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WORKSHOP ON THE UTILIZATION OF COAL AS AN ALTERNATIVE TO PETROLEUM FUELS IN THE ANDEAN REGION

VOLUME I:
SUMMARY REPORT

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WORKSHOP ON THE UTILIZATION OF COAL AS AN ALTERNATIVE TO PETROLEUM FUELS IN THE ANDEAN REGION

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VOLUME I:
SUMMARY REPORT

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I

SUMMARY

In 1960, the contribution made by coal to meeting the world's primary energy requirements was 49 percent; by 1973, it had dropped to 29 percent. As petroleum prices escalated in the late 1970s, utilization of coal for energy began to rise once again. Notwithstanding the fact that coal resources worldwide are large, and that technology exists to exploit those resources, further efforts are required once again in the 1980s to promote greater coal use.

The Workshop on the Utilization of Coal as an Alternative to Petroleum Fuels in the Andean Region was one regional effort to examine issues involved in developing coal as a major energy source. Held in Lima, Peru, June 24-28, 1985, and funded by the Government of Peru and the U.S. Agency for International Development (AID), the workshop examined technological measures and economic policy initiatives needed to promote coal development, particularly in Peru, Bolivia, and Ecuador.

Of the three Andean countries involved in the workshop, Peru is known to have significant underutilized coal reserves. These reserves could become economically attractive and could contribute to long-term energy self-sufficiency.

At present, many industrial operations and electricity-generating facilities in Bolivia, Ecuador, and Peru are dependent on fuel oil either from diminishing domestic reserves or from imports. Because current prices of coal are substantially below those for residual petroleum fuels (based on energy content), the exploitation of Andean coal as an alternative to petroleum fuels is an attractive option. Increased use of coal would provide an economically viable energy source needed to improve living standards and to promote rural industrialization. Moreover, in addition to creating employment in mining, transporting, and marketing of coal, development of a domestic market would release substantial quantities of petroleum products for export, thereby earning needed foreign exchange.

The workshop brought together a group of experts from the Andean region and the United States to examine opportunities for increasing coal production to promote greater conversion from oil to coal in applications such as thermal electric generation, industrial process

heating, and domestic cooking and heating. Both technical and socioeconomic constraints were discussed as a prerequisite to the development of policy measures to stimulate the production and use of coal in the region.

Responsibility for planning, organizing, and conducting the workshop was shared by the U.S. National Research Council (NRC) through its Board on Science and Technology for International Development (BOSTID) and Empresa Promotora del Carbón, S.A. (PROCARBON), an autonomous agency of the Peruvian Ministry of Energy and Mines. Luis Morán, president of PROCARBON, served as general chairman of the workshop. BOSTID recruited a panel of 12 international experts from Chile, Colombia, and the United States in the areas of coal production technologies, coal utilization, and energy economics. Ulrich Petersen, professor of economic geology, Harvard University, was the panel chairman. PROCARBON organized participation from the Andean countries, including approximately 60 industrial energy users, coal producers, coal processors, development planners, energy policy makers, and representatives from universities and other technical groups working in solid fuels. PROCARBON also arranged for the participation of a specialist from Korea. The international panel members presented technical papers and led the discussions on geology, mining, transport, utilization, marketing, and socioeconomic aspects of coal. Presentations and discussion were held in Spanish.

Several recommendations, dealing primarily with ways to increase the use of coal economically in the region, emerged:

- Encourage small-scale mining.
- Support the adaptation of standard metal mining methods and equipment for the extraction of coal under Andean conditions of steep and narrow seams.
- Promote the use of coal for cooking and heating in the Andean highlands and nearby major cities, using briquetting technology.
- Address the transportation problem by siting power generation sources near the mines and by investigating slurry pipelines as an alternative to transport by road or rail.
- Support social and economic development of coal producing regions through education, agriculture, and health services.
- Investigate cost-effective ways to substitute coal in power generation and thermal processing.

Papers presented at the workshop are published as Volume II of this report. Individual papers are listed in Appendix C and may be obtained from the authors listed in Appendix B.

II

WORKSHOP ACTIVITIES

INTRODUCTION

In 1960, the contribution of coal to the world's energy use was 49 percent, but by 1973 it had fallen to 29 percent. With the two oil crises of 1973 and 1979, it became clear that other sources of energy should be investigated. Fortunately, worldwide coal reserves are large, and technologies are available to exploit those reserves. It is also true that economically available reserves are unequally distributed. Nevertheless, the Andean countries of Peru, Ecuador, and Bolivia--which were the focus of this workshop--possess substantial coal deposits; these resources, if utilized intensively for thermal electric power generation, industrial processes, and domestic heating and cooking, could reduce dependence on more costly petroleum.

During the 1970s, energy for the growth of urban centers, for expansion of mining and mineral processing, and for transportation networks in most Andean countries was primarily derived from liquid hydrocarbons and, to a lesser extent, from hydropower. These resources were domestically produced, and prices were held to artificially low levels for consumers, even though world petroleum prices were rising. Although liquid fuels and electricity are more convenient to transport and use than solid fuels, coal is becoming an increasingly attractive alternative, especially in Peru, because governments are now permitting petroleum prices to rise to world market levels.

In rural areas the rapid disappearance of firewood has been called "the second energy crisis." Forests are disappearing as trees are used more rapidly than they can mature and as population growth adds pressures to clear woodlands for crops. Here again, coal, in the form of fabricated briquettes, offers an alternative fuel. Moreover, briquette making is an employment-generating activity that may be managed as a small industry with low capital investment. Thus, coal shows promise as a domestic fuel substitute for petroleum in rural as well as urban and industrial areas.

