. - 4:00 p.m. *Coffee Break*

4:00 p.m. - 5:30 p.m.
WORKSHOP PAPERS *(continued)*

A. Chiewwattakee, Sr. Economist, Dept. of Energy Development and Promotion, "Reducing Environmental Impact From Using Coal and Lignite in Thailand," Thailand

L. Miller, Dep. Asst. Sec. for Clean Coal, USDOE, "Yesterday's Fuel, Today's Concern and Tomorrow's Solution: Achieving Environmental Acceptability with Clean Coal Technologies," U.S.

K. Connor, Sr. Assoc., Decision Focus, Inc., "Air Emissions From Coal-Fired Power Plants: Challenges and Opportunities," Hong Kong

R. Kaminski, Raytheon Engineering & Constructors, U.S.

WORKSHOP B(1)
COOPERATION AND PARTNERSHIP

Co-Chairs

***B. McKee**, Dir., International Program Coordination, Office of Coal Technology, USDOE, U.S.*

***C. Wang**, Pres., China Huaneng Group, PRC*

***Rapporteurs: J. Wilcox**, Deputy Chairman of ACTT, Australia*

***A. R. Jack**, Scientific Services Officer, China Light & Power Co., Ltd., Hong Kong*

8:00 a.m. -9:45 a.m.

OPENING REMARKS OF THE CO-CHAIRS

WORKSHOP PAPERS

R. LeGassie, Chair, Committee on Technology Collaboration, USEA; Sen. Vice Pres., Technology & Management Services, Inc., "New Approach to Technology Collaboration," U.S.

J. Topper, Commercial Dir., Coal Research Establishment, "Improving Coal Use in Developing Countries Through Technology Transfer," U.K.

S. Schweitzer, Chief, Energy Innovation and Private Sector Division, USAID, "USAID Experience in Cooperation and Partnership," U.S.

J. Lin, Engineer, Nanjing Coal Mining Machinery Factory, "Promoting International Cooperation of Coal Patent Technology Development," PRC

L. P. Reade, Dir. General, US-AEP, "How US-AEP Programs are Supporting Energy, Environment and Economic Development," U.S.

9:45 a.m. - 10:15 a.m.—*Coffee Break*

10:15 a.m. - 11:45 a.m.

WORKSHOP PAPERS *(continued)*

K. Ramakrishnan, Corp. Dir., Bharat Heavy Electricals, Ltd., "Technology Transfer and Technology Options - An Indian Experience," India

B. Worthington, Exec. Dir., USEA, "International Utility Partnership Program," U.S.

J. Tilley, Head, Energy Technology Collaboration Div., IEA, "Role of Multilateral Cooperation in Technology Development and Deployment - The IEA Experience," IEA - Paris

Z. Lu, Assoc. Research Prof., Energy Research Institute, "Coal Technology in China: Options, International Cooperation and Partnership," PRC

T. Abe, Senior Staff, International Cooperation Dept., Center for Coal Utilization, "Comprehensive Promotion of Coal Use Technology and International Cooperation for Transfer of Appropriate Technology," Japan

WORKSHOP B(2)
TECHNOLOGY OPTIONS/DESULFURISATION AND INTEGRATED GASIFICATION COMBINED CYCLE

Co-Chairs
***H. Feibus**, Chair, IEA/CLM Executive Committee, U.S.*
***M. Zhang**, Chief Engineer of Boiler Research Dept., Thermal Power Research Institute, PRC*
***Rapporteur: M. Willingham**, Technical Advisor in Energy and Environment, UN*

8:00 a.m. - 9:45 a.m.
OPENING REMARKS OF THE CO-CHAIRS

WORKSHOP PAPERS

J. Klingspor, Dir., Technology Development, ABB Environmental Systems, "Advanced 'Stealth' Wet Flue Gas Desulfurization," U.S.

I. Smith, Head of Environmental Group, IEACR, "Flue Gas Desulfurisation for Coal-Fired Power Generation in the Asia-Pacific Region: An Overview of Best Available Options," U.K.

R. Meyers, Mgr., Chemical Technology, TRW, Inc., "Gravimelt Process for Coal Desulfurization and Demineralization," U.S.

R. J. Batyko, Mgr., Environmental Projects, Babcock & Wilcox, "Available Technologies for Flue Gas Desulfurization in Thermal Power Plants," U.S.

