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Report on the Stockholm Initiative on Energy, Environment and Sustainable Development (SEED): Strategies for Implementing Power Sector Efficiency

Stockholm, 13-15 November 1991

Organized by the United Nations Department of
Technical Co-operation for Development
Hosted by the Government of Sweden

Co-Sponsors

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German Bundesministerium für Wirtschaftliche Zusammenarbeit
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This document contains the proceedings to the consultative meeting: *Stockholm Initiative on Energy, Environment and Sustainable Development (SEED): Strategies for Implementing Power Sector Efficiency*, held in Stockholm, November 13-15, 1991. The meeting included 21 developing country key decision makers in government and industry and heads of major utilities, and 24 senior officials from bilateral and multilateral organizations.

The consultative meeting was designed to build on a number of programs to promote efficiency as the centerpiece of a strategy for meeting rising power demand. These programs included the Electric Power Utility Efficiency Improvement Study (EPUES), a collaborative project sponsored by the World Bank, United Nations Development Program, and several bilateral organizations that researched utility performance in developing countries. The meeting recommended joint North-South initiatives that focus on reducing energy-related environmental degradation, mobilizing capital, and improving power sector performance. The recommendations have been submitted to Working Group I of the Prepcom to the *United Nations Conference on Environment and Development* (UNCED), scheduled to be held in Brazil in June 1992, which will provide an opportunity to present a compelling message to Heads of State on the central role of efficient energy strategies in achieving economically and environmentally sound and sustainable development.

SEED was organized by the United Nations Department of Technical Cooperation for Development (UNDTCD), hosted by the Government of Sweden, and co-sponsored by the British Overseas Development Administration, German Bundesministerium für Wirtschaftliche Zusammenarbeit, the Netherlands Ministry of Foreign Affairs, Swedish Agency for International Technical and Economic Cooperation, United Nations Development Program, and United States Agency for International Development.

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Stockholm Initiative on Energy, Environment
and Sustainable Development (SEED)

Report to the UNCED Prepcom from the Consultative Meeting
on Strategies for Implementing Power Sector Efficiency

Stockholm, 13-15 November, 1991

The power sector is a major contributor to environmental degradation. Electric power is also central to development. Energy efficiency, obtainable through power systems rehabilitation and sustainable improvements in institutional performance, is the most cost-effective route to reducing environmental damage while increasing electricity services delivered to end-users. Strategies to harmonize environment and development must therefore have energy efficiency as their centerpiece within the overall framework of social and economic development.

Background and Problem

Power systems in most developing countries are in poor health. While the total installed generating capacity in developing countries is an impressive 470,000 megawatts, capacity utilization is far below international standards, averaging less than 50 percent capacity factor on baseload plants. Power delivered to consumers falls short of demand by 10-25 percent, with adverse effects on the production and earnings of the overall economy.

The World Bank has estimated that under a "business-as-usual" scenario, developing countries will require a near doubling of capacity to 850,000 megawatts by the year 2000, costing over one trillion dollars. Financing this enormous investment, equivalent to the entire debt burden of the developing world, is truly impossible. The total capital available to the power sector in developing countries from all multilateral and bilateral development agencies is a mere 10 percent of this sum. This serious capital mobilization problem is aggravated by the stagnant or deteriorating rate of return on power investments, caused largely by poor management and tariffs that do not cover costs.

Only part of the primary energy used in power stations is delivered to the ultimate customer as useful power. Apart from unavoidable thermodynamic limitations, poor efficiency in conversion, transmission, distribution, and end-use results in avoidable losses, leading to additional environmental degradation. These losses can be two to three times higher in deficient power systems than in efficiently run ones.

Hence, developing countries are caught in a "triple bind"--insufficient investment capital, poor institutional performance, and adverse environmental impacts--calling for innovative and comprehensive strategies with energy efficiency as the centerpiece.

Analysis and Solutions

Managerial and technical remedies to power systems deficiencies are readily available from an increasingly concerned business community in the North. By providing such remedies to developing country power institutions through North-South collaboration, power shortages and environmental degradation can be mitigated in a cost-effective manner.

The transfer of technology, managerial know-how, and financial resources will be rendered more effective if performed on the basis of market orientation, and directed to professional autonomous organizations. Tariff setting should be determined by market forces, subject to an objective regulatory framework, as is the case in all countries enjoying a sound energy economy.

Through efficiency improvements in existing power systems and appropriate changes in governance and management, availability can be restored, capacity factors increased, losses reduced, plant life extended, and electricity services provided to consumers at the least economic and environmental cost. The result is added power deliveries to the end-user, obtained at typically one-fifth to one-half the cost of new plants. The scarce investment capital currently available for power sector development would provide greater service to the end-user if a more substantial portion were used for efficiency improvement and rehabilitation of existing systems.

A comprehensive global energy efficiency strategy in developing countries could save up to 60 billion dollars annually, an amount comparable with the annual interest payments on the total debt of developing countries. Local, regional, and global benefits to the environment from efficiency improvements will also be substantial, reducing environmental pollution in many cases by 50% or more.

Plans and Recommendations

The SEED Consultative Meeting in Stockholm, Sweden on November 13-15, 1991, convened by the UNDTCD, hosted by the Government of Sweden, and co-sponsored by several bilateral agencies, included participants from more than 20 developing countries and 10 multilateral and national development agencies. This Meeting is a continuation of two technical conferences organized under the same auspices in Stockholm in 1988 and 1989. The SEED Participants have endorsed a set of recommendations, which are

appended[1], that address the roles of developing country institutions and bilateral and multilateral organizations in promoting energy efficiency and providing quality electric power to consumers.

SEED recommends that energy efficiency be a major objective of Agenda 21, with an accompanying implementation strategy. The strategy should promote the rehabilitation and modernization of power systems, policy reforms, innovative financial and institutional mechanisms, private sector participation, and information exchange through existing donor and developing country institutional networks.

SEED emphasizes that a forceful and determined effort to implement appropriate strategies for energy efficiency can contribute gainfully to North-South cooperation in the energy sector, which is of such crucial importance both with regard to environment and development

In this regard, SEED will favorably consider recommendations by the UNCED Prepcom for actions that SEED can undertake to promote energy efficiency Specifically, SEED recommends the following

- Create financing mechanisms to support joint ventures between developing and industrialized countries in efficient and environmentally sound energy technology development and commercialization

- Strengthen global energy and environmental management networks of bilateral and multilateral donor organizations, and developing country institutions.

SEED is exploring the potential of a Working Group meeting in Rio de Janeiro during the UNCED Conference.

[1]The Recommendations are included in the following paper, and, therefore, are not included in this version of the UNCED Message.

Recommendations for Promoting Environmentally Sound
and Sustainable Development

Adopted by the Participants to the
Stockholm Initiative on Energy, Environment and Sustainable Development (SEED): Strategies for Implementing Power Sector Efficiency

Background

Key decision makers in government and industry, heads of major developing country utilities, and representatives from bilateral and multilateral organizations met in Stockholm, Sweden, November 13-15 1991, to deliberate issues related to developing country power sector efficiency. The resulting recommendations endorsed by the Participants call for supply- and demand-side energy efficiency measures that promote policy reforms, innovative financial and progressive institutional mechanisms, and information exchange through existing donor and developing country institutional networks involved in energy and environmental issues.

The recommendations are an outgrowth of specific issues brought out at two conferences organized by the United Nations Department Technical Co-operation for Development (UNDTCD) Program in cooperation with the Government of Sweden (*Operation, Maintenance, and Rehabilitation of Power Plants*, 1988), and (*Energy Conservation in Developing Countries*, 1989), which were successful in highlighting the cost effectiveness and environmental soundness of energy conservation and power system modernization in developing countries. Other concurrent efforts to promote energy efficiency have also played a major part, including the Global Energy Efficiency Initiative (GEEI), launched in 1989 to foster a worldwide partnership for incorporating energy efficiency improvements in the development strategies of developing countries and Eastern Europe.

Working Group I of the Preparatory Committee to the *United Nations Conference on Environment and Development* (UNCED), which focuses on energy-related environmental issues, has asked that the proposed SEED recommendations be submitted for consideration in the UNCED Agenda. The UNCED Conference, scheduled to be held in Brazil in June 1992, will provide a unique opportunity to present a compelling message to Heads of State on the central role of efficient energy strategies in achieving economically and environmentally sound sustainable development.

Since 1950, electricity generation capacity in developing countries has expanded at an unprecedented rate, driven primarily by a desire for improved standards of living, staggering population growth, expansion of industrial and transportation infrastructures, and rural-urban migration. This expansion is the result of an ever growing demand for electricity, which currently averages 7% annually. A widening gap between the need for electricity and the available capacity has led to unmet demand and unreliable and deteriorating services desperately needed to meet the demands of economic development. Developing country utilities,

which must find ways to close this gap, also face a triple bind of (1) inadequate capital to finance capacity expansion, (2) poor technical and financial performance, and (3) growing concerns about the environmental impacts associated with power sector development

At the current rate of growth in electricity demand, developing countries will require a near doubling of capacity from 471 gigawatts[2] in 1989 to 855 gigawatts in 2000, requiring an investment totaling over $1 trillion. Fuel supply, transportation, and other supporting investments will add an additional $100 billion per year.

Meeting these investment levels, even with generous external assistance, will be impossible. All external sources of capital, including the multilateral development banks (MDBs) and commercial banks, currently provide less than 10% of the expected annual capital requirements Success in mobilizing local currency is difficult because tariffs are often insufficient to cover even current operating costs much less system expansion, resulting in a high risk investment Increased public sector support for power expansion, which currently averages 25-30% in developing countries, will further deplete funding for other vital sectors such as family planning, health, and education

The performance of these electric utilities is a matter of serious concern to developing country officials and consumers. The financial rate of return in the power sector steadily decreased from a peak of 11% in the late 1960s, to settle below market interest rates at approximately 2.8% by 1989 Many utilities are experiencing negative rates of return Technical and nontechnical energy losses persist, in some cases exceeding 40% of total generation, and the overall quality of service remains poor, causing very large economic losses to power users In India, for example, the value of lost industrial production caused by power shortages is estimated at $6 billion/year, or approximately 10% of total output.

The primary causes of poor utility performance are aging power plants, lack of maintenance and spare parts, and a low plant load factor Many utilities also suffer from management problems, primarily caused by a lack of autonomy from government, and the growing tendency to view public utilities as political patronage machines and a vehicle for local employment generation.

Increasing concern over environmental impacts of power development complicate the power expansion plans of developing countries. Recent studies show that energy use is the most significant contributor to local air and water pollution, comprising, for example, an estimated 49% of total greenhouse gas emissions that affect climate change The power sector renders a third of the energy sector share, or 15% of total emissions.

Currently, total developing country contribution of global greenhouse gas emissions are small, accounting for only a quarter of the global CO_2 output from commercial energy. By 2025, however, assuming a "current trend" scenario, developing countries will be contributing a larger portion of global energy-related pollution than the OECD countries, resulting in increasingly dangerous levels of urban air pollution. Other environmental impacts from hydropower expansion will include resettlement, deforestation, saltwater intrusion, and increased human waterborne diseases.

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[2] 1 gigawatt = 1000 Megawatts or 1 billion watts.

These problems create added difficulties for developing country utilities and require innovative approaches on several fronts to foster investment and capital mobilization, accelerate supply- and demand-side energy efficiency incentives, and negate adverse environmental impacts of power supply. For example, implementation of operational efficiency measures, which include a 20% improvement in heat rates, reduction in non-technical losses and tariff reforms, has the potential of reducing pollution to an extraordinary 50-57% of existing levels.

Recommendations

Participants in the SEED Meeting have endorsed a set of recommendations that seek to address these constraints through cost effective and environmentally sound supply- and demand-side energy efficiency measures. Averaging less than one-fifth the cost of traditional capacity expansion, a comprehensive developing world strategy in supply side and end-use efficiency could save as much as $60 billion annually, which equals the current interest payments of the entire $1 trillion Third World debt. These dramatic savings would be obtained through environmentally sound measures that promote sustainable economic development.

These recommendations seek to promote the rehabilitation and modernization of power plants, policy reforms, innovative financial and progressive institutional mechanisms, and information exchange through existing donor and developing country institutional networks involved in energy and environmental issues. The dramatic savings for developing countries could cover the current annual debt payments in developing countries, or provide support for other vital sectors, such as family planning, health, and education:

Developing countries

1. Developing country governments should develop and implement programs for improving power sector efficiency, both in supply and demand. These programs should focus on greatly improved operations compatible with an integrated energy strategy and environmental sustainability.

2. Developing country governments should also support efficient alternatives to capacity expansion for utilities through better utilization of existing capabilities, and the development of independent private power facilities. Tariff reforms that make the sector credit worthy should be an integral part of such measures. However, the political, economic, and social conditions in individual countries underscore the need for a country-specific approach in addressing these issues.

3. Developing country governments should strengthen financial mechanisms, institutions, and associated policies and regulations to provide innovative lending in supply and demand side power sector efficiency. including direct lending for private sector initiatives Financing sector entities, including development financing institutions with portfolios in industrial modernization, agriculture, the environment, and housing, are targets for such institutional reforms.

Bilateral and Multilateral Institutions

1. Bilateral and multilateral institutions should dramatically alter their investment priorities to support end-use efficiency, sustainable and reliable operations and maintenance programs, and private sector initiatives, in addition to traditional investments in supply.

2. Bilateral and multilateral institutions should provide financial and technical support to improve the legal and regulatory framework as well as the management and institutional performance of power utilities.

3. Bilateral and multilateral institutions should expand their financing to cover joint ventures in environmentally sound electric power-related technology cooperation.