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BACKGROUND

The concept for a workshop originated in the Office of Energy, Bureau for Science and Technology, U.S. Agency for International Development (AID), as part of its strategy to assist developing countries in energy policy planning, conservation, and management. In 1983, after discussions with officials from the Ministerio de Energía y Minas and Empresa Promotora del Carbón (PROCARBON) in Lima, AID representatives reached an agreement that a cooperative and regional activity on coal utilization would be undertaken, with Peru serving as host country, and with participation from Bolivia and Ecuador. AID then invited the Board on Science and Technology for International Development (BOSTID) of the National Research Council (NRC) to plan the workshop, to select a panel of experts in collaboration with PROCARBON, and to make necessary preparations for the participation of approximately 60 persons from the three Andean countries. Because it was felt that workshop discussions would be facilitated if conducted in Spanish, preference in the selection of the expert panel was given to individuals fluent in that language.

The purpose of the workshop was to promote information and technology transfer on technical and economic factors affecting coal production and utilization. Use of coal as an alternative to petroleum fuels was the principal rationale.

Workshop organizers planned the agenda around several major issues:

- Coal policy planning in energy development
- Coal resources
- Coal mining, transport, and processing technology
- Coal marketing both in and outside the Andean region
- Substitution of coal for petroleum in domestic and industrial applications.

The workshop agenda is given in Appendix A; the participants list, Appendix B; and a list of the contributed papers, Appendix C. Volume II of this report contains the contributed papers.

COAL POLICY PLANNING

Although each paper presented for discussion covered some aspect of energy policy planning, two focused specifically on policy issues and coal development strategies.

The first of these, "Coal and Oil Policy Implications," was prepared by Dr. Nathaniel Arbiter, a mining engineer and economist with experience in minerals consulting, industrial operations, research, and university teaching. Because of unforeseen circumstances, Dr. Arbiter was unable to attend the workshop, but Dr. Eugene Thiers from SRI International, who also was a member of the BOSTID international panel,

presented Dr. Arbiter's paper and led the discussion on coal-oil policy issues.

The paper was based on a historical overview of energy development and events. By 1983, even after two severe energy crises during the 1970s, worldwide energy was supplied by one-third solid fuels and two-thirds liquid or gaseous fuels. Coal as a substitute for petroleum was subject to the following qualitative trends:

- Coal is not used for transport. Given the present state of coal technology, liquefaction is not economically competitive where access to petroleum resources in world markets is unrestricted.

- For industrial uses in most countries, coal now competes favorably with both oil and gas. Increasing use of coal in industry is a matter of individual economic trade-offs; combustion technology using coal is well understood and, generally speaking, is undergoing continuous improvement, enabling coal to maintain a competitive position.

- For electricity generation, coal is already the dominant fuel in most industrialized countries and could continue to displace oil or gas. There are, however, socioeconomic factors as well as environmental considerations that retard the expansion of coal as fuel of choice in thermal electric generation. One of the most serious of these is sulfur content because of the effect of SO_2 generation and its unrestricted release to the atmosphere.

- For household and commercial use, coal is used essentially for heating. Here, customer preference favors liquid fuels, but coal can and does compete, particularly in western industrialized countries. In developing countries, firewood has been the fuel of choice for heating, but scarcities are developing so rapidly that coal, particularly in the form of briquettes, is an attractive alternative.

A second paper on the policy theme, "Colombian Coal Development," was given by Ing. Carlos de Greiff, an engineering consultant from Bogotá with long experience in energy use and development in his country. De Greiff was a leader in the government and private sector team that conducted a thorough assessment of the energy supply and demand balance in Colombia. A major outcome of that analysis was the recommendation of options for Colombian energy conservation and development to the year 2000. The energy balance projection led to a government decision for a major coal resource development program, the Cerrejon project, and Colombia's entry in 1985 into the world market of coal exporters. The quality of Colombian coal makes it especially

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useful for coking applications in steel making. Because coking coals are scarce in Peru, Colombian coal could become a strong contender for use in iron and steel manufacturing in Peru, and possibly elsewhere in the Andean region.

COAL DEVELOPMENT: A SOCIOECONOMIC OVERVIEW

Workshop organizers also viewed the topic of "coal development" in terms of its social and economic impacts on society. A case study of the Appalachian region of the United States was presented as an illustration. The paper was prepared and presented by Professor Curt Harvey, University of Kentucky, who spoke about Appalachia, a region in the eastern part of the United States where coal mining has long been the dominant industry. In 1984, 50 percent of U.S. coal came from the states of Kentucky and West Virginia in Appalachia as well as from Pennsylvania. Coal is the driving force in the economies of eastern Kentucky, West Virginia, and smaller regions of other nearby states. Economic highs and lows of coal-consuming industries, such as electric utilities and metal producers, are the crucial factor in determining employment and income for many coal-producing areas. The same phenomenon of a single commodity dependence, based upon minerals and mining, has had similar effects upon the economic development of Bolivia, Chile, and Peru.

These fluctuations have a dominant impact on the Appalachian region's economic growth. Because the coal resources are owned and managed by interests outside the region, the profits typically have not been reinvested in the coal-producing areas. Capital formation is minimal, and much of the secondary impact that could have been realized through investment diversification and local management was lost. This in turn affects the tax base needed to make infrastructure investments in public services and facilities. Thus, Appalachia has traditionally been a region of underdevelopment and poverty within the United States. Physical isolation, topography, and lack of educational and medical facilities have compounded efforts to attract new investments and promote socioeconomic diversification.