9:45 a.m. - 10:15 a.m. — *Coffee Break*

10:15 a.m. - 11:45 a.m.
WORKSHOP PAPERS *(continued)*

N. Nagasaki, Senior Engineer, Hitachi, Ltd., "Total Energy Systems Centering on IGFC," Japan

O. P. Rao, Scientist, Council of Scientific & Industrial Research, "Techno Economic Feasibility Assessment of Integrated Gasification Combined Cycle (IGCC) Power Generation Technology with High Ash Indian Coals," India

S. Tam, Mgr., Advanced Process, Bechtel Corp., "Indirect Coal Liquefaction Via Fischer-Tropsch Technology for Baseload IGCC Plant," U.S.

S. Li, Beijing Research Institute of Coal Chemistry, PRC

WORKSHOP B(3)
TECHNOLOGY OPTIONS/PYROLYSIS AND FLUID BED COMBUSTION

Co-Chairs
***D. Ding**, Dep. Chief Engineer, CITIC, PRC*
***Y. Jia**, Vice Chairman, Admin. Committee, WEC, PRC*
***Rapporteur: J. Forrer**, Group Mgr., Technology & Management Services, Inc., U.S.*

8:00 a.m. - 9:45 a.m.
OPENING REMARKS OF THE CO-CHAIRS

WORKSHOP PAPERS

T. Kawamura, Senior Researcher, Nippon Steel Corp., "Coal Complex Centering on Coal Pyrolysis," Japan

E. Someus, Dir., Product Control, "Cleaning of Sulphur Contaminated Coal with Product Control Indirect Flash Pyrolysis Technology," U.K.

B. Ion, Head, Mech. Equip. Eng. Dept., Energy Research and Modernization Institute, "Solid Fuels Energy Technology and Environment," Romania

P. Rozelle, Vice Pres., EFH Coal Co., "Meeting Needs of Regional Systems Through Coal Preparation Circuit Design for Multiple Markets," U.S.

9:45 a.m. - 10:15 a.m. --*Coffee Break*

10:15 a.m. - 11:45 a.m.
WORKSHOP PAPERS *(continued)*

Y. Li, Dir., and D. Qiu, Professor, INET/ITEESA, "Circulating Fluidized Bed Gas-Steam Cogeneration and Its Environmental Assessments," PRC

R. Skowyra, Engineering Mgr., Fluidized Bed Steam Generation, ABB Combustion System, "Design Considerations for Utility Size CFB Steam Generators," U.S.

S. Jansson, Mgr., Science and Technology, ABB Carbon AB, "Pressurized Fluidized Bed Combustion—Efficient, Clean and Compact Power Generation," Sweden

T. Ogawa, Asst. Gen. Mgr., EPDC, "Technology Integration in Efficient and Clean Coal Use for Utilities," Japan

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WORKSHOP B(4)
REGIONAL NEEDS AND PUBLIC OUTREACH

Co-Chairs
K. Seiki, Exec. Dir., Global Industrial and Social Progress Research Institute, Japan
K. Mak, Officer-in-Charge, Energy Resources Branch, Dept. of Economic and Social Development, UN
Rapporteur: B. Peters, USAID Coordinator for India, PETC, USDOE, U.S.

8:00 a.m. - 9:45 a.m.
OPENING REMARKS OF THE CO-CHAIRS
WORKSHOP PAPERS

M. Su and S. Gu, Asst. Prof., INET/ITEESA, "Case Study: Integrating Improved Coal Technologies into Energy System of Changshu in China," PRC

L. Z. Min, Chief, Shanxi Province Energy Economics Inst., "A Case Study on Improving the Efficiency of Coal Utilization - Case Study in Taiyuan," PRC

S. Xia, Professor, Tsinghua University, "Energy-Environmental Issues in Shanxi Province and Taiyuan City," PRC

R. Hui, Assoc. Professor, Shanxi Province Planning Committee, "Coal-Fired Power Stations and Their Effect on the Environment in Shanxi, China," PRC

Z. Ma, Central Coal Mine Research Institute, "The Way of Utilization of Lignite in Yunnan Province of China," PRC

A. Razzaque, Chief Geologist, Pakistan Mineral Development Corp., "Lignite Coal of Sindh," Pakistan

P. Sutabutr, Sec. General, National Energy Administration, "Forest Conservation and Briquette," Thailand

9:45 a.m. - 10:15 a.m.—*Coffee Break*

10:15 a.m. - 11:45 a.m.
WORKSHOP PAPERS *(continued)*

N. Hashimoto, Mgr., CWM Project Operations Dept., JGC Corp., "Clean Coal Transport System CWM Chain Between China and Japan," Japan

G. Shedji, Superintending Engineer, Maharashtra State Electricity Board, "Coal Use: Public Perceptions," India

J. M. Biddison, Commissioner, Public Utilities Commission of Ohio, "The Affects of Environmental Compliance on Coal Use in the Midwestern United States: How Regulators Balance the Competing Interests," U.S.