4. Bilateral and multilateral institutions should commission a study investigating the lack of progress of private sector involvement in developing country power sectors.

5. Bilateral and multilateral institutions should provide insurance for private sector power projects to enable capital mobilization from commercial and other markets.

6. Bilateral and multilateral institutions should create a fund in specific countries to support the availability and delivery of critical spare parts to ensure high system availability.

Institutional Linkages

1. Bilateral and multilateral institutions should, together with developing countries, perform long-term power and environmental sector appraisals to formulate policy reform packages and investment priorities for public and private entities

2. Existing bilateral and multilateral networks in energy and environment should be strengthened and expanded to link with developing country financing institutions and recognized centers of excellence.

3. The SEED recommendations should be widely disseminated to relevant agencies, developing country governments, and the private sector. They should also be presented to the refocused ESMAP program and its consultative group of donors and developing country representatives.

AGENDA

Consultative Meeting

Stockholm Initiative on Energy, Environment, and Sustainable Development (SEED)
Strategies for Implementing Power Sector Efficiency

Industry House
Storgatan 19, Stockholm
November 13-15, 1991

Tuesday, November 12

6:30 PM — Informal Welcome Reception and Information at Park Hotel organized by the Swedish Trade Council/SWEBEX

Wednesday, November 13

08:15 — Bus departs from Park Hotel for Industry House

08:30-09:00 — Registration

09:00-12:30 — Session 1: Inaugural Session and Overview of Meeting Objectives

Opening Session
- Ms. D. Pastizzi-Ferencic, UNDTCD
- Ms G. Olofsson, BITS
- Mr. G. Schramm, World Bank

United Nations Conference on Environment and Development, B. Kjellen, Swedish Government, UNCED Prepcom

Approx 10:30 — Break

Strategies for Implementing Power Sector Efficiency, M. Willingham, UNDTCD

Issues and Problems in the Power Sector, G. Schramm, World Bank

Implementing Power Sector Solutions, D. Jhirad, USAID

12:30-02:00	Lunch (Lindström Room, Industry House)
02:00-05:00	Session 2: Issues and Options in Energy Efficiency: The International Experience
	Panel: Electric Power Utility Efficiency Study (EPUES)
	Open Discussion
Approx 04:00	Break
	Open Discussion on Experiences with Energy Efficiency

Thursday, November 14

09:00-12:10	Session 3: Institutional Mechanisms for Implementing Energy Efficiency Projects
09:00-09:25	Global Environmental Facility (GEF), E. Ayensu
09:25-09:50	United Nations Development Programme (UNDP), F. Pinto
09:50-10:15	Business Council for Sustainable Development (BCSD), Ms. C. Nystedt
10:15-10:30	Break
10:30-10:55	Donor Coordination in Energy Efficiency, S. Thomas
10:55-11:20	Energy Management Consultation and Training (EMCAT) project Padmanabhan
11:20-12:10	Open Discussion
12:15	Departure by bus for Stockholm City Hall
12:30-02:30	Buffet Reception by the City of Stockholm at the City Hall (with short guided tour)
	Short addresses by Ms. M. Schwarz, Chairperson of the Stockholm City Council and Under-Secretary-General Ji Chaozhu, DTCD
	Return by bus to Industry House

03:00-05:30	Session 4: International Collaboration in Energy Efficiency
	Panel: Policy, Institutional, and Financing Options
Approx 04:00	Break
	Open Discussion and Conclusion
05:35	Bus departure for Park Hotel
	Evening Free

Friday, November 15

09:00-05:00	Sessions 5: Reports and Open Discussion
	Recapitulations and Observations by Key-Note Speakers in Session 1
10:00-10:00	Break
	Open Discussion on Recommendations and Action Plan
12:30-02:00	Lunch (Lindström Room, Industry House)
02:00-05:00	Finalizing Recommendations and Action Plan
05:05	Bus departs for Park Hotel
06:40	Departure by bus from Park Hotel for Grand Hotel
07:00	Buffet Reception at Grand Hotel host by the Swedish Trade Council

Saturday, November 16

08:15	Departure by bus from Park Hotel
	Study Tour, including visits to Hammarby District Heating Station and seventeenth century warship Vasa,
	Lunch
Approx 02:00	Return to Park Hotel

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November 13-15, 1991

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Strategies for Implementing Power Sector Efficiency

Prepared for the Consultative Meeting:

Stockholm Initiative on Energy, Environment and Sustainable Development (SEED): Strategies for Implementing Power Sector Efficiency.

by

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BACKGROUND

Since 1950, the developing world has established a large and increasing appetite for electrical energy to support economic expansion. Over the past 40 years, investments in these countries have totalled more than $500 billion for electrical power, and power projects now represent one quarter of their public capital investments.

Energy consumption in the developing world has been growing at much higher rate than in developed countries, driven primarily by faster economic growth, expansion of energy-intensive industries, rural-urban migration, adoption of energy-intensive technologies, and the inability to significantly improve the energy intensity of domestic use. In relative terms, the rate of increase for the GNP of developing economies averaged seven times larger than in OECD countries between 1973 and 1987.

Unfortunately, the financial position of LDC utilities has not been able to keep pace, and has actually declined over the same period. By 1986 the total debt of LDC utilities was approximately $180 billion, or one fifth of their total accumulated debt. Increased cost of debt service has been spurred by higher interest and fuel costs. Revenues, on the other hand, have failed to keep pace because of a combination of poor equipment maintenance, power theft, inadequate billing procedures, and lack of personal and corporate incentives.

As a result, the electricity generation sector in developing countries is facing extremely high demand, primarily unmet, with considerable adverse economic and environmental implications at the local, regional and global levels. Growth in electricity consumption in developing countries has been 50 percent higher than the increase in final energy consumption during the same period, and has been consistently above the economic growth rate. This, as recognized by the OECD, has the potential for significant environmental impacts.

> The increasing share of electricity as an end-use energy form may have both desirable and less desirable impacts on the environment. For instance, shifts from fossil fuel to electricity in industry can have a beneficial effect on the environment, particularly if associated with utilization of waste heat and with switching to low polluting fuels like natural gas. This is also true of commercial and residential sectors.[1]

Today, however, these increasing concerns over global environmental quality have combined with increasingly scarce bilateral and multilateral funds for capital expansion to curtail developing country electricity growth. The shortfall between available domestic and external donor funds and the unmet demand for electricity has been estimated at $40-$50 billion annually over the next twenty years. Consequently, there has been a marked increase in interest directed at the role of energy efficiency and conservation in serving both energy and environmental objectives.

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[1]OECD, The State of the Environment, Paris, 1991, p.28. Globally, electricity generation accounts for one-third of the carbon dioxide emitted. Coal combustion emits significantly more carbon dioxide than does either oil or natural gas combustion (11 percent and 67 percent more, respectively).

PURPOSE OF SEED

The *Stockholm Initiative On Energy, Environment and Sustainable Development* (SEED), to be held in Stockholm, Sweden in November 1991, attempts to address these objectives by focusing on the significant improvements available in energy efficiency for the electrical power sector. SEED will build on the results of two previous Seminars in Stockholm organized by the United Nations Department of Technical Cooperation for Development (UNDTCD) in cooperation with the Government of Sweden and the Swedish State Power Board/SwedPower. The results and recommendations from the two earlier seminars are summarized below.

Stockholm I: Power Plant Operation, Maintenance and Rehabilitation

The Seminar, held in October 1988, was organized to acquaint developing countries with current technology for small- and medium-scale generating plants. The goal was to encourage improvements in overall plant efficiency in developing countries, and to facilitate the exchange of views and information to make those improvements possible.

Stockholm I stressed that energy conservation and improved efficiency of existing facilities are the most cost-effective means to improve the availability of electricity and reduce environmental impacts in developing countries. Energy conservation programmes should be supported by financial incentives, demonstration projects and regulatory and legislative measures. Scarce funds from domestic, bilateral and multilateral sources should be directed to improving existing systems before investing in new capacity.

Energy conservation was identified as a rational, cost-effective, and immediate way for most developing countries to reduce energy costs and stretch their energy supply base without heavy investment. To assist in this effort, financial institutions were encouraged to harmonize their policies in favor of energy conservation and efficiency improvements.

Stockholm II: Energy Conservation in Developing Countries

Stockholm II, held in September 1989, accepted the premise that *The purpose of the electricity supply is to provide reliable power to the consumer at the cheapest possible cost.* For this to be achieved, it is necessary to aim at a good availability of the system components (facilities), particularly the generating plant. Good availability depends on many factors, including:

- equipment of adequate size and reliability;
- satisfactory operation and operating personnel;
- adequate preventive maintenance;
- rehabilitation when necessary; and
- good management.

Availability is the key to a reliable power supply, and a primary indicator of overall utility viability. The seminar recognized that low availability in developing countries is primarily a result of: (a) maintenance and operational inadequacies; (b) low grade fuels; and (c) shortage of capital and skilled manpower.

The two seminars highlighted the necessity and feasibility of improving the electric power sector of the developing nations. Stockholm I outlined the potential benefits of increased maintenance and rehabilitation programmes. Stockholm II demonstrated the potential for conservation in the power generation sector, and stressed the advantages of such initiatives to developing nations. Stockholm II also emphasized the environmental benefits, both regional and global, that would accompany improvements in efficiency and conservation.

Stockholm I and II can be considered as a turning point in the perception of, approach to, and cooperation for the provision and supply of electricity to the developing world. In meeting these needs, electricity production can and must be primarily increased through alternative - fundamentally efficient - means, namely enhancement of efficiency for existing capacity over the creation of new capacity. Figure I, which shows the generation capacity factor for public power utilities in 100 developing countries, clearly demonstrated the considerable additional capacity available from these efficiency improvements.[2]

This is particularly true in view of the financial, human resource, technological, and environmental constraints facing the developing world. 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 beneficial, but also encourages international cooperation.

AFTER STOCKHOLM II: PROGRESS IN PLANT REHABILITATION

The recommendations of Stockholm I concerning power plant rehabilitation are reviewed as a reference point for SEED. In addition to a general call for re-direction of priorities, the recommendations included:[3]

- Multilateral Development Banks and Bilateral Assistance Institutions were asked to develop lending and assistance instruments that encouraged rehabilitation over capacity expansion ("KWh over KW"), with emphasis on recurrent funding for preventative maintenance and spare parts programmes;

- Highly-qualified and motivated personnel should be selected and suitably rewarded in order to ensure the success of maintenance programmes;

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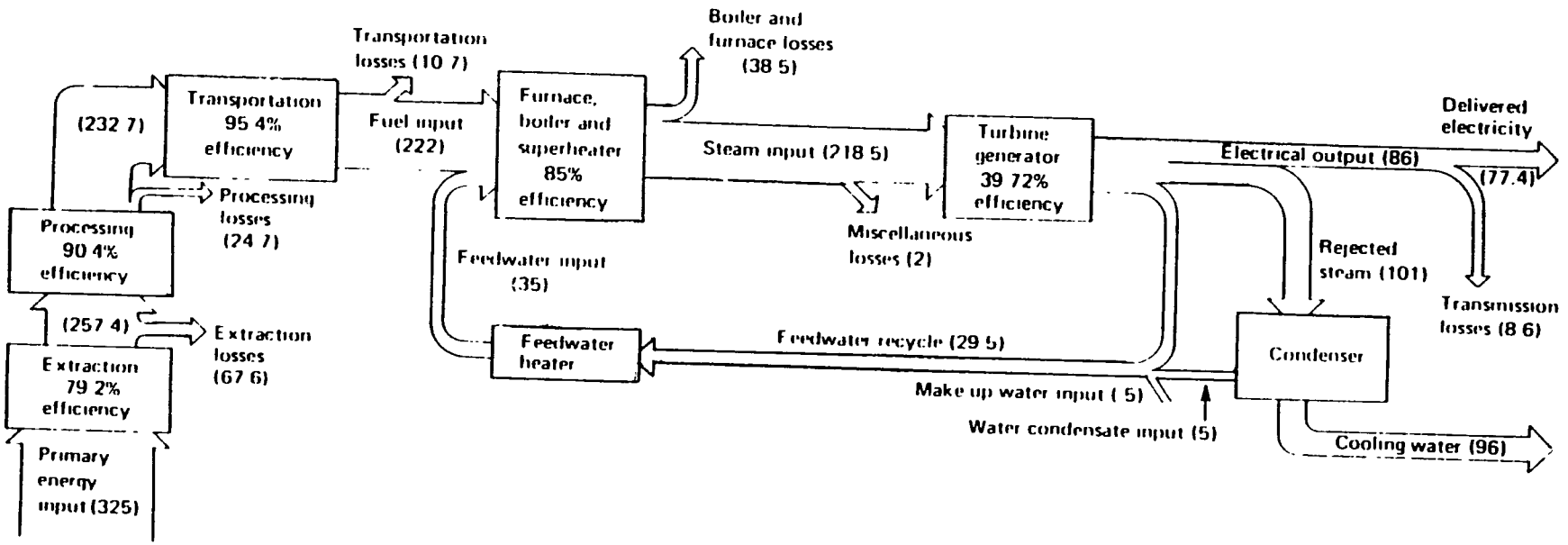
[2]Jose R. Escay, Summary 1988 Power Data Sheets for 100 Developing Countries, World Bank, August 1991.

[3]United Nations, Power Plant Operation, Maintenance and Rehabilitation, TCD/SEM.88/09 INT/88/R30, New York 1989. See pp. 85-89.