The Appalachian experience has shown that a region with an economy based on a single commodity must give attention to issues of equality and distribution of employment opportunities and income as well as to the creation of a hospitable climate for economic growth.

A second case study, Korea, was presented by Dr. Jung Il Yang, an economist from the Korea Institute of Energy and Resources. Because the Government of Korea has successfully promoted economic growth that raised the GNP by an average rate of 8.6 percent per year between 1965 and 1983, energy demand also soared. But with no domestic oil and the onset of the worldwide energy crisis in 1973, the country was forced to develop its only naturally occurring fossil fuel resource, anthracite coal. Within 10 years (by 1983), coal represented 33 percent of the total domestic energy consumption.

In Korea, local coal is principally used by service industries, by other small industries, and for household heating and cooking. Bituminous coal, which must be imported, is mainly used in larger industrial applications. Anthracite, with estimated recoverable reserves of 0.65 billion tons, is the only indigenous fossil fuel. By 1983, production of anthracite reached 10 million tons annually, most of which was fabricated into briquettes for space and water heating in homes, commercial establishments, the service sector, and small industries. There are over 250 briquetting plants distributed throughout Korea, producing up to 20 million cylindrical briquettes of 3.6 kg each per day. Production costs are estimated to be US $0.15 each; the consumer price is about $0.20 each, and is competitive with other energy prices. Despite the inconvenience in handling the coal and disposing of ash, Korean briquettes have been readily accepted. Locally produced combustion furnaces have been designed and adapted to the traditional home heating and cooking system, and for supplying hot water. Daily consumption per household is commonly 2 to 3 briquettes, and the price per briquette is about the same as 1 kg of flour or 1 kg of cabbage, which are staples in the Korean diet.

The principal beneficiaries of the Korean domestic coal policy are the low- and middle-income families in both rural and urban areas. Domestic coal prices are regulated at wholesale and retail levels; subsidies are provided to the coal industry indirectly through mine safety incentives, transportation, housing for coal miners, education for miners' children, and for coal product research and development.

COAL RESOURCES

Ecuador

An overview of Ecuador's coal resources within the context of the country's 1982 energy inventory was given at the workshop by Dr. Juan Sosa, Directorate for Geology and Mines, with the collaboration of Ing. Claudio Alvarez, National Polytechnic School (Quito), and Dr. Byron Arroyo, National Institute of Energy.

Ecuador is a petroleum exporting country with no significant domestic production of solid fossil fuels. Nevertheless, the government has recognized the importance of coal as a substitute for petroleum in industry and has initiated a program to:

- Map coal resources and prepare an inventory of economic deposits
- Assimilate and adapt technologies appropriate for exploitation and rational use of coal
- Establish an appropriate role for coal within the national energy plan
- Create institutional and financial conditions to stimulate coal development.

Surveys indicate that economically significant Ecuadorian coal deposits are located in the high Andean regions and perhaps in the Amazonian regions as well. Preliminary evidence suggests that the largest deposit in the country is on the order of 22.5 million metric tons.

Peru

A detailed presentation of the geological basis for known and potentially profitable coal deposits in Peru was given by Professor Estanislao Dunin-Borkowski, National Engineering University, but the information was not made available in written form.

A report entitled "Coal: Opportunities for Peru" was prepared by PROCARBON and given to workshop participants. This report indicates that coal production has been irregular during this century primarily because of limited local demand. The country's domestic market is only about 100,000 metric tons per year. Roughly half (55,000 metric tons) is consumed for coking requirements in metals production, and the remainder for all other uses. The major Peruvian coal deposits are shown in Table 1.

The Peruvian cement industry has begun planning to convert from oil to coal. This conversion would increase the local market to 150,000 metric tons per year. An increase of that magnitude could lead to lower production costs, thereby stimulating further domestic uses.

Bolivia

Extemporaneous remarks were made about Bolivian coal resources and production possibilities. Because petroleum and gas reserves are large, there has been no incentive to conduct extensive coal exploration. Furthermore, geological conditions are not as favorable for the presence of coal deposits in Bolivia as they are in Ecuador and Peru.

TABLE 1 Major Coal Deposits in Peru

Coal field	Location	Coal type	Total reserves (metric tons)
Alto Chicama	Otuzco (E. of Trujillo)	Anthracite	270 million
Oyon	N.E. of Lima at Oyon	Anthracite	160 million
Goyllarisquizga	E. of Oyon	Subbituminous	7.4 million
Jatunhuasi	E. of Lima	Subbituminous	60 million

COAL MINING, CLEANING, AND TRANSPORT

Three papers were presented dealing with coal technologies per se and with economic factors that influence coal mining, cleaning, and transport in the Andean countries, especially Peru. The three papers were:

- Review of U.S. Coal Mining Technology for Small Mines: Applicability to the Coal Deposits of the Andean Region, given by Anthony B. Szwilski.
- Coal Cleaning Technology--An Overview, presented by Frederick V. Karlson.
- Coal Transport: Conventional and Slurry, delivered by Robert T. Mott.

Distribution of primary energy consumption in 1981 for the countries of Bolivia, Ecuador, and Peru is given in Table 2.