Y. Dia, Assoc. Professor, Energy Research Institute of State Strategic Planning Commission, "Public Perspective," PRC

F. Wong, Pres., FKW Enertech, Inc., U.S.

WORKSHOP B(5)
ENVIRONMENTAL STRATEGIES

Co-Chairs
***K. Samadikun**, Dir., General Planning, PLN, Indonesia*
***H. Steingass**, Energy Advisor, Asian Bureau, USAID, U.S.*
***Rapporteurs: S. Hirano**, Dir. of Project Promotion, NEDO, Japan;*
***K. Thompson**, Deputy Dir., Office of Export Assistance, USDOE, U.S.*

8:00 a.m. - 9:45 a.m.
OPENING REMARKS OF THE CO-CHAIRS
WORKSHOP PAPERS

J. Dong, Professor, Shanxi Academy of Social Sciences, "On the Use and Economization of Energy in China," PRC

P. Mathusa, Program Dir., New York State Energy Research and Development Authority, "Energy Efficient Air Pollution Control for Fossil Fueled Plants," U.S.

Z. Li, Committee of Energy and Environment of China, Energy Environmental Commission, "Environmental Decision Making," PRC

M. Holden, Professor, University of Virginia, "Regulatory Policies and Regulatory Implementation: Perspective from Governmental and Corporate Experience," U.S.

P. Yusgiamtoro, Exec. Dir., Indonesian Institute for Energy Economics, "Indonesia's Coal Development and Utilization: Past, Present and Future," Indonesia

J. Rosa, Advisor to Dep. Prime Min., Office of Prime Min., "Environment Management in Transition Economics," Czech Republic

9:45 a.m. - 10:15 a.m. – *Coffee Break*

10:15 a.m. - 11:45 a.m.
WORKSHOP PAPERS *(continued,*

R. Patil, Chief Engineer, Maharashtra State Electricity Board, "Coal Technology and Environment," India

X. Song, China University of Mining and Tech., "The Role of Clean and Efficient Use of Coal in the Future Energy and Environment of China," PRC

W. Cavanaugh, Ogden Environment and Energy Services, "Environmental Sound Facilities Management," U.S.

H. M. Chen, Senior Economist, China Energy Research Society, "The Clean and Efficient Use of Coal in China," PRC

K. Sullivan, Technical Advisor, Coal & Allied Industries, "Reducing Environmental Impacts Through Increased Performance Efficiency," Australia

S. Stallard, Project Manager, Black & Veatch, "CQE: Bringing New Dimensions to Fuel Decisions," U.S.

CONFERENCE STEERING COMMITTEE

Sergio Garribba (Co-Chair)
International Energy Agency, Paris

Jack Siegel (Co-Chair)
Department of Energy, United States

John Cameron
Department of Primary Industries and Energy, Australia

Ukar Soelistijo
Centre for Mineral Technology Research and Development, Indonesia

Guido Gallizioli
ENEL, Italy

Peter Peiser
ENEL, Italy

Akira Kinoshita
Electric Power Development Company, Japan

Hodaka Nakanishi
MITI, Japan

Lee In-Chul
Energy Conversion Research Laboratory, Korea

Mohd. Annas H.J. Mohd. Nor
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Sven Jansson
ABB Carbon AB, Sweden

Prathes Sutabutr
Ministry of Science, Technology and Energy, Thailand

John Trubshaw
IEA Coal Research, United Kingdom

Jacques Lambotte
Coal Committee UN
Economic Commission for Europe, United Nations

Kui-Nang Mak
Science, Technology, Environment and Resources Division, United Nations

Robert Driscoll
US-ASEAN Council, United States

William McCollam
Edison Electric Institute, United States

Robert McFarren
Stone & Webster Engineering Corporation, United States

James Sullivan
USAID, United States

Ian Torrens
EPRI, United States

Kurt Yeager
EPRI, United States

John Tilley
International Energy Agency, Paris

CONFERENCE ORGANISING COMMITTEE

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US Department of Energy, United States

James Tapper (Co-Chair)
International Energy Agency, Paris

John Cameron
Department of Primary Industries and Energy, Australia

William Brekke
American Consulate General, Hong Kong

Jane Tang
Exxon Energy Limited, Hong Kong

Morse K.H. Tsang
China Light & Power Company Limited, Hong Kong

Shigeyoshi Hirano
New Energy and Industry Technology Development Organisation, Japan

Kui-Nang Mak
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US-AEP, United States

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International Energy Agency, Paris

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