FIGURE 1: THE INPUT-OUTPUT STRUCTURE OF LARGE-SCALE ELECTRICAL POWER GENERATION



The Input-Output Structure of Large-Scale Electrical Power Generation. The figure is based on a modern, 1,000-megawatt coal-fired plant. All energy flows are shown in millions of kilocalories per hour. Adapted from Earl Cook, *Man, Energy, Society* (San Francisco: W. H. Freeman and Co., 1976), p. 37.

- International guidelines should be established for targeting training and human resource development;

- Closer cooperation between utilities in developed and developing countries should be sought, in order to transfer experience, analytical and operational systems, and organizational structure; and

- Rehabilitation should be recognized by LDC governments as the more preferable and cost-effective means of adding capacity over the construction of new plants.

It is important to establish what actions, if any, have been undertaken in response to the recommendations of Stockholm II in the ensuing two years. In particular, if no follow-up has taken place within participating organizations, attention should be given to the failure to substantively influence the assistance process.

ENERGY AND ECONOMIC EFFICIENCY: THE GOAL OF REHABILITATION

Electricity supply and end-use must be understood as an integrated system, starting with fuel inputs and carrying through to electric service consumption.[4] The main objective in the electricity sector is to increase energy efficiency, which in operational terms means to reduce specific consumption (defined as energy consumed per unit of output).

It is widely accepted that electric utilities in developing countries are capable of significant improvements in efficiency. However, there is less understanding over what that efficiency really is. Since many of the arguments for power plant rehabilitation are based on some criterion of efficiency, it is useful to consider the definition(s) in some detail.[5] The inefficient operation of electric plants and utilities also must be analyzed in reference to the particular constraints of the economy and the incentive structure of the electric utility. Within that context, it is necessary to establish a hierarchy of initiatives.

Energy efficiency may be viewed in several distinct iterations, as suggested by the following taxonomy (presented in order of increasing efficiency):

Current performance: a "satisficing" optimum for the main constituencies - shareholders, lenders, Government, and customers - but without maximizing financial performance;

[4]International Atomic Energy Agency, Senior Expert Symposium on Electricity and the Environment: Key Issue Papers, Vienna, Austria, 1991. p28.

[5]Figure 1 is an input-output schematic illustrating the energy flows and system losses for a 1,000 MW coal thermal power plant. See Philip G. LeBel, Energy Economics and Technology, Johns Hopkins University Press, 1982. p92.

Financial optimum: a level of energy efficiency consistent with a profit-maximizing objective, and providing a reasonable return on investment for upgrading current performance facilities;

Economic optimum: similar to financial optimum but with energy and commodity prices determined by economic opportunity costs;

Externality optimum: a level of energy efficiency that incorporates negative externalities created with the consumption of fuels; and

Theoretical optimum: a level of energy theoretically achievable without regard to economic cost.[6]

The efficiency of an energy conversion process is usually measured from an energy or an economic perspective. Generally speaking, for fossil-fueled technologies, one refers to the net generating efficiency, defined as the electric energy produced per unit of energy input as fuel. Higher net efficiency thus leads to reduced fuel costs and related emissions.

Net operating efficiency implies the maximum conversion of input resources to useful energy, and is ultimately limited by thermodynamic considerations. However, for a particular technology net efficiency is not uniquely defined. For example, the requirement to control pollution through the installation of energy-intensive controls (e.g., scrubbers, electrostatic precipitators) will reduce net operating efficiency by diverting energy for operation of pollution control equipment. In this instance, net operating efficiency (economic optimum) is decreased. However, if the pollution control requirements are based on the environmental impacts of pollution, the resulting system will be economically efficient in terms of the externality optimum.[7]

The theoretical optimum efficiency - the efficiency of a perfect device performing the same task - does not consider the costs involved, and may never be realized in practice. *There is no way to tell in advance if the increase in energy efficiency that would be gained by approaching the ideal would cost so much that the advance would not be worth it.* In addition, exclusive concentration on the energy that is supplied directly to carry out a service tends to obscure the very important gains in real efficiency that can be derived from replacing energy by a capital input.[8]

The determination of efficiency is a function of demand as well as supply constraints. Although there are alternative generating technologies with differing degrees of thermodynamic efficiency, optimum

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[6]World Bank, India - Industrial Energy Efficiency and Modernization Project, November 27, 1989, p2.

[7]The U.S. Electric Power Research Institute (EPRI) estimates that pollution control systems account for as much as 20 percent of the capital cost of new coal-fired power plants, with an associated energy penalty of between 2 and 4 percent.

[8]Energy Economics and Technology, p120.

economic efficiency with a given technology will depend largely on the selection of prices in response to particular patterns of demand.

For instance, if a relatively invariant pricing structure is adopted, then utilities must keep in reserve a considerable degree of spare capacity not only to service baseload consumption requirements but also to satisfy any incremental variations in demand. Moreover, since electricity cannot be stored except by conversion to an alternative energy stock, the capital-intensive nature of electrical costs is easier still to understand.[9]

It is obvious that increasing energy efficiency has direct environmental benefits, as noted above. To illustrate this point, consider the potential capacity expansion available through efficiency increases in 100 developing countries as shown in Figure 2. If system losses were reduced to 10 percent (See Figure 3) in conjunction with a higher generation capacity factor, the result would be an increase in capacity of approximately 50 percent, with no commensurate increase in emissions.[10]

Energy efficiency is closely linked to energy conservation, particularly when conservation is considered primarily the achievement of economic efficiency in the use of a resource. However, there is no simple measure of conservation, and it is necessary to adopt criteria that distinguish between energy conservation and energy curtailment.[11]

A considerable literature has been directed at the role of energy conservation for both the supply and demand side, and the potential efficiency improvements (e.g., shifting electricity away from use in heating water). Many of these improvements were the subject of Stockholm I, but will not provide the primary focus of SEED.

EFFICIENCY IN POWER GENERATION IN DEVELOPING COUNTRIES

Generating efficiency is often low in developing countries. Typical existing baseload power plants in OECD nations have heat rates (BTUs of fuel per kilowatt hour) ranging from 9,000 to 11,000. While new plants in developing countries are in this range, deterioration in performance due to aging is accelerated by a lack of proper maintenance and spare parts, inadequately trained personnel, and by the use of low-quality fuel. The result is that typical existing power plants often operate at 13,000 BTU per kilowatt hour, thereby increasing fuel requirements by 18 to 44 percent.

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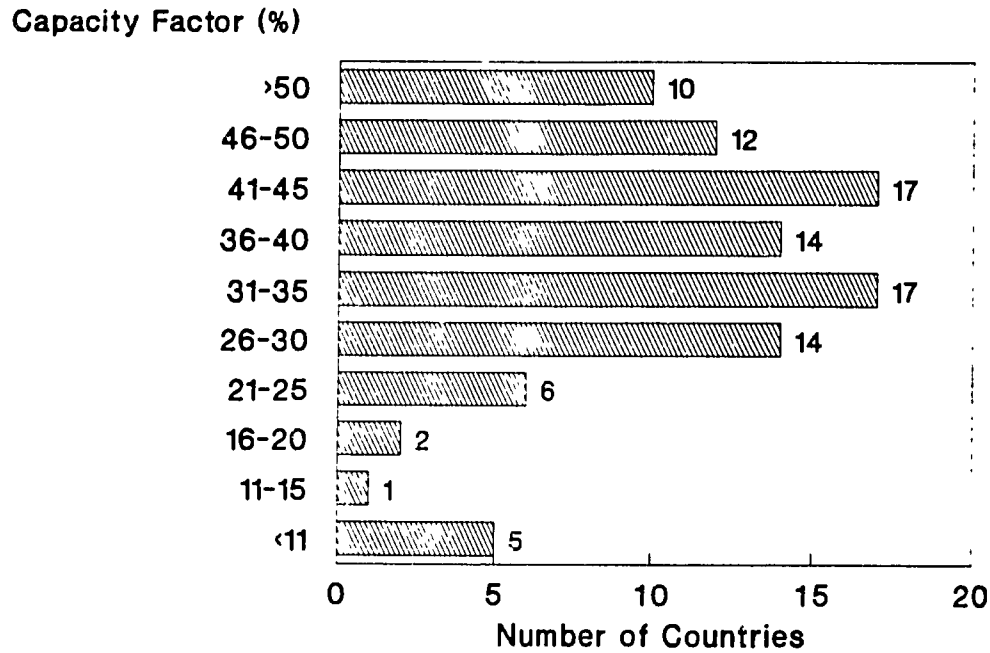
[9] Energy Economics and Technology, pp. 354-6.

[10] Figures 2 and 3 are taken from Jose R Escay, Summary 1988 Power Data Sheets for 100 Developing Countries, World Bank, August 1991. Care must be taken in directly translating these estimates, since it is not possible to determine what fraction of the savings can be derived solely from the electricity supply side.

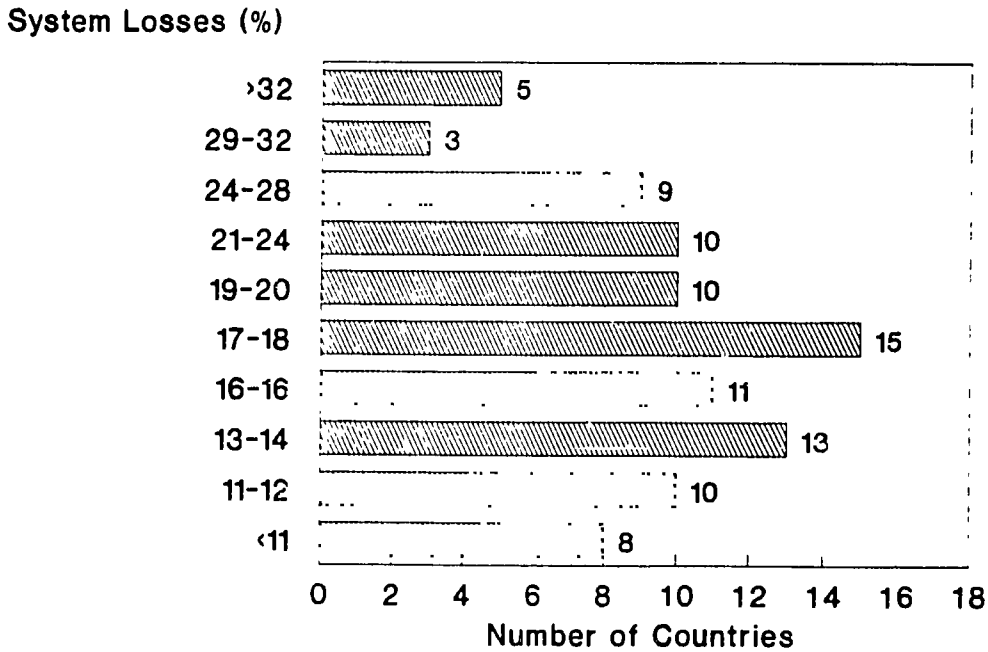
[11] Energy: The Next Twenty Years, Report by a Study Group Sponsored by the Ford Foundation and Administered by Resources for the Future, Ballinger Publishing Company, Cambridge, Massachusetts, 1979, p119.

Figure 2: Distribution of Public Power Utility Generation Capacity Factor (%)



Sample size = 98 countries
Source: Escay (1991: 1-2)

Figure 3: Distribution of Public Power Utility Total System Losses (%)



Sample size = 94 countries
Source: Escay (1991: 1-2)

Total system losses, including transmission and distribution losses, are very high in developing countries. A recent survey of 100 developing countries by the World Bank estimated average losses at 17 percent.[12] In OECD countries, typical losses are in the range of 6 to 8 percent. Even correcting losses in developing countries for theft and inadequate billing procedures, it is likely that losses in developing countries are at least 50 percent greater than those in OECD countries.

CAPITAL REQUIREMENTS FOR POWER EXPANSION IN DEVELOPING COUNTRIES

The potential market for innovative and environmentally sound power generation equipment is tied to forecasts of demand growth. The United States Agency for International Development reports an annual growth rate in power sector demand of 7 percent over the past two decades. Assuming a modest economic growth rate of 4.5 percent, an additional 1,500 gigawatts of additional generating capacity, along with the associated transmission and distribution facilities, would be required by the year 2008.

Meeting this demand would cost over $2.6 trillion, or an average of over $125 billion per year. Government-owned utilities and the development banks will be able to supply only 40-60 percent of the capital required-leaving a potential shortfall of $45-60 billion per year.[13]

Total capital expenditures required for electric power sectors located in 70 developing countries of Asia, Latin America and Caribbean, Sub-Saharan Africa, the Middle East, North Africa and Europe in the 1990s, were estimated at $742.0 billion. East and South Asian developing regions would require 61.3 per cent (approximately $455 billion), while the Latin American and Caribbean region would require approximately $155 billion, or 20.9 per cent of total requirements. Together, the Asian and Latin American developing countries represent 82.2 per cent of the total capital expenditure required by the 70 developing countries for developing their electric power during the current decade. In contrast, similar capital expenditure requirements by the Middle Eastern, North African and European developing countries were estimated to represent only 16.3 per cent of total requirements ($120.95 billion), whereas the Sub-Saharan African countries' capital expenditure requirements were estimated at $11.13 billion, or 1.5 per cent of the total requirement.

THE ROLE OF REHABILITATION

Plant rehabilitation, which normally involves modifications, refurbishment or part replacement, is becoming increasingly important in both developed and developing countries. It is motivated by the need

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[12] Summary: 1988 Power Data Sheets for 100 Developing Countries.