TABLE 2 Distribution of Primary Energy Consumption, 1981 (in percent)

Source	Bolivia	Ecuador	Peru
Oil	48.2	71.0	60.0
Gas	10.0	--	5.2
Subtotal hydrocarbons	58.2	71.0	65.2
Hydroelectricity	6.0	8.0	7.1
Coal	0.7	--	0.7
Firewood and misc.	35.1	21.0	27.0
TOTAL	100.0	100.0	100.0
Percentage of Requirements Imported			
Petroleum	0	0	0
Coal/Coke	0	0	0

Source: Bundesstelle für Aussenhandelsinformation, Markt Information: Bolivien Energiewirtschaft 1981/82, Köln, 1984
_____ Ecuador Energiewirtschaft, 1982
_____ Peru Energiewirtschaft, 1982

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If coal is now to supply a greater proportion of Andean domestic energy requirements and replace liquid petroleum fuels, several issues must be faced.

- In Peru, the current relatively low level of coal demand does not justify major capital improvements for much-needed rail and highway facilities to bring supplies from remote high Andean deposits to the major centers of consumption. Thus, the transport improvements must occur incrementally. The development of a major coal briquette market for home heating, cooking, and water heating, as well as for some commercial heating offers one possibility by introducing the new fuel to markets near production areas. Another is the conversion from oil to coal for cement production and brick making. These steps, if successful, could support greater investment in roads and rail transport, which could further lower coal transportation costs as use spreads away from mines.

- Similarly, the economics of coal recovery in Peru presents challenging problems. Most coal mining is characterized by small-scale operation and low productivity. The geologic factor of highly folded coal deposits in narrow seams discourages mechanization with existing equipment. The challenge is to design new equipment suitable to these conditions.

- Improvements must be made in coal cleaning (washing) at many mine sites to raise the quality of the product and to reduce, somewhat, the transport requirements. Although coal cleaning methodologies have changed greatly in industrialized countries in recent years, it is not clear that newer technologies are economically applicable to Andean countries.

- There are no technological breakthroughs on the horizon that offer the promise of dramatically lowering transport costs. Coal slurry pipelines are attractive but require investment capital, which is scarce and will remain so for some years to come. For economic return on investment, slurry pipelines require high-use factors at nearly constant volume as well as abundant and reliable water supplies at the mine site where a pipeline would originate. Furthermore, maintenance costs in mountainous terrain like the Andes have yet to be determined.

In summary, coal mining, coal cleaning, and coal transport constitute a set of interrelated issues requiring detailed study before major investments can be made for Andean coal production. Recommended studies are presented later in this report.

COAL UTILIZATION: THERMAL ELECTRIC GENERATION, METALLURGY, AND CEMENT PRODUCTION

On a worldwide basis, the most widespread use of coal is for direct combustion in electrical generation. Also important is the use of coal to provide coke for smelting and metallurgical refining operations, particularly iron and steel. Another use, which has potential in Latin America, is as a substitute for petroleum in cement making. In the context of developing greater coal utilization for industrial processes, each was discussed at the workshop. Background papers were as follows:

- Coal Utilization: Thermal Electric Stations, by B. F. Gilbert and R. A. Hevia
- Utilization of Andean Coals in Metallurgy, by Eugene A. Thiers
- Utilization of Coal in the Cement Industry, by Ing. Ruben Céspedes.

The Gilbert and Hevia presentation highlighted current practices of coal utilization as a fuel for steam (thermal) electric generation and for industrial steam installations. Specific subjects discussed were:

- Combustion and steam process principles, a general introduction to technical and economic factors
- Equipment and applications, a discussion of steam boiler types and methods of firing
- Coal specifications and design of steam-generating equipment
- Environmental considerations, a review of coal handling and of the physical and chemical aspects of combustion in the context of their potentially adverse effects on the environment
- Conversion of existing steam generators from petroleum or gaseous fuels to coal or coal-derived fuels, coal liquefaction and gasification, coal slurries, and fluidized bed combustion
- Conversion feasibility studies.

In the paper discussing coke production, Dr. Thiers gave an overview of metallurgical uses for coal, discussed the technology of conventional and nonconventional coke-making with attention to economic factors, and suggested some alternatives for bypassing coke use in metallurgy. Current consumption of metallurgical coals in Peru is small, and is almost nonexistent in Bolivia and Ecuador.

Ing. Ruben Céspedes presented Chile's experience in converting from oil to coal for cement production. Technical characteristics of a process being used in Antofogasta were reviewed, with attention to coal

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requirements (including such factors as analysis, hardness, particle size distribution, heating value, and ash content). Overall, economic factors considered before making the conversion to coal included:

- Comparative unit costs for energy (oil versus coal)
- Assurance of high quality and consistent coal supply
- Effect of coal use on cement product quality
- Equipment review (equipment needed and possibilities for local fabrication), giving attention to alternatives (such as the use of reconditioned equipment), maintenance costs, and availability of spare parts
- Comparative studies of the supply of new equipment with respect to its design and compatibility with existing equipment
- Technical assistance needed
- Availability of credit and its terms.

COAL MARKETING

A general discussion of factors important in developing a viable system of coal marketing for domestically produced coal in Peru was presented by Bruno A. Fichna. Given the uncertainty in the coal reserves and the cost of production in Peru, even modest expansion requires careful feasibility studies before major investments can be made. In particular, the extent of reserves and the reliability of coal analyses from a given site must be determined with a high degree of certainty. Economic trade-offs between petroleum and coal must be determined, and the need for job creation and stimulation of local markets for coal deserves careful review.

Substitution of coal for petroleum in domestic uses (space heating and hot water) has a high priority in areas where fuelwood is rapidly becoming depleted. In addition, the policy in both Ecuador and Peru is to remove subsidies from kerosene and other petroleum fuels. Coal briquettes, therefore, are seen as a viable fuel for domestic use in Peru. But market development requires skill and ingenuity to convince people to change from established fuel consumption patterns to alternatives. Thus, the issues facing Peru are not so much technical as economic and social. In the not too distant future, some of the same issues in energy policy and marketing may become more important to Ecuador.