[13] Philip C. Cruver, "The Emerging Trillion-Dollar Electric Energy Market", Strategic Planning for Energy and the Environment, Spring 1990, pp.74-77.

to extend the useful life of a facility and improve efficiency and performance. Stockholm I identified six factors influencing the prospect of rehabilitation:

- Excessive cost of new investment and shortage of capital, particularly in developing countries;
- Economics of investment--often it is more economical to lengthen the life of an existing facility than to buy a new one;
- Lack of physical plant space for expansion, particularly in densely-populated areas;
- Difficulty in obtaining licenses and permits for new facilities;
- Improving efficiency or output of existing installations; and
- Making good existing derating of power plants.

The World Bank has systematically used policy-based operations and freestanding technical assistance loans to address the common problems of state enterprises as a group. In the power sector, which in recent years has accounted for about 20 percent of total Bank lending, such institutional reforms and performance improvements are always part of the overlending strategy pursued by the Bank. These efforts have been less than successful, leading the Bank to conclude: *The Study shows a declining trend in power sector performances in spite of Bank involvement in the sector . . .*

Stockholm I reported that:

> This experience is not limited to World Bank supported operations. Other aid agencies are facing similar problems,...over the last 20 years the overall performance of the majority of publicly-owned electric utility companies in developing countries has steadily worsened. Frequent power outages and voltage fluctuations are very costly to power users, as well as to the utilities themselves. Key elements causing this deterioration are lack of financial resources, poor management, poor operational procedures and a lack of maintenance.

In order to develop appropriate and workable solutions, several aid agencies (including KfW and GTZ from Germany, FINNIDA. British ODA, USAID and UNDTCD) together with the World Bank, developed a joint research project designed to address the issues involved and to develop appropriate remedial measures and policy approaches. Specifically, the objectives included the following:

- Identify the underlying causes of poor operating performance of publicly-owned utility companies;
- Measure the economic and financial costs of this poor performance to the utilities themselves, to power users, and to the economy as a whole; and
- Develop implementable programme and project packages designed to remedy these shortcomings on a permanent basis.

The central hypothesis of the working group was that:

> this poor performance is not just the outcome of readily observable external factors or deficiencies such as lack of spare parts, foreign exchange and/or financial resources but, more importantly, the consequences of a set of institutional and human constraints both within and without the organization itself. It can be postulated that the performance of the utilities is strongly conditioned by external but more generally internal factors . . . The usual approaches of governments and donor agencies e.g. to focus on physical rehabilitation programmes combined with limited technical assistance and training of staff, are insufficient to remedy the situation and bring about sustained change. What will be needed, in addition, are policy and management reform packages etc...

THE ROLE OF PLANT EXTENSION

Stockholm II participants recognized the close relationship between plant rehabilitation and life extension of older power plants. Many utilities are now examining low cost alternatives to new plant investment, particularly in view of the uncertainties tied to both electricity demand projection and possible environmentally-driven regulatory requirements. Since many older units are smaller than their newer counterparts, one of the most likely alternative candidates involves the refurbishment of older plants. This concept, known as *life extension* or *plant betterment*, has particular import for coal-fired generating capacity in both developed and developing countries. In the United States, for example, the Department of Energy estimated that by 1995, more than 60 percent of all coal-fired units will be at least 30 years old, and will account for 26 percent of total coal-fired generating capability.[14]

The results of a recent plant betterment conference sponsored by the American Public Power Association indicate that plant life may be economically extended to between 45 and 75 years.[15] In the June 1986 meeting of the Air Pollution Control Association, a paper presented by Environmental Protection Agency staff concluded that 60 years was a reasonable assumption for total plant life, with sensitivity analyses developed for a range from 45 to 75 years.[16]

The upgrade economic analysis is usually directed at specific components, but many of the factors used in the analysis are derived from overall plant performance, including capacity factor of the unit, system replacement energy cost, and system replacement capacity cost. One approach to determining the factors involves a power system production simulation model, which can be used to compute system reliability, generating unit capacity factors and operating expenses, capital expenditures, and total electric revenue requirements. The information derived from such simulations is fed to the component economic evaluation,

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[14]U.S. Department of Energy, Annual Outlook for U.S Electric Power 1986, DOE/EIA-0-474(86), April 1986, p.25.

[15]Power Plant Life Extension, Renovation and Upgrading Workshop, presented by the American Public Power Association, Omaha, Nebraska, May 22, 1984.

[16]DeMocker, J., Greenwald, J., Schwengels, P., Extended Lifetimes for Coal-fired Power Plants: The Implications for Air Quality Analysis and Environmental Policy, presented at the 79th Annual Meeting of the Air Pollution Control Association, Minneapolis, Minnesota, June 22-27, 1986.

which is based on probability of component failure, consequence of failure, upgrade characteristics, and economic evaluation.

Ultimately, the net present worth expenses for the various options (e.g., upgrading in year A as opposed to year B) are translated into equivalent capitalized investment costs, thus allowing the utility to choose the upgrade schedule that is most efficient in terms of both economics and reliability.

Stoll described one upgrade scenario based on GE's Optimized Generation Planning Program (OGPP), where the system reliability was based on 50 year unit life, after which units were replaced with new units, and compared this with the scenario where the same system upgraded coal-fired units after 25 years of service. The simulation showed that over a 30 year study period, the net present value of upgrade costs for the 25-year case were estimated at $300/kilowatt, measured against costs of $460/kilowatt for the 50 year case.[17]

A COUNTRY EXAMPLE: THE POWER SECTOR IN NIGERIA

The real focus of any rehabilitation programme must be at the country level. The country profile in the following case study, identified in a recent UNDP Needs Assessment Programme for Nigeria with the participation of UNDTCD, is representative of conditions encountered in many developing countries:

> Nigeria's electricity generation sector has been plagued by technical inefficiencies and inadequate maintenance programmes. From 1981 to 1988 total grid installed capacity increased from 2513 MW to 4534 MW (28% hydro, 44% steam, 28% gas turbines), representing an annual increase of 6.3%. In 1985 a system rehabilitation programme resulted in the purchase of spare parts (jointly funded by Government and a World Bank loan). However, the desired improvements in financial operations of NEPA were not realized because of delays in implementing the necessary institutional reforms. As a consequence, the sector recorded a growth rate of 1 percent in 1986. Even with such low growth, the system rated reserve capacity margin in 1990 was approximately 150 percent, in contrast to a margin of 50 percent encountered in other developing countries, driven primarily by the decision to install new capacity to maintain the electricity supply rather than repair and upgrade existing capacity. [NOTE: The actual operating margin was 30 percent, indicating that many generating units were not available or in service]
>
> One of the major problems for the under-utilization of existing installed capacity is frequent breakdowns and untimely fuel supplies (especially gas). Other reasons include lack of funds for spare parts, and drought resulting in low water levels. However, high energy losses are described as the major problem, due to physical deterioration of transmission & distribution facilities, inadequate metering and billing systems, and theft. A US$70 million World Bank loan is envisaged for the power sector maintenance and rehabilitation programme.
>
> Manpower constraints and inadequate institutional and supporting facilities are described as major reasons for the poor performance of NEPA. High turnover of staff due to low salaries is given as one of the reasons, but poor in-house training is also mentioned. The Inspectorate Division cannot fulfill its role because of inadequate provision of personnel, poor office accommodation, lack of stationary, transport, radio telecommunication,

[17] Stoll, H. G., The Economics of Power Plant Upgrading, presented at the Power Plant Life Extension, Renovation and Upgrading Worksnop, presented by the American Public Power Association, Omaha, Nebraska, May 22, 1984.

computers, etc. The inadequacy of basic local industries to produce transformers, underground cables, meters fuses, switch-gears, etc. forms another major constraint.[18]

THE UNITED NATIONS DTCD PROGRAMMES FOR POWER SYSTEM UPGRADING

In 1988, the United Nations Department of Technical Co-operation for Development (UNDTCD) initiated a large-scale programme on power plant upgrading, rehabilitation, operation and maintenance. Four U.N. interregional seminars on the problem have been held. They include: *Increasing the reliability and efficiency of electricity generation, transmission and distribution in developing countries* in Minsk (USSR) in 1987; *Power plant operation, maintenance and rehabilitation* in Stockholm (Sweden) in 1988; *Power plant operation, maintenance, rehabilitation and distribution in the Arab Region* in Amman (Jordan) in 1989; and *Electrification and power generation* in Jyvaskyla (Finland) in 1990.

More than 100 energy specialists from 74 developing countries have participated in the Seminars. The UNDTCD/NRED Energy Resources Branch is also implementing or initiating projects in several countries, including China, Vietnam, Jordan, Thailand, and Libya. Some of these are described below:

Modernization of 200 MW Fossil Fuel Generating Unit: A project in the People's Republic of China, which includes the following objectives: to increase the efficiency of steam turbines by 1.5-2 percent through design modification of low pressure turbines; to increase the plant's output, reliability and availability through the modification; and to train a group of Chinese power plant design and maintenance engineers in industrialized countries. The project is a basis for future modernization of more than 100 similar coal-fired units installed in China's power plants. The coal consumed by the plants would decrease by 2 percent, and power output would be increased.

Power Plant Maintenance and Training Facilities: A project in Vietnam, which was completed in 1988. The project objectives, which have been achieved, were to provide a central workshop at Thu Duc Power Station for Power Company No.2 (Southern Region), train staff and improve the maintenance of power stations. The productivity of the workshop built and equipped under the project has increased by a factor of 10. The overseas training programme, carried out in Ireland, Sweden, and Switzerland, entailed 90 man/months, while the local training programme consisted of about 400 man/months.

A similar but more limited response was called for in the Central area under the responsibility of Power Company No. 3 and in the Northern Region area for Power Company No. 1. A new project *Power Plant Upgrading* for the two regions was initiated in 1989. The principal element of this project is the establishment of power plant maintenance and training facilities and the training of local personnel in appropriate maintenance tasks. To make the training process more effective, power plants which are representative of the regions concerned will be rehabilitated with the employment of local personnel undergoing training.

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[18] United Nations DTCD/NRED Back-to-Office Mission Report, M.G. Willingham, October 1991

During the past few years, an increasing number of countries have sought advice and assistance from UNDTCD for improving the operation, maintenance, and rehabilitation of their power systems.

New project documents have been prepared by the UNDTCD consultants within the programme for the following projects: *Energy Conservation and Plant Life Extension* in Jordan and *Power Plant Upgrading* in Thailand; and the *Preparation of Power Sector Improvement* Programme in Libya.

The *Power Plant Upgrading* project envisages the following three main objectives:

(a) Study and training if national personnel on power plant life extension from 20-30 years to 40-50 years, including fuel conversion;

(b) Study of and training on energy conservation in power plants; and

(c) Study of and training on advanced operation and maintenance systems.

The project can be expanded to *Power System Upgrading* by including new objectives for hydropower plant rehabilitation, operation and maintenance, and transmission and distribution system studies (including their performance and optimization). The effectiveness in implementing the findings of the studies (project phase II) is considered to be very high. For example, life extension of power plant unit(s) of an installed capacity of only 50 MW will result in savings of $30-50 million, since the rehabilitation of the equipment and prolongation of its life is much cheaper than the construction of a new power plant. Energy demand reduction in the power plant unit(s) due to increasing operating heat rates by 10 percent and decreasing costly fuel consumption will result in fuel savings of $5-10 million. The implementation of computerized operation of maintenance systems will also result in fuel economies from the increased reliability and efficiency of the power units.

The UNDTCD is also contacting authorities in Mexico, Colombia, Chile, Pakistan, Sudan, Philippines, Peru, Dominican Republic, Indonesia, Tunisia, and Sri Lanka (as well as other developing countries) who have expressed their interest in solving the problem of power system upgrading, rehabilitation, operation and maintenance, and proposing the new UNDTCD projects under V Country Programme IPF Cycle (1992-1996). The proposed preparatory works would be initiated in 1991.

SUMMARY: THE FUTURE FOR REHABILITATION PROGRAMMES

Power plant rehabilitation programmes present a very attractive alternative to construction of new capacity, but the promise has not been realized to any great degree. The following general remarks provide a capsule summary of the factors that will determine the market penetration of rehabilitation programmes.

Most developing countries urgently need to increase the efficiency of power supply through the reduction of losses in power generation and transmission and distribution. System losses in electricity generation and transmission and distribution account for 20 percent of total power production in developing countries, and

losses in excess of 30 percent are common. Since optimal losses are approximately 10 percent, new and continued efforts are needed to rehabilitate systems, improve operations, and upgrade dispatching facilities.

International financial resources are not adequate to address the unmet electricity demand in developing countries, and the result is a limitation of economic growth in all sectors of the economy. Freeing additional capacity through efficiency improvements and supply-side conservation will reduce pressures on developing countries to devote their scarce financial resource to plant construction.

There is general agreement that significant efficiency improvements can be attained for the electrical utility sector in developing countries. These improvements are a function of technology, economics, and institutional factors. There is no clear dominance of any one of these factors as the principal contributor to energy inefficiency.

Electricity supply and use must be understood as an integrated system, starting with fuel inputs and carrying through to electric service consumption.

The lack of information about energy efficiency technologies and strategies has been cited as a major obstacle to their successful adoption. This has been cited for both the donor community and recipient countries.

Human resource development and technical training are an integral part of any technical assistance programme to guarantee lasting improvements from upgrading and rehabilitation of electrical generation, and transmission and distribution equipment.

Investments in improving the efficiency of electrical services are a cost-effective way of expanding this sector, but its implementation will require significant shifts in the policies of industrialized countries, multilateral institutions, and developing countries.

Electric utilities and government regulators will not implement efficiency improvements unless there are clear incentives to do so. In order to provide a true understanding of the costs and benefits of efficiency improvements, it is necessary to eliminate incorrect pricing signals (e.g. fuel subsidies to government or parastatal utilities). In addition, energy efficiency concerns should be incorporated into project analysis for funding agencies.

Private power initiatives and independent power producers (IPPs) can provide a financially and environmentally attractive alternative to capacity expansion programmes, and may provide incentives for state-owned and parastatal utilities.

The cost of energy efficiency improvements in the power sector should be compared to the cost of providing the same services through demand-side options in addition to comparison with supply side alternatives.[19]

Plant rehabilitation and energy conservation programmes will have an immediate and significant impact on the regional and global environment through the reduction of pollutants per unit of useful energy delivered.

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[19] Julie VanDomelen, Power to Spare: The World Bank and Energy Conservation, World Wildlife Fund, 1988, p49.

QUESTIONS AND UNRESOLVED ISSUES

The remarks and observations presented in this paper are drawn from a wide array of reports and articles concerned with power plant rehabilitation. Although many arguments and conclusions are country- and site-specific, it is apparent that rehabilitation initiatives have fallen far short of their potential. In order to focus on the underlying reasons for this shortfall, the following questions are proposed for discussion by SEED participants:

- In view of initiatives by multilateral assistance agencies and international lending agencies, as well as the various symposia directed at power plant rehabilitation, what are the most critical actions that should now be undertaken? What can external donors do to facilitate rehabilitation programmes, and what are the incentives required for them to respond?

- What is implied by harmonization of policies for financial institutions concerned with plant rehabilitation programmes? What new instruments and initiatives have been created? What else is needed?

- What is the role of private power and independent power producers in influencing rehabilitation decisions?

- Are there generally-applicable methodologies to assist in making the choice between efficiency improvements and installation of new capacity? Are these tools actually employed in developing countries? How are the decisions resulting from these methodologies treated in the national decisionmaking forum?

- Technical and professional training in all aspects of utility operations has been clearly identified as a major need for developing countries. However, many developing countries have been slow to avail themselves of training opportunities. What are the root causes of the perceived lack of interest in training. What can the international community do to encourage the incorporation of technical training and human resource development programmes as central ingredients in utility operations?

Issues and Problems in the Power Sectors of Developing Countries

A Background Paper prepared for the

STOCKHOLM INITIATIVE ON ENERGY, ENVIRONMENT AND SUSTAINABLE DEVELOPMENT (SEED)

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INTRODUCTION

Thirty or forty years ago the supply of electric power in most developing countries (*less developed countries*, or LDCs, for short) was limited to a few of the larger cities and, within those cities, to a limited number of connections. The vast majority of people did not have access to electricity, and the power industry itself relied mainly on some small diesel, steam, or hydroelectric plants. Since then, growth has been rapid almost everywhere, even in countries that experienced little or even negative economic growth. Between 1971 and 1989, electricity production grew[1] at an average annual rate of 6.3 percent in Africa, 7 percent in Latin America, and 8.3 percent in Asia, compared with an average of 3.3 percent for the OECD countries. The LDCs' electricity production growth rates far outpaced their GDP growth in the same period.

However, even with this rapid growth, LDC electricity production on a *per capita* basis[2] is still far below that of the developed world, ranging from a 1988 low of 14 kWh/capita in Togo to a high of 3,713 kWh/capita in Yugoslavia. Compare this with an average[3] of 6,655 kWh/capita in Western Europe and 12,683 kWh/capita in North America.

To support further economic growth and development, electricity use should increase at equally rapid rates in the future, since electricity is an essential input to most modern sector activities, which, after all, represent the primary engines of economic growth. A projected annual average GDP growth of 4.5 percent in the developing countries between now and the turn of the century is likely to generate a rate of growth of electricity demand of some 6.6 percent per annum, compared with an estimated 1.2 percent in the developed world (Schramm 1990). At this differential, it would take about 13 years for power production in the developing world to reach the current level of production in all OECD countries combined.

The implications of such growth, if it can be brought about, in terms of investment capital and skilled labor requirements, fuel consumption, and added environmental pressures, are staggering indeed. But there are serious doubts that this growth can be achieved unless rather fundamental changes can be made in how the sector is organized, financed, managed, and operated.

ISSUES AND PROBLEMS

Many factors will influence the attempts of LDCs to develop their power sectors, and hence their economies, to levels approximating those of the OECD countries. Among these are enormous requirements for investment capital (estimated at US$1 trillion during the 1990s); the problematic financial performance and inappropriate investment policies of many LDC power utilities; and a host of operational, managerial, institutional, and environmental issues.

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[1]International Energy Agency 1991: 174 ff

[2]Escay 1991: 1-2, for Escay's full data set, see the annex to the present paper.

[3]Calculated from International Energy Agency (1991 and World Bank (1990) Table 1

Huge Requirements for Investment Capital

To accommodate the growth projected by the various LDC power utilities in the 1990s, about US$745 billion in 1989 dollars (US$ 1 trillion in current terms) would be needed to finance the required capital investments (Moore and Smith 1990; for breakdowns of these figures by region and by type of power generation plant, see figure 1 of the present paper, taken from Moore and Smith 1990, figure 2.4). According to the announced plans, total power supply capacity by the turn of the century would increase by some 384 GWe, or about 80 percent above the 1989 level. In addition, large investments would be required to develop the necessary primary energy resources (coal, gas, and petroleum) as well as the added transportation infrastructure. Of the direct investments needed by the utilities themselves, about US$40 billion annually would be required in the form of foreign exchange; US$ 60 billion would represent domestic capital requirements.

Raising the required domestic capital of some $60 billion per year will be an equally daunting task.[2] In the majority of LDCs, local capital markets are embryonic, if they exist at all. In the past, much of the needed financing was raised by the respective governments through deficit financing. As a result, the power sectors of quite a number of LDCs (Brazil, Colombia, Argentina, to name but a few) became indirectly a major cause of high domestic inflation rates.[3] The strong efforts to reduce inflation by many of the LDCs will close off this convenient financing option.

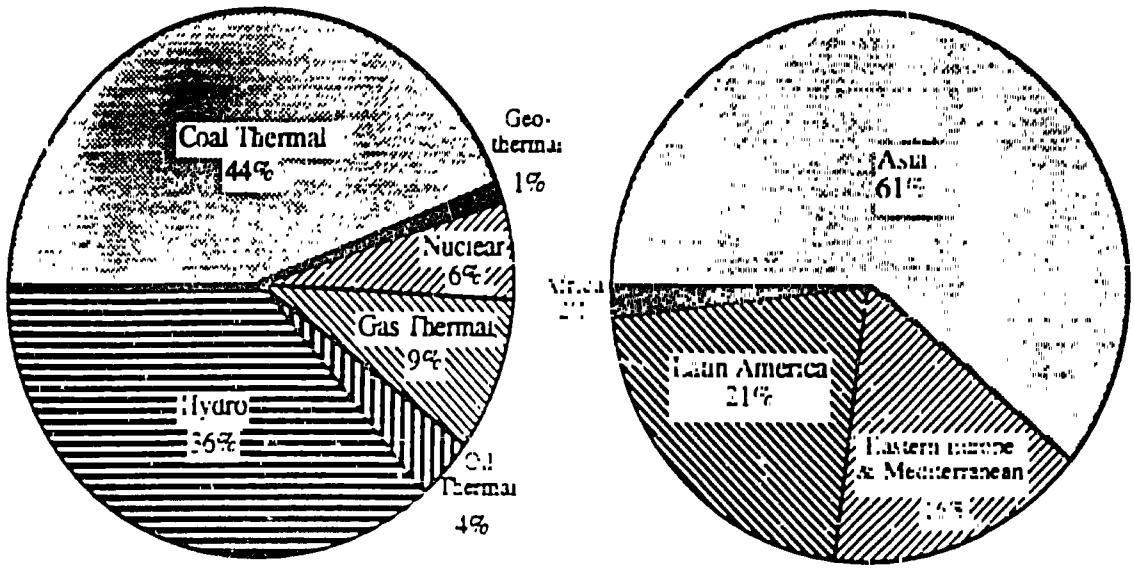
The experiences of the 1980s suggest that these huge sums will not be mobilized. Official financing agencies, such as the World Bank, in recent years have supplied approximately US$7 billion per year (Schramm 1990: 7; see figure 2 of the present paper). It is unlikely that these "official" flows will be substantially increased, given the many other claims on these types of funds from other economic sectors (or from Eastern Europe and Russia, for that matter). Private foreign financing agencies that until the early 1980s had supplied the bulk of the foreign exchange sector funding (usually via direct loans to the respective governments) had largely withdrawn from lending by the mid-1980s, given the mounting difficulties of many of the LDCs' governments to service their debts. These include some US$60 billion of publicly guaranteed power loans.

---

[2]It is important to note that almost 85 percent of these domestic capital requirements will have to be raised in just two countries: India and China (both of which have well-developed indigenous construction and power equipment manufacturing sectors but poorly developed domestic capital markets; Moore and Smith 1990, Annex 4.6).

[3]In Latin America, for example, the overall self-funding ratio of the power utilities during the late 1980s fell to -93 percent, ranging from a high of 48 percent in Venezuela to -300 percent in Trinidad and Tobago, with Brazil, which accounted for roughly half of the Continent's total investments, showing an abysmal -174 percent (World Bank and OLADE 1991, Table III-1).

Fig. 1: Projected Power Capital Expenditures in the LDCs in the 1990s (US$745 billion total)



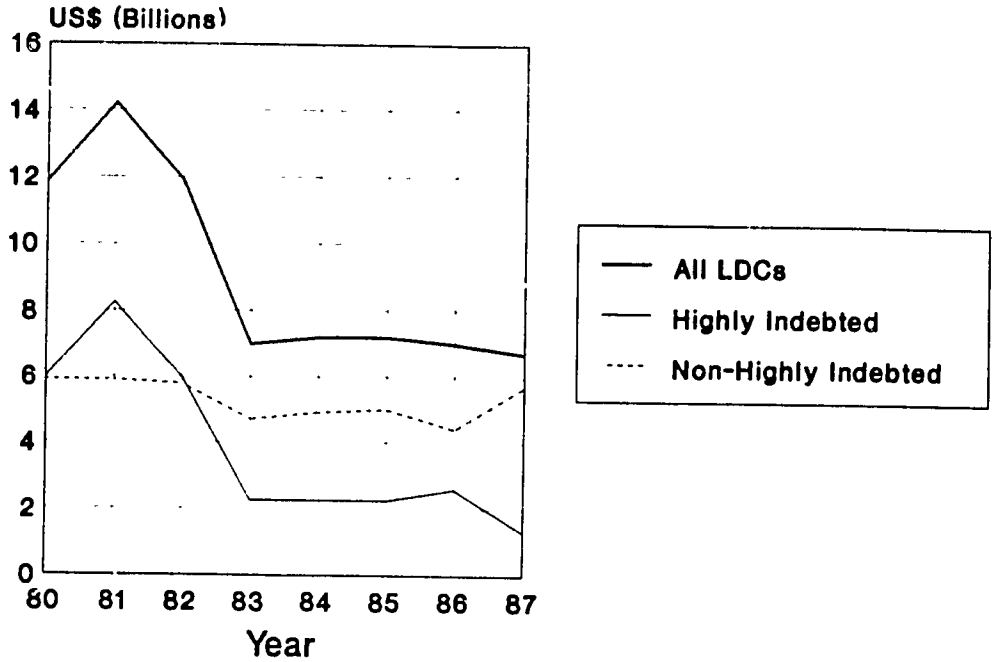
Breakdown by Plant Type **Breakdown by Region**

Source: Moore and Smith (1990, fig 2.4)

It is obvious, of course, that not all power utilities in the developing world will face the same degree of difficulty in financing their expansion programs. Some utilities, ones having healthy balance sheets and located in countries with reasonable credit ratings (Korea, Thailand, and Chile come to mind), may face few or no difficulties. Others may find it next to impossible to raise new funds at all or may be able to raise only a fraction of what their own plans call for.

What, then, can be done? As Dr. Jhirad points out (Jhirad 1991), the options range from doing more with less (i.e., increasing operational and financial efficiency); opting for less costly rehabilitation instead of construction of new facilities (which is the powerful message from the two previous Stockholm Conferences; for a summary, see UNDTCD 1989); to increasing revenues (via higher tariffs, improved collection methods, reduction of nontechnical losses); to full commercialization and full or partial privatization. In most situations and in most countries, a combination of several or all of these actions is likely to yield the best results. But action must be taken as soon as possible if further deterioration in performance, with its huge cost to the respective economies, is to be avoided.

Fig. 2 Trends in Total Foreign Financing for the LDC Power Sector



Source: Besant-Jones (1990).

Deteriorating Financial Performance

A major issue directly related to the problem of raising investment capital, as well as to the problems of poor operational performance (discussed below), is the deteriorating financial performance of the majority of publicly owned LDC power utilities. Figure 3 provides an overview based on a sample of some 360 actual financial rates of return from 57 World Bank Member Countries. As can be seen, average rates were less than 5 percent between 1987 and 1989, having fallen to as little as 2.8 percent in 1989. Table 1 provides similar information for selected countries for the years 1980 and 1988, with emphasis on Latin America and the Caribbean. For the latter area as a whole, rates of return have been consistently below 4 percent per year since 1982 (2.8 percent in 1988), compared with average interest rates of around 8 percent (World Bank and OLADE 1991, figure III-3). Clearly, from a financing point of view, an industry whose rate of return is consistently below market interest rates can hardly expect to be welcome in domestic or world financial markets.