A second paper, entitled "Production and Marketing of Colombian Coal," was given by Dr. Jairo Londoño. Coal production in Colombia is following two parallel paths. First is the development for export of

the vast, high quality bituminous deposits in the Cerrejón coal fields, where millions of invested dollars to ensure high productivity and competitive prices promise to make Colombia a major supplier in the world market. Second is the slowly increasing production by independent coal producers and by 12 cooperative associations for the Colombian domestic market in thermal electric generation; metals industries including iron and steel; home heating and cooking; and small industries such as cement, food, and paper. Dr. Londoño addressed his remarks mainly to the second area, because the lessons learned would be more applicable to Peru, and later to Ecuador, as their domestic coal markets are developed.

According to Dr. Londoño, production of coal by 1983 in Colombia reached an estimated 4.9 million tons, of which 300,000 tons was exported. By 1985, domestic production was expected to be 5.5 million tons, with an additional 3 million tons from the Cerrejón field for export. About one-third of the total (449) number of mines in Colombia are cooperatives organized into 12 regional organizations. These organizations provided 27.5 percent of Colombia's coal (about 1.3 million tons) in 1984. Through the cooperatives, the Colombian government authority for coal, Carbones de Colombia, S.A. (Carbocol), has provided legal assistance to small and intermediate mines, and has established five regional training centers for mining technicians. The cooperatives work among themselves and with Carbocol on legal issues, availability of credit, technical assistance, mine safety, marketing, standardization, and other matters affecting both production and productivity.

A specialized paper given by Ing. Guillermo Blacker related technical aspects of combustion to coal mining and marketing. A need is now being felt by large metallurgical producers to predict combustion characteristics of coal blends. With computer models, it is possible to estimate combustion products and the resulting ash characteristics. A general application of modeling techniques would allow coal producers to identify potential markets for blended coal mixtures under specified situations. Producers could then assist customers by specifying coal blend formulas to optimize chemical, physical, and economic parameters.

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III

WORKSHOP CONCLUSIONS AND RECOMMENDATIONS

Both in the public and private sectors in Andean countries, there is a growing appreciation for real costs of energy and the need to conserve domestically produced petroleum for export. Because Peru, in particular, is in a favorable position to develop local coal reserves, the use of coal as a substitute for petroleum-based fuels has recently been given greater emphasis. The Workshop on the Utilization of Coal as an Alternative to Petroleum Fuels in the Andean Region was organized to promote information and technology transfer in the participating countries and to serve as a catalytic influence in energy policy planning.

Conclusions and recommendations given below are the product of joint discussions that occurred during the week of the workshop.

1. **To assess coal reserves, it is recommended that an inventory of coal resources in each of the three countries be undertaken based upon known information from currently operating mines, geological evidence of coal deposits, and sites that are reported to contain coal but that have been insufficiently explored.**

Discussion: The long experience from mining of metals in Andean countries can be adapted to exploration for geological conditions that favor the accumulation of coal. Studies should also be undertaken to find correlations among known deposits in given areas and thus infer extensions of known deposits.

Currently available information in Peru suggests that coal reserves are sufficient to warrant feasibility studies characterizing those reserves and their associated mining costs for investment decisions. (Examples are Alto Chicama, Oyon, Jatunhuasi, and perhaps others.)

2. **It is recommended that, in addition to an inventory of coal resources, analyses of representative samples from the sites be made in order to assess suitable industrial and commercial applications.**

Discussion: Adequate, reliable sampling and laboratory analyses are frequently given low priority in coal exploration. The detailed characterization of a coal deposit by actual testing is as important as information on reserves, when making decisions for investment and exploitation.

3. In the near term, it appears feasible to develop a domestic market for Peruvian anthracite fuels in the form of coal briquettes for cooking, for home space and water heating, and for process heating in small industries. This market possibility should be vigorously pursued.

Discussion: Because the Peruvian government continues to subsidize petroleum hydrocarbons for domestic uses, an economic rationale for the substitution of coal for petroleum fuels (kerosene) is clearly evident. Because substantial savings of petroleum could be realized, export earnings would be increased. Also, given the increasing scarcity of firewood, which is the traditional fuel in rural areas, coal briquettes should be vigorously marketed as an alternative. By starting a pilot program of coal briquette marketing in a few areas, experience would be gained for a larger effort and, eventually, for a national program. Incentives and credit for the purchase of coal-burning stoves and training in safe combustion techniques are important elements in a marketing strategy.

4. Peru, and possibly other Andean countries, should investigate the feasibility of building small- to medium-size (15-30 MW), mine-site thermal electric generating stations to serve neighboring communities and areas.

Discussion: The World Bank and Empresa Electricidad de Peru have entered into an agreement (World Bank loan contribution, $13.5 million) to finance studies to improve administrative systems and commercial operations of regional utilities in Peru; to identify causes for present high transmission and distribution losses; to develop performance indicators and targets; to undertake feasibility studies for regional generation projects; and to purchase equipment for communications, maintenance, and analytical laboratories. The agreement opens the possibility for feasibility studies of mine-site, thermal electric generating stations.

Perhaps Peru and Ecuador should consider adopting a policy similar to that currently being implemented in Colombia. In its national energy policy statement, Colombia affirms the need to stress conversion of existing oil- or gas-fired thermal electric generating stations to coal. The Colombian policy is to build only coal-fired thermal electric facilities in the future, reserving more costly liquid hydrocarbons for transport and export.