Table 1
Financial Rates of Return, 1980 and 1988
Selected Countries

Country	1980		1988	
	Rate of Return	Average Interest Paid (%)	Rate of Return	Average Interest Paid (%)
Belize	NA	2.7	14.6	11.7
Republic of Korea	NA	NA	14.0 b)	7.2 b)
Dominica	-9.9	NA	12.4	15.0
Chile	3.4	7.8	9.6	5.8
Pakistan	NA	NA	9.4 b)	7.6 b)
USA	NA	NA	9.3	9.1
Suriname	8.0	8.0	7.8	8.0
Guatemala	6.9	1.9	7.4	10.6
Panama	7.9	10.7	6.8	11.7
Jamaica	-1.1	7.8	6.2	6.6
El Salvador	16.6	4.1	6.0	12.9
Ghana	NA	NA	5.7	1.2
Costa Rica	10.3	7.0	5.5	10.9
Honduras	9.4	5.1	4.8	5.8
Paraguay	7.6 a)	0.8 a)	4.6	2.3
Barbados	5.3	13.8	4.5	10.7
Columbia	14.9 a)	8.6 a)	4.5	7.2
St. Vincent	NA	NA	4.2	0.0
France	NA	NA	3 8 c)	NA c)
Brazil	6.4	NA	3.8	6.9
Venezuela	0.6	9.6	3.4	5.8
Uruguay	2.4 a)	11.4 a)	2.5	6.0
Bolivia	8.8 a)	NA	1.9	NA
Haiti	4.5	5.3	1.4 b)	6.4 b)
Mexico	1.7	15.5	1.0	23.7
Bangladesh	NA	NA	0.9 b)	1.5 b)
Ecuador	NA	NA	0.5	6 5
Guyana	NA	NA	-0.9	24.1
Trinidad & Tobago	-19.9	5.3	-3.0	0.0
Dominican Rep.	-10.7	NA	-3.2	12.1
Peru	3.5	12.6	-4.0	13.6
Nigeria	NA	NA	-4.5 b)	7.8 b)
Argentina	1.0	13.1	-9.4	12.9
Latin America & Caribbean Region	4.9	12.5	2.7	7.5

Source: World Bank and OLADE (1992)

a) 1981 data

b) 1987 data

c) 1989 data

But the poor financial performance of the industry does not only affect its ability to raise investment capital. The lack of adequate income has an even more deleterious effect on the day-to-day performance of the utility itself, on its ability to undertake required maintenance, and on its ability to attract and hold competent managerial and technical staff.

Two major factors are responsible for the poor financial performance: inadequate tariffs and poor revenue collections. Figure 4 provides a summary of tariffs charged by a representative sample of utilities in 60 World Bank Member Countries, expressed in constant 1986 U.S. cents (US¢) per kilowatt hour (kWh). As can be seen, average tariffs have drifted down from an already low US¢ 5.21/kWh in 1979 to US¢3.79/kWh in 1988, a reduction of some 32 percent in real terms! There was no justification for such declines; in most cases they came about because of high rates of domestic inflation and the unwillingness of governments to adjust tariffs accordingly. As can be seen from figure 5, weighted average tariffs of a sample of 63 developing countries, expressed in current 1988 U.S. dollars, were US¢4.46/kWh in 1988, compared with a weighted average for all OECD countries of US¢8.07/kWh, a difference of more than 80 percent.

While there are a few utility operations in the developing world that have inherently low cost structures (low-cost hydro, short transmission lines, mainly large-volume customers), in general, on technical and economic grounds (mostly imported equipment, less-than-optimal system sizes, low average consumption per connection), average tariffs should be significantly higher in LDCs than in OECD countries in order to cover costs. For Latin America and the Caribbean, for example, tariffs covered on average only 71 percent of long-run incremental costs, ranging from a low of 20 percent in Peru to 139 percent in Honduras (Argentina, 48 percent; Mexico, 64 percent; and Brazil, 76 percent (World Bank and OLADE 1991, Table II-5).

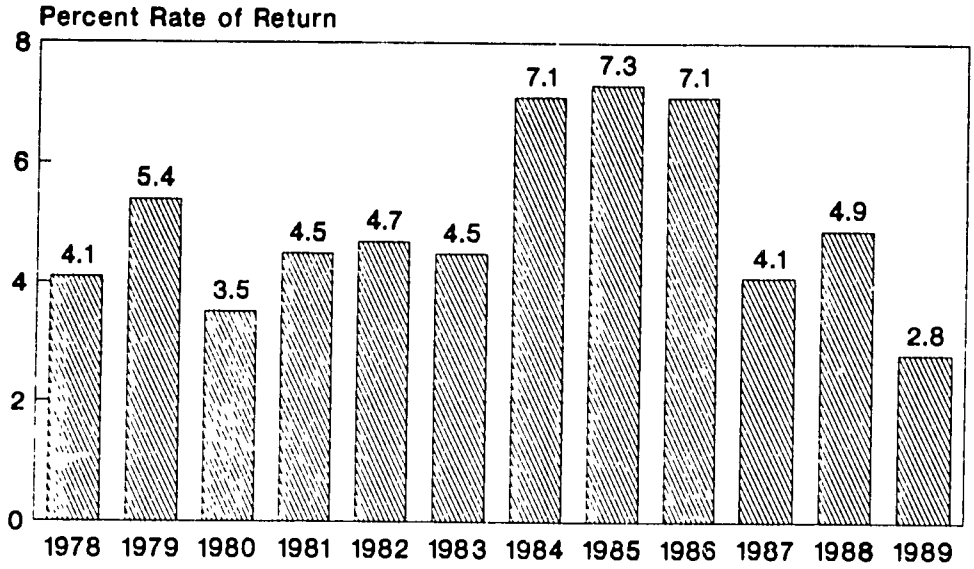
Poor revenue collection has many causes: poor meter reading, accounting, and billing; inaccurate record keeping, lack of meters, and nonpayment by governmental organizations that cannot be disconnected. Accounts receivables, expressed in months outstanding, are commonly used as a measure of good or poor revenue collection performance.

Figure 6 provides an overview of accounts receivables, based on a sample of 51 countries (1988 data). While there are a number of well performing utilities with averages of less than 1.5 months outstanding, there are others that have averages of 15 months or more! In those cases, it can safely be assumed that a substantial proportion of outstanding accounts will never be collected. The mean average for the 51 in the sample utilities is 4.3 months; for Latin America it is 3.8 months (World Bank and OLADE 1991, Table II-4). This may be compared with a U.S. average of slightly less than 1 month.

Inappropriate Investment Policies

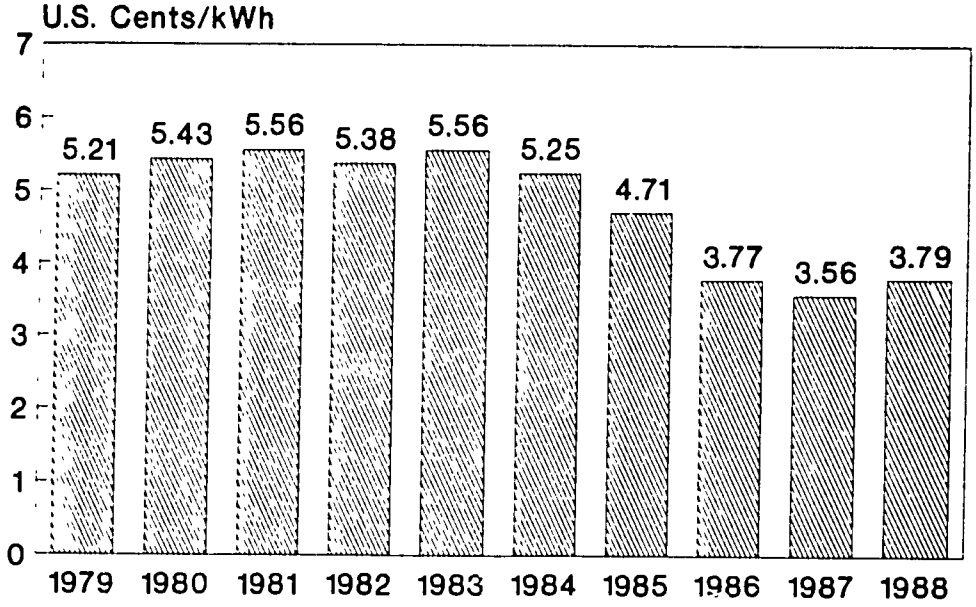
A number of utilities are plagued by continuing capacity shortages, but many others, in fact, have substantial excess generating capacity. In well-run utilities, reserve capacity margins are usually kept at somewhere between 15 and 30 percent above peak load, depending on system characteristics.

Figure 3: Mean Annual Rate of Return on Revalued Net-Fixed Assets for Developing Countries



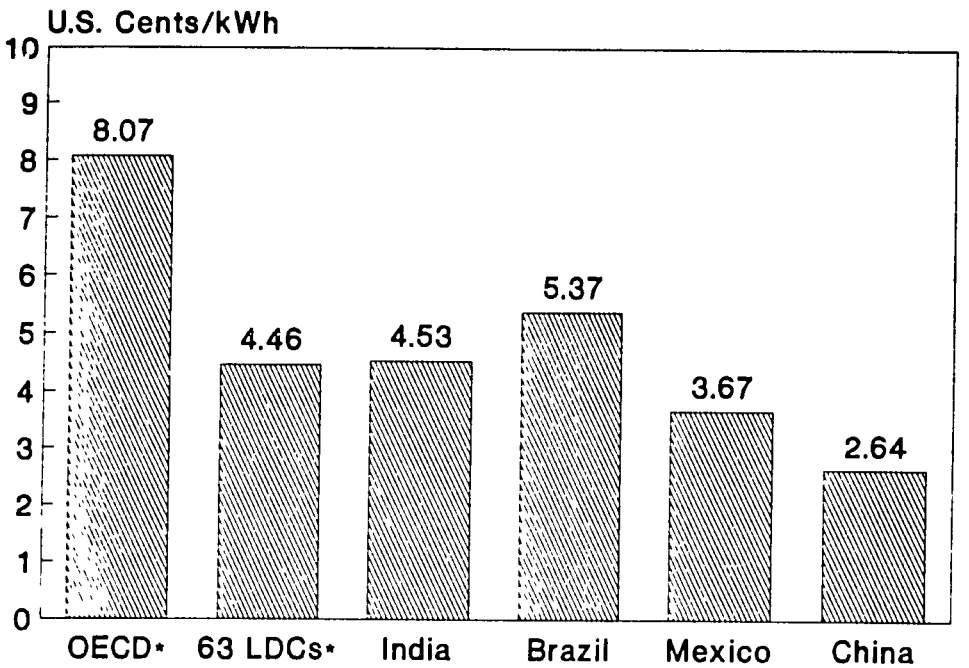
Source: World Bank
Based on sample of 360 actual financial rates of return for 57 IBRD countries

Figure 4: Trends of Electricity Tariffs in Developing Countries (1986 US$)



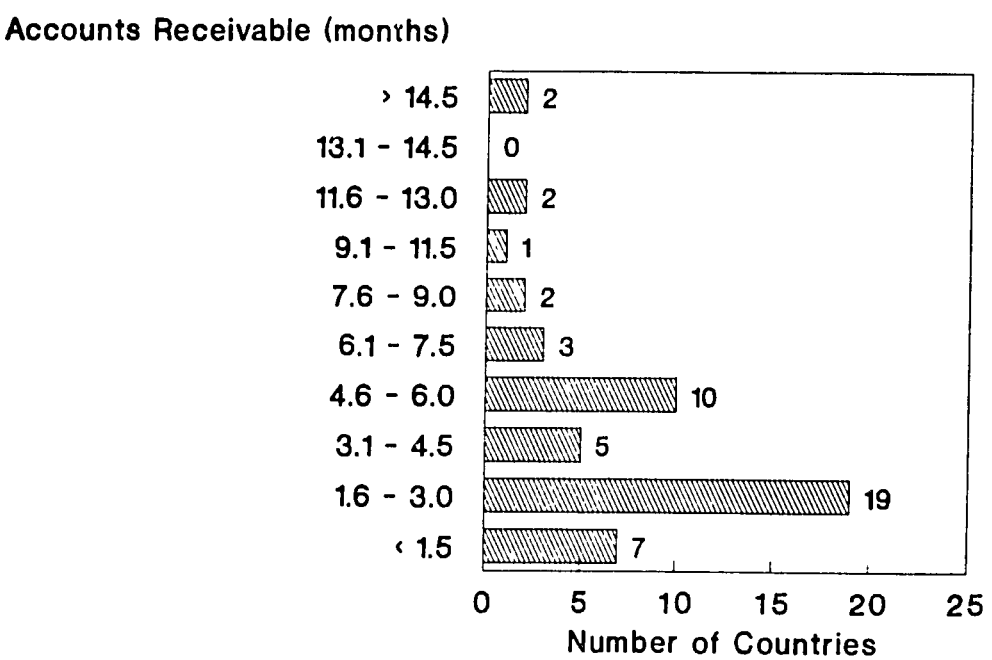
Source: World Bank (1990)
Based on a sample of 60 World Bank member countries

Figure 5: Comparative Electricity Tariff Levels (in 1988 US$)



* Weighted Average

Figure 6: Distribution of Public Power Utility Accounts Receivables for Developing Countries



Sample size = 51 countries

However, in the majority of developing countries, capacity reserve margins are excessive--typically between 40 percent and 59 percent, as shown in figure 7, which indicates the distribution of generating capacity reserve margins in 1989 for 70 developing countries. The overall average for all 70 countries was 43 percent. Relative to the 1989 total systems load of 331 GWe and a target reserve margin of 30 percent, this means the excess capacity was 43 GWe, representing an investment of about US$50 billion, using $1,150/kW as the weighted average mix of capital costs for hydro, thermal, nuclear, and geothermal.[4] The 43 GWe capacity savings would meet two years of load growth at 6 to 7 percent p.a. So improved maintenance to increase unit availability and reduce the capacity reserve margin to 30 percent could save both US$50 billion initially and roughly US$25 billion each year (starting in year 3) in terms of future generating investments.

However, in many of the countries with excess generating capacity, there has been a systematic neglect of subtransmission and distribution investments and maintenance with the result that circuits are overloaded, voltage drops chronic, and power supplies in general highly unreliable.

High Systems Losses

Systems losses -- the difference between electricity sent out and electricity billed--are unacceptably high in many LDCs. Any power system will incur technical losses in transmission and distribution, but with present technology, these losses should generally range between 7 and 10 percent. A few LDCs are within that range, but most are not. As figure 8 shows, of a sample of 94 utilities, only 8 had losses of 11 percent or less; another 34, or slightly more than one-third, had losses ranging between 11 and 16 percent, while some 21 showed losses in excess of 21 percent. Table 2 compares a few countries with high and low losses. These are 1988 data. Since then, the trend in a number of countries has been up, not down. For example, for Bangladesh and Nigeria, recent reports indicate losses of as much as 42 percent; several Indian State Electricity Boards have similarly dismal records.[5] It is important to note that high losses are not necessarily correlated with underdevelopment. As Table 2 shows, Korea had losses of only 6 percent, the same as low-income Cameroon (1988 per capita income $1,010), while even poverty-stricken Burkina Faso with a per capita income of only $210 still managed a reasonably respectable 11 percent.

Systems losses above about 15 percent almost always are the result of inaccurate and oftentimes fraudulent billing and collection systems, or of outright theft through meter tampering or illegal connections. Where these "unexplained" losses become prevalent, it becomes exceedingly difficult to reduce them, because fraud and theft become acceptable modes of behavior among power users.

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[4]For Latin America alone, the cost of excess generation investments in the 1980s has been estimated at ranging between US$8.7 billion and US$13.0 billion (World Bank and OLADE 1991:14).

[5]Even though they are often obfuscated in official records by assigning excessively high consumption to nonmetered agricultural users.

Figure 7: Distribution of Generating Capacity Reserve Margins for Developing Countries (1989)

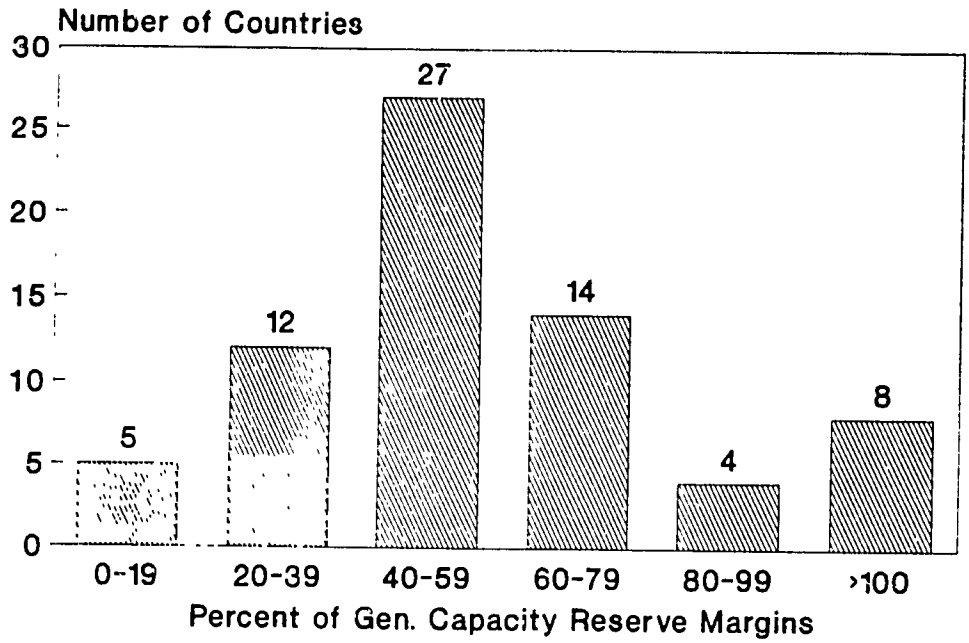
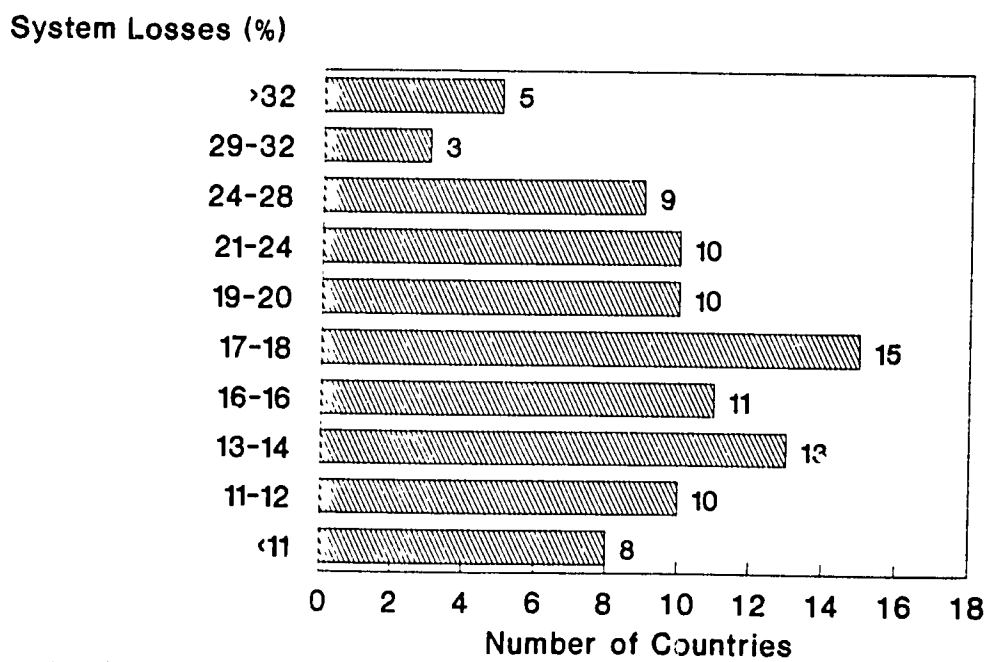


Figure 8: Distribution of Public Power Utility Total System Losses (%)



Sample size = 94 countries
Source: Escay (1991: 1-2)

Table 2
Total System Losses

High Performance		Low Performance	
Country	%	Country	%
Korea	6	Haiti	39
Cameroon	6	Guinea Bissau	32
France	7	Dominican Republic	28
Italy	8	Comoros	27
United States	8	Colombia	26
Barbados	9	Central African Republic	26
Botswana	9	Bangladesh	39
Fiji	11	Lao P.D.R.	24
Costa Rica	11	Liberia	25
Burkina Faso	11	Ecuador	23

System losses refers to combined technical and nontechnical losses. They are calculated on the basis of Net Generation minus Total Sales, divided by Net Generation.

Source: Escay (1991: 1-2)

In some cases, only physical protection of lines, meters, and circuits may be able to reduce these losses.[6] In Bangladesh, for example, the World Bank's lending program for power consisted of six projects over 11 years, each of them specifically addressing the issue of excessive losses. These were 35 percent before 1979, ranged from 33 to 43 percent on an annual basis during 1980-88, peaked at 46 percent in October 1987, and were still 43 percent in May 1990. These high losses continued despite a number of covenants in the various lending agreements requiring that losses be reduced to at least no more than 32 percent. An early 1991 report stated that payment for electricity reflected only 57 percent of the energy generated.

Poor Operating Performance

The most serious affliction of the majority of publicly owned LDC power utilities is their poor operating performance. It manifests itself in many ways: unreliable service and frequent outages, high voltage and frequency fluctuations, excessive generating capacity margins, short life expectancies of plant and equipment, high systems losses and excessive pollution loads on the environment.

[6]This was the situation in Haiti in the late 1960s, for example, where losses reached an astonishing 67 percent of generation. Physical protections such as armored meters and tamper-proof wiring were needed to bring about systematic reductions (Schramm 1988).

For electricity users, failure to receive electricity reliably is by far the most costly consequence of the poor operating performance of utilities. As has been shown in a number of studies, the cost per kWh of electricity not supplied, when supply was expected to be forthcoming, can be, and usually is, exceedingly high, ranging anywhere from several times the long-run marginal costs of supply to as much as several hundred times that level. In estimated cost per kWh, this translates to anywhere between $0.25/kWh and as much as $12.00/kWh in LDCs, depending on type of use, time of day, duration, frequency, availability of substitutes (e.g., self-owned standby generation; see Sanghvi 1991, Table 5).

The total economic losses caused by outages can be staggering indeed. In Pakistan, for example, where power outages are frequent, the aggregate net losses to overall GDP resulting from power outages affecting the industrial sector amounted to about 1.8 percent of GDP per year in the 1985-86 period.[7] For India, Sanghvi (1991:430) has estimated something like 1 percent of GDP, employing extremely conservative assumptions

Since in both countries industry accounts for only a modest share of GDP (24 percent in Pakistan, 30 percent in India in 1988; World Bank 1990, Table 3) and other sectors, such as agriculture (i.e., irrigation) are heavy power users as well, overall GDP losses from power outages may well be close to double the costs estimated for industry alone.[8] These aggregate annual GDP losses, then, may have amounted to some 35 to 50 percent of actual annual GDP growth in these two countries.[9]

For Nigeria, a World Bank study conducted in 1988-89 on costs to manufacturers for infrastructure deficiencies found that all but 14 of 179 industrial firms studied had standby power facilities because of the unreliable public service (Lee and Anas 1989). The 14 without standby were small firms that could not afford the investment for their own power facilities. On average 75 percent of the manufacturers' electricity was taken from the National Electric Power Authority (NEPA) grid at the low price of US¢1/kWh at the time of the study (raised to US¢4/kWh in late 1989), and 25 percent was self-generated at an average cost of US¢61/kWh (the estimated range was between 10 and 80 US¢/kWh). This resulted in an average cost of US¢9/kWh in late 1989, or 2.25 times the tariff charged by NEPA. This clearly demonstrates the high worth of a reliable supply of electricity to industrial establishments.

As in Nigeria, self-generation, or at least the acquisition of standby generating facilities, is widespread in countries in which public supplies are unreliable. In Indonesia, for example, about 40 percent of total generation comes from privately owned plants.

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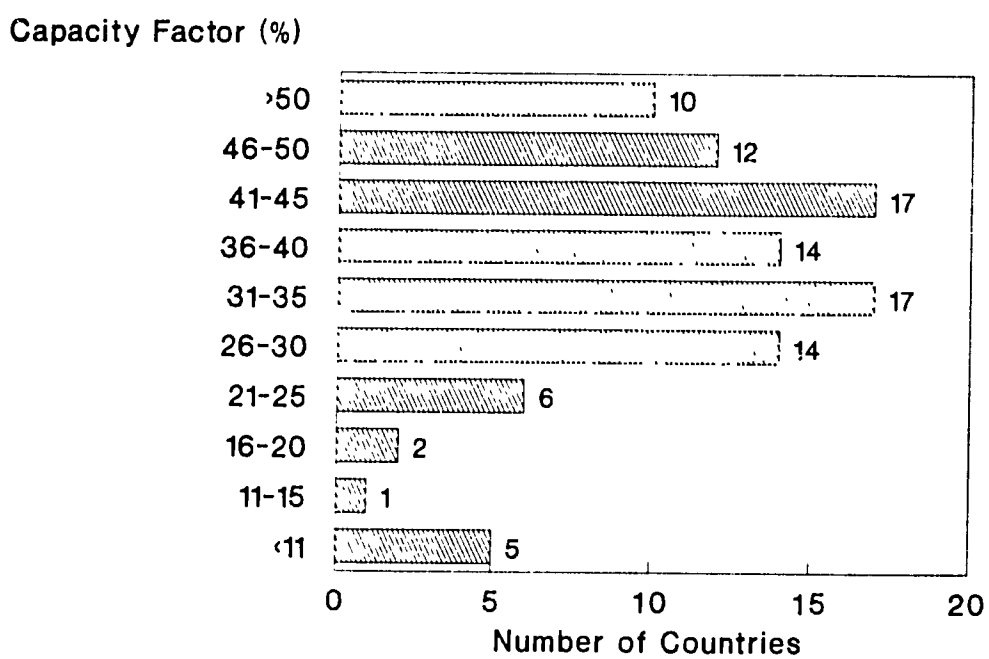
[7] In 1984-85, the average annual number of planned (i.e., preannounced) outages was 105, with an average duration of 1.67 hours, while the number of unplanned outages was reported to be 34, with an average duration of 0.85 hours (Pasha, Ghaus, and Malik 1989, Table 2).

[8] For India, agricultural production losses caused by power shortages for 1983-84 were estimated to amount to 2.3 percent of sector production which, in turn, accounted for about one-third of total GDP (Sanghvi 1991, Table 10).

[9] Average rates of GDP growth were 5.2 %/yr in India and 6.5 %/yr in Pakistan in the 1980-88 period (World Bank 1990, Table 2).

In a few of these countries the reason for the frequent power outages and curtailment of services is a genuine inability of the public utility to satisfy all demands because of lack of available generating capacity, particularly during peak periods. But in most cases the real reason for the shortages is the fact that much of the existing generating capacity is unavailable because of breakdowns, lack of spares; and generally poor maintenance. This is apparent from the very low generation capacity factors achieved by the majority of LDC utilities. As figure 9 shows, of a sample of 98 utilities only 10 achieved a capacity factor of 50 percent or more; some 59 of them, or 60 percent, achieved 40 percent or less, and, of those, 14 had a utilization factor of 25 percent or less.[10] The waste and inefficiency of this poor performance is quite staggering. For Nigeria alone, the over investment in generating capacity due to inadequate maintenance of existing facilities has been estimated to amount to US$ 2.4 billion (see Box 1).