5. There are attractive options to substitute oil for coal in a number of process industries in Andean countries. Examples are cement making, ceramics, brick making, and sugar refining. In the case of Peru, it is recommended that at least two industries be identified and that prefeasibility studies be undertaken to ascertain economic and social consequences of oil-to-coal conversion.

Discussion: In making prefeasibility studies, valuable lessons can be learned not only from industries in the United States, where coal conversions have occurred, but also from Chile and Colombia. In these latter countries, the experience, although less extensive than elsewhere, may bear a closer relation to Peru because of scale factors,

coal transport constraints, the need to reduce capital requirements, and greater similarities in the area of labor utilization and maintenance procedures.

6. **Because of the geography and geology of coal occurrences, and because of current socioeconomic development factors, questions of mining technology require special study.**

Discussion: The geology of coal deposits in the Andes presents special problems for extraction, for which European and North American mining experience may be only marginally applicable. Andean coal most commonly occurs in thin seams and highly folded formations. Currently available mining machinery was developed for relatively broad, horizontal seams. Thus, most underground coal mining machinery is unsuitable for general application in Peru. Underground metal mining techniques and production systems used in Europe and North America, however, are similar to techniques used in the metal extraction industries in Peru. Local expertise to adapt metal mining technologies, therefore, is available in the Andean region.

Given the need to emphasize labor-intensive, cost-effective mining technologies so that domestically produced coal can compete with available, low-cost coal imports, properly structured government incentives for coal mining entrepreneurs are required. The Colombian government does this by supporting road building and maintenance in the Andean departments, credit programs, regional training centers for mining technicians, legal assistance, and research and development on small-scale mining technologies.

7. **The problems of transportation between mine sites and potential users need early and careful study.**

Discussion: Because of enormous topographical barriers to the movement of coal from deposits in the high Sierra to potential users, transport is an issue of overriding significance. The scale of improvements in roads, railroads, and ports to significantly reduce coal transport costs in Peru or Ecuador is so high as to be economically prohibitive, particularly when measured in relation to the potential domestic coal market. Moreover, the option of coal slurry pipelines, which is also very capital intensive, is applicable only in special situations. The transport situation argues for a coal development strategy in the short term by building small-scale, thermal electric power plants at or near mine sites, thereby transmitting electricity instead of carrying coal long distances, and by promoting briquette manufacturing and vigorous marketing efforts throughout the coal-producing regions.

8. **Issues of coal cleaning are site specific and market specific. Decisions about the type and extent of washing can be made only when an end user (market) and coal type (deposit) are determined.**

Discussion: In point of time, a decision on coal cleaning can be made only when the end use for a particular coal is known. Benefits of quality improvement from coal cleaning must at least offset the cost. Examples of quality improvement in combustion processes that derive from coal cleaning are:

- Increased plant capacity and efficiency, coupled with reduced maintenance costs

- Reduced ash generation and disposal

- Reduced sulfur, with its effects upon corrosion and environmental impact

- Reduced handling and transportation costs (when cleaning occurs at mine site)

- Reduced coal composition variability.

The data essential to assess the potential for cleaning any given coal sample are derived from washing tests and from technical specifications for a particular coal. Three options exist for washing operations by small-scale coal users: (1) the conventional, mine-site or single purpose washing plant, (2) the "package" washing plant, either permanent or transportable, and (3) the shared, multiple-capability plant located at site, at a transport collection area, or at the point of coal use. The degree (amount) of cleaning that is economically justified is the governing criterion.

9. Utilization of newer combustion technologies offers an additional incentive to substitute coal for oil in many industrial applications.

Discussion: At present, three combustion techniques seem most appropriate for application in Andean countries:

- Substitution of coal-oil mixtures (COM) for up to 50 percent of oil currently used in a particular application. The advantages of this technique are that plant conversion is simple, the cost is relatively low, and the technology is proven. Although the maximum reduction of fuel oil in this approach is limited to 50 percent, the technique provides an economical and immediate means to effect substantial saving, especially when oil prices are high.

- Substitution of coal-water mixtures (CWM) for up to 100 percent of the oil. (CWM can be made with coal concentrations of 55 to 75 percent by weight, with the remainder being water additives.) Although the technology is newer than that for COM, a significant amount of test data exists; equipment required is standard, readily available, off-the-shelf items with proven reliability. The most significant advantage of this option is that it permits the use of 100 percent coal-based fuel in a liquid form, thereby simplifying transportation and fuel handling.

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- Substitution of pulverized coal (PC) for all the oil being fired. This is a time-proven technology extensively applied worldwide with reliable equipment that is readily available. Disadvantages are that the coal must be handled in solid form and an on-site pulverizing system must be installed to prepare the fuel. This adds to capital costs. In many locations where PC conversions have been made, the plant design retains the ability to fire 100 percent oil when required by operating conditions.

Before any decision is made to convert to a particular fuel option, basic design requirements should be reviewed and economic studies prepared for that particular conversion. In many cases, these technoeconomic feasibility studies can be made by individual plant owners and their technical personnel with a minimum of outside assistance.

10. **Specialized training opportunities should be made available to strengthen manpower capabilities in technical and economic aspects of coal mining, coal-to-oil conversion studies, and engineering design.**

Discussion: Among the training opportunities thought to be most useful are:

- Observation and study visits by Andean country mining engineers to small-scale high-production underground mines (for example, in eastern Kentucky and perhaps the U.K.)

- Specialized training in coal use for metallurgical applications, perhaps at an R&D department of a major steel producer in the United States, Japan, or western Europe

- Specialized training in coal washing and cleaning technologies and economic studies at a facility such as that of the Electric Power Research Institute plant in Pennsylvania

- Exchanges between Peru and Colombia to study small-scale mining operations and management systems in Andean areas

- Regional cooperation. Regional cooperation on coal mining and utilization issues has special significance for the Andean countries. Initially, the cooperation may be primarily in the form of seminars for sharing experiences and technical information followed by more formal training and cooperative R&D programs.

11. **One area that requires further input from mine owners, coal users, and energy planning authorities is that of financial incentives and government regulations that can catalyze oil-to-coal conversion under economically justifiable conditions. This implies the gradual removal of special subsidies for consumption of locally produced gaseous and liquid fuels.**

Discussion: This recommendation is one that arises from energy pricing policies that are country specific. Several of the Andean countries are addressing petroleum pricing questions within constraints and opportunities of their individual sociopolitical situations. Oil prices, gaseous fuel prices, and coal prices should be harmonized within the framework of a national energy development strategy. Colombia has shown that difficult trade-offs can be made when there is wide participation from the industrial and agricultural sectors, energy producers, small consumer groups, and the government.

12. Pollution control at mine sites and in densely populated areas where coal is to be utilized needs realistic appraisal, regulation, and enforcement.

Discussion: Environmental pollution is a cost that has too often been passed over in energy planning. The costs are real and can be significant. Realistic attention to the potential of environmental pollution during the planning phase quite often provides the opportunity to minimize adverse effects. By choosing a technology that is appropriate, and by including needed safeguards during project design, it is usually possible to avoid much greater costs in the future.

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APPENDIX A

AGENDA

Monday, June 24		
9:00 a.m.	Registration	
Inaugural Session		
10:00 a.m.	Luis F. Morán Board Chairma PROCARBON	
	Alberto Sabadell USAID Washington	
	Luis Chang Vice Minister Ministry of Energy and Mines	
	Ulrich Petersen Chairman of the Workshop	
11:00 a.m.	Break	
Morning Session	**Energy Policy**	**Chairman** Ulrich Petersen
11:15 a.m.	Coal and Oil Policy Implications	Eugene Thiers
11:45 a.m.	Coal Development in Colombia	Carlos de Greiff
12:15 p.m.	Discussion	

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Afternoon Session	Social Impact of Coal	Chairman Robert Mott
2:45 p.m.	Coal Development: Socio-economic Impacts, Lessons from Appalachia	Curt E. Harvey
3:30 p.m.	Social Impact of Coal Development--Case of Korea	Jung Il Yang
4:15 p.m.	Break	
4:30 p.m.	Discussion	

Tuesday, J

Morning Session	Coal Resources	Chairman Eugene Thiers
9:00 a.m.	Coal Resources of Bolivia	Mario Flores
9:30 a.m.	Coal Resources of Ecuador	Juan Sosa
10:00 a.m.	Coal Resources of Peru	Estanislao Dunin-Borkowski
10:30 a.m.	Break	
11:00 a.m.	Review of Coal Mining Technology	Anthony Szwilsk
11:30 a.m.	Discussion	

Afternoon Session	Coal Washing, Preparation and Transport	Chairman Mario Flores
2:00 p.m.	Coal Washing and Preparation	Fred Karlson
2:45 p.m.	Coal Transport: Conventional and Slurry	Robert Mott
3:30 p.m.	Break	
3:45 p.m.	Coal Utilization in Metallurgical Industry	Eugene Thiers
4:30 p.m.	Discussion	

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Wednesday, June 26

Morning Session	Coal Utilization	Chairman Juan Sosa
9:00 a.m.	Coal Utilization for Domestic Use in Peru	Carlos Soldi
9:45 a.m.	Break	
10:15 a.m.	Coal Utilization for Steam and Electric Generation	Benjamin F. Gilbert
11:15 a.m.	Break	
11:30 a.m.	Discussion	
Afternoon Session	**Coal Marketing**	**Chairman** **Carlos de Greiff**
2:00 p.m.	Marketing of Colombian Coal	Jairo Londoño
2:45 p.m.	International Marketing of Coal	Bruno Fichne
3:30 p.m.	Break	
4:00 p.m.	Coal Combustion Technologies and Marketing	Guillermo Blacker
4:45 p.m.	Discussion	

Thursday, June 27

Morning Session		Chairman Benjamin Gilbert
9:00 a.m.	Coal Utilization in the Cement Industry	R. Céspedes
9:45 a.m.	Project for Oil to Coal Conversion: Peruvian Case Study	Ricardo Rizo Patron
10:30 a.m.	Break	
10:45 a.m.	Training Program	Steven Ebbin
11:15 a.m.	Energy Policy Planning	Arthur Heyman

Thursday, June 27 (Continued)		
12:00	Break	
12:15 p.m	Discussion	
Afternoon Session	Plenary Session	Chairman Carlos Soldi
2:45 p.m.	Introduction to the Plenary Sessions	
	Part I Coal Geology and Mineralogy	
4:00 p.m.	Break	
4:15 p.m.	Part II Coal Treatment and Use	
Friday, June 28	Plenary Session	Chairman Luis Morán
9:00 a.m.	Part III Transport and Marketing of Coal	
10:00 a.m.	Break	
10:45 a.m.	Presentation and Discussion of Conclusions	
12:00	Closing Session	

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APPENDIX B

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APPENDIX C

Outlines of Contributed Papers

Note: All papers listed below are found in the publication "Workshop on the Utilization of Coal as an Alternative to Petroleum Fuels in the Andean Region: Volume II, Contributed Papers," Board on Science and Technology for International Development, National Research Council, Washington, D.C., 1985.

Coal Policy Planning

1. Arbiter, Nathaniel. Coal and Oil Policy Implications

   - Historical background: fuels and energy since the industrial revolution
   - Developing technology for direct coal use
     - -- Fluidized bed combustion
     - -- Conversion of coal to liquid and gaseous fuels
     - -- Summary and policy considerations

2. De Greiff Moreno, Carlos. Colombia: Coal Development (Original paper in Spanish)

   - Summary and introduction
   - Historical background
   - New legislation (Reform of 1974)
   - Institutional changes
   - Changing situation (Coal for export)

Coal Development: Socioeconomic Overview

3. Harvey, Curt E. Coal Development: Socioeconomic Impacts, Lessons from Appalachia

   - Introduction
   - Regional economic development in Appalachia (An historical summary)

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- The process of economic development
- Development linkages
- Distributional aspect of development
- Contemporary issues affecting the Appalachian coal industry

4. Yang, Jung Il. Social Impact of Coal Development: Case of Korea

- Introduction
- Industrial coal
- Domestic coal
  - -- General aspects
  - -- Yontan coal briquette industry
  - -- Yontan coal briquette techniques
  - -- Practical aspects
- Coal Policy
  - -- Industrial
  - -- Domestic
- -- Conclusion

Coal Resources

5. Alvarez, Claudio; Arroyo, Byron; and Sosa, Juan. Coal Possibilities of Ecuador (Original paper in Spanish)

- General geological characteristics
- Plains region
- Amazon region
- Andean region
- Principal characteristics of Ecuadorean coal
- Coal deposits

6. Empresa Promotora del Carbón (Lima), Coal: Opportunity for Peru

- Summary Tables
  - -- Table 1 - Locations of main Peruvian coal fields
  - -- Table 2 - Potential coal resources (known deposits)
  - -- Table 3 - Reserves by type and coal quality
  - -- Table 4 - Approximate analyses of typical samples
  - -- Table 5 - Quality of Peruvian coals
  - -- Table 6 - Main productive deposits (1983)
- Coal Production
- Coal Consumption

Coal Mining Technology and Coal Transportation

7. Szwilski, Anthony. Review of U.S. Coal Mining Technology for Small Mines: Applicability to the Coal Deposits of the Andean Region

- Mineability of coal seams
- Room and pillar mining
  - -- Continuous mining
  - -- Conventional mining
  - -- Determining mining costs
- Case studies
  - -- Anthracite mining in Appalacia
  - -- Steep seam mining
- Applicability of mechanized mining methods in Andean region

8. Mott, Robert T. Coal Transport: Conventional and Slurry

- Introduction
- Technical and economic factors in the transport of coal.
  - -- Coal transport modes: Capabilities and costs
  - -- Rail systems
  - -- Truck
  - -- Ship
  - -- Slurry pipeline
  - -- Coal handling and storage facilities: capabilities and costs
- Prospects for expanded use of coal in the Andean Region: Th role of transportation development
- Conclusions

Coal Utilization

9. Thiers, Eugene. Utilization of Andean Coals in Metallurgy (Original paper in Spanish)

- Introduction
- Conventional cooking technology
- Nonconventional cooking technologies
- Metallurgical innovations
- Conclusions

10. Soldi, C.G. Anthracite Briquetting: A Strategy for the Development of the Coal Mining Industry in Peru

- Introduction
- The coal industry in Peru
- The need for a short-term strategy
- The anthracite briquetting project
- Future actions

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11. Céspedes B., Ruben. Use of Coal in the Cement Industry (Original paper in Spanish).

- Introduction
- Coal as an alternative
- Conversion from petroleum to coal
- Characteristics of coal for the cement industry
- Coal analysis
- Coal pulverization and combustion
- Planning the conversion from oil to coal

12. Gilbert, B.F. and Hevia, R.A. Coal Utilization: Thermal Electric Stations

- Combustion and steam process principles
- Typical equipment applications
- Coal specifications
- Environmental considerations
- Coal conversion alternatives
- Conversion project feasibility studies

Coal Marketing

13. Londoño Arango, Jairo. Production and Marketing of Colombian Coal (Original paper in Spanish)

- Mining of coal in Colombia
- Contribution to the national economy
- Production of coal
- Mining systems
- Technology and productivity
- Cooperation and coal production
- Coal commercialization
- Fuel substitution in Colombia
  - -- In homes
  - -- In industry
  - -- In transportation
  - -- In electrical power generation

14. Fichna, Bruno A. Marketing of Peruvian (Ecuadorian and Bolivian) Coal

- A situation of great risk
- Scenario for coal marketing
- Macroeconomics of the world market
- Regional markets - South America
- Local markets - Boliva, Ecuador and Peru
- Recommendations

Miscellaneous

15. Parker, Harry; and Reid, William. Coal Combustion Technologies Become an Important Consideration in Coal Mining and Marketing (Paper presented by Guillermo Blacker)

- Introduction
- Utilization of information
- Ash slagging and fouling correlations
  - -- Silica
  - -- Base-acid ratio
  - -- Ash fusion temperature
  - -- Critical viscosity temperature
  - -- Slagging factor
  - -- Fouling factors
  - -- Alkalies
  - -- Ash content
  - -- Potential capture of SO_2 and fly ash

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