Figure 9: Distribution of Public Power Utility Generation Capacity Factor (%)



Sample size = 98 countries
Source: Escay (1991: 1-2)

[10]The 98 utilities account for about 96 percent of the total power generation by publicly owned utilities in LDCs worldwide. For a complete listing, see the annex.

Manpower Issues

As the EPUES Core Report (Central Project Team 1991: 36) points out, "Manpower is one of the most fundamental components of performance in every organization, profit or not-for-profit, whether in an industrialized or developing country. It is certainly fundamental in the electric power sector."

Inappropriate skill mixes, gross overstaffing, but, at the same time, shortages of competent middle-level management and technical staff, low staff morale, inadequate staff compensation for skilled personnel with alternative employment opportunities, inability of management to make independent hiring and firing decisions, and lack of training facilities are some of the major issues that have been identified as root causes for poor institutional performance.

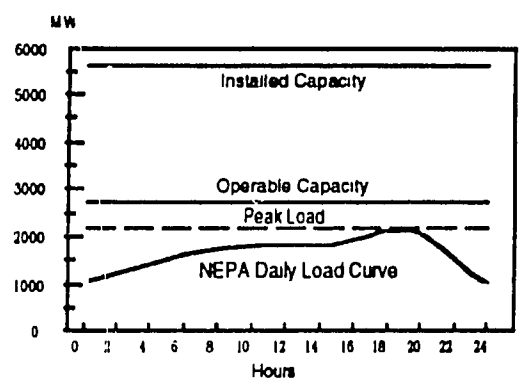
Overstaffing is a serious problem in many LDC utilities. This can be seen from Table 3, which shows the ratio of utility customers to the number of employees. While the better performing utilities have ratios of between 150 and 400, the poorest ones show ratios of 50 or less. Most of the overstaffing occurs in the semi- and unskilled categories and are usually the result of heavy-handed government attempts to use the publicly owned utilities as employment pools. This is not only costly to the utilities in terms of excess wage costs but has the further debilitating consequence that staff morale suffers because of the presence of so many underemployed people that are just in each other's way.

Box 1

Nigeria's Power System Has a $2.4 Billion Over investment Because of Poor Maintenance

In late 1990, the installed generating capacity on the power system of Nigeria's National Electric Power Authority (NEPA) totaled 5,700 MW in hydro, gas turbine, and steam power plants. However, the operable capacity was only 2,600 MW because of plant breakdowns, overdue maintenance, failed equipment, etc., giving an inadequate operating margin of only 400 MW or 18 percent above the peak load of 2,200 MW. So the installed "nameplate" reserve capacity margin was 160 percent (3,500/2,200), while the available reserve was only 18 percent (400/2,200).

If maintenance could be improved through training, adequate spare part supply, and support from manufacturers, it should be possible to operate with a lower reserve capacity margin of, say, 50 percent , or 3,300 MW installed capacity based on the peak load in 1990. The 2,400 MW excess capacity (5,700 minus 3,300) represents an over investment of about US$2.4 billion based on a $1,000/kW unit cost for mixed hydro and thermal capacity.



Comparison of Capacity and Load in Nigeria

Proper, autonomous management that can act with authority, good training, and high staff morale supported by adequate compensation packages are key factors in the performance of utility operations. This is true even in very low income countries facing severe shortages of most inputs and foreign exchange difficulties, as can be seen from the story in Box 2 of two contrasting power operations in one of the poorest countries of Africa.

Institutional and Management Issues

Institutional and management issues have been found to be at the heart of the poor performance of most public power utilities. Undue government interference in many organizational and operational matters that should be left under utility control are common. Such interference undermines the accountability of those responsible for day-to-day management functions.

Table 3
Ratio of Utility Customers/Employee, 1988

High Performance		Low Performance	
Country	Customers/ Employee	Country	Customers/ Employee
China	396	Botswana	8
Korea	311	Burundi	13
Bolivia	210	Central African Republic	14
El Salvador	188	Malawi	17
Indonesia	181	Liberia	24
Colombia	180	Comoros	25
Argentina	175	Guinea Bissau	26
Cyprus	165	Djibouti	29
Jamaica	155	Lao P.D.R.	30
Brazil	146	Kenya	33
		Bangladesh	39
		Burkina Faso	41
		Ghana	41
		Cape Verde	49
		India	49
		Ethiopia	50

Source: Escay (1991: 1-2)

It also heavily influences procurement decisions, oftentimes opening them up for graft and corruption. Governmental, politically motivated interference mitigates against least-cost choices for plant, equipment,

and fuels; it distorts the allocation of funds between rehabilitation and maintenance on the one hand, and investments in new plant and equipment on the other; it results in the inability to raise power tariffs to levels that would cover costs; and it restricts the utility's access to foreign exchange. It mandates low utility staff salaries, oftentimes tied to civil service pay levels rather than competitive market wages. It also promotes overstaffing, often through no-firing rules based on inappropriate civil service models.

These factors, in turn, have contributed heavily to inadequate utility management and organization; lack of accountability; the loss of experienced and capable staff due to noncompetitive employment conditions; weak planning, inefficient operation, and insufficient maintenance; high technical and nontechnical losses; and weak financial monitoring, controls, and collections.

Box 2: Vast Difference in Performance of Public Utility and Commercially Operated Diesel Plants

There is a vast difference in the reliability and overall performance of a group of diesel plants operated by the government-owned public utility of an African country and, in the same country, a diesel plant supplying a publicly owned but commercially operated mining operation in a company town of 6,000. The mine plant is 33 years old, yet six of the original diesel sets are still operating with operational hours in the 100,000 to 150,000 hour range. This diesel plant has never been shut down because of a technical failure, although load shedding has been necessary during fuel shortages.

In comparison, in a typical public utility plant, half the diesels of types similar to those at the mine plant are already out of service after only 25,000 hours of operation, and the electric service is very unreliable. The success of the mine plant has been credited to good management and high staff motivation. Although salaries are not as high as the public utility scales, mine employees enjoy free training, housing, electricity, water, medical care, and education to college level. Employees are highly skilled and proud of their diesel plant, which is clean, in excellent condition, and has an adequate spare part stock monitored by computer. The success at this mine demonstrates the African staff can effectively operate diesel plants if they are properly managed and motivated.

Source: Central Project Team (1991, Annex 2; Note: Identities of the countries in the EPUES study were coded and held confidential in the Core Report).

To bring about lasting changes and improvements, the compact between governments and utilities will have to be changed and new, "arms-length" relationships established between them. To quote the findings of the EPUES (Central Project Team 1991: 4, 6) study:

> EPUES has concluded that government interference in all utility operations must be eliminated before efficient and sustainable performance is possible. Although EPUES recommends that governments and utilities focus primary attention on increasing autonomy, it stresses that it is equally important for governments to hold utilities accountable for their performance.

The study continues by advising that:

> Governments must (1) set clear and attainable objectives linked to performance; (2) maintain control without undue interference; (3) hold managers accountable for results; (4) appoint capable managers or assure that managers with appropriate skills are available; and (5) reward managers for good performance and sanction them for poor performance.

Boxes 3, 4, and 5 illustrate the importance of these factors with snapshots of the experiences of three publicly owned utilities, two very small ones in Africa and a large one in Korea. In each case, the major factors determining success or failure were those that are listed above. In the African cases, the provision of outside management expertise proved to be the decisive factor; in Korea, it was the combination of greater management authority, staff incentive structures and a very conservative, full cost-recovering tariff policy that proved decisive.

Box 3: Poor Performance of the Power Sector in a Small African Country

The Government utility in an African country is an example of a small utility performing poorly while functioning largely as a government department providing electricity, water, and sewerage services. The power component has roughly $5 million gross income, 40 MWe of generating capacity, 12,000 consumers, and one-third of the staff of 1,000. Government dissatisfaction with electric service is apparent from the eight changes of the managing director in 12 years. Various approaches have been used: prior to 1981 UK expatriate assistance was used; from 1981 to 1988 GTZ (Germany) funded an expatriate technical assistance team that acted in reality as line management.

During that period operations were reasonable; in late 1987 the utility signed a performance contract with the Government, but results have been disappointing. Government is now considering various options: (a) a management contract with fixed fee; (b) leasing with a rental fee; (c) selling the utility to a private firm regulated by Government; and (d) continuing the present performance contract arrangement. Meanwhile system shutdowns averaging two hours in duration continue to occur once or twice a week. This operating record proves outside technical and managerial support is required for utilities such as this.

Note: Information obtained from mission reports of the Electric Utility Efficiency Improvement Study Project (see Central Project Team 1991).

Environmental Implications of Poor Performance

It is beyond the scope of this paper to review the various environmental consequences of electric power production, transmission, distribution, and utilization or the types and quantities of pollutants produced. There exists, in any case, a plethora of information on these subjects (WRI 1991; International Energy Agency 1988; Moore 1991). Energy, overall, is a major contributor to global pollution. In terms of the increasing accumulation of greenhouse gases, the energy sector's share is estimated as about 49 percent of the total from all sources (WRI 1991). Use of fossil fuels for power production, in turn, is estimated to amount to about 30 percent of total energy's share, or about 15 percent of all greenhouse gases (British Petroleum Corporation 1990). Given the projected much more rapid growth of electricity use compared with other energy sources, this share is bound to grow, particularly in the developing world.

More pressing in the sense of immediate impacts are, of course, the regional and local effects of pollution emanating from thermal power plants (i.e., the releases of sulfur dioxides, nitrogen oxides, carbon oxides, suspended particulates, ash, and waste water and the environmental, health, water-quality and human-settlement impacts of hydro projects). Atomic power plants, of course, have their own set of environmental problems, as illustrated by Chernobyl and Three Mile Island. These have been discussed in a number of recent background papers for the World Bank's forthcoming *World Development Report* 1992,

as well as in many other publications (see Anderson 1991 and Moore 1991a).

Control technologies to mitigate a significant proportion of these environmental effects are available, of course, and have been widely introduced in the developed world. However, they are also costly and add significantly to the generating costs of power plants; they also reduce net energy outputs and increase the operational complexity of plants.[11] Small wonder, therefore, that LDCs have made very few efforts so far to adapt these technologies, even though pressures to do so mount both from environmental groups inside and financing agencies from outside these countries. As reported, so far there exists only one single coal-fired power plant in all of the LDCs with operational flue-gas desulfurization equipment, the TATA-owned Trombay plant in Bombay (Moore 1991b: 31).

Box 4: Success Story in Guinea-Bissau

The introduction of a five-person management team under an expatriate management contract has been effective in improving the performance of this small country's national electric utility, *Electricidade e Aguas de Guinea-Bissau*. Before the management team started, service interruptions were chronic, and most areas had electricity for only a few hours a day. Turnaround can be seen in the comparative 1987 and 1990 statistics below.

Parameter	1987	1990
Installed Capacity (MWe)	7.2	8.6
Operable Capacity (MWe)	2.2	7.5
Capacity Factor	0.32	0.51
Fuel Consumption (kg/kWh)	0.300	0.254
System Losses	30%	26%
Electricity Sales (GWh)	14	28
Average Revenue (US$/kWh)	0.12	0.25

Implementation of the expatriate management contract was a joint initiative of the French Ministry of Cooperation, UNDP, the African Development Bank, and the World Bank. It reduces wastage of foreign aid (in the previous 10 years, foreign funding for power was more than three times the estimated value of the utility at the end of the period) and provides reliable service necessary for economic expansion.

Source: World Bank documents.

An alternative to the installation of costly pollution abatement equipment is to switch to different generation technologies. Where available, natural gas (or oil-fired) combined-cycle plants have proven to be both more cost-effective and far less polluting than standard steam power plants (Moore 1991b). This can be seen from the data in Box 6, which compare the pollution loads of gas-fueled combined-cycle and coal-fired steam plants with scrubbers. Another new technology just at the verge of being introduced consists of integrated coal-gasification, combined-cycle power plants (Bechtel 1991). Use of these technologies, of course, can only be considered when new plants are to be built. They do not affect existing installations.

[11] Quoting IEA data, Moore (1991b: 23) states that total emission control costs based on a combination of flue-gas desulfurization (FGD), selective catalytic reduction (SCR) and improved combustion control measures (CC) amount to 9.1, 6.7 and 1.3 US¢/kWh in 1987 US$ for coal, heavy oil, and natural gas steam plants, respectively.

Box 5: Korea: A Focus on Evaluating Management

The major power producer in Korea is the Korean Electric Power Company (KEPCO), a parastatal responsible for most generation and all transmission and distribution. At the time of the first World Bank loan in 1979, KEPCO was considered a relatively well managed company but subject to excessive government regulation and control. It also was experiencing high staff turnover because of inadequate salaries and benefits. Coordination of its many operating units was posing problems, and concern was growing that its original organizational structure established in 1961 was no longer appropriate if it were to maintain or increase efficiency. It was also noted that KEPCO needed to improve its planning and organization, that the pricing structure was inadequate, and that there were no clearly defined financial goals.

Following a subsequent study, it was concluded that government control over KEPCO was excessive and that KEPCO should be allowed greater autonomy for managing its affairs. As a result, internal organizational changes were made. Then, in 1984, the Government Invested Enterprise Management Act introduced a new management structure for KEPCO and other public enterprises giving greater powers to a new external regulatory board, which separated policy making from the executive functions. KEPCO's president and management became fully accountable to this external regulatory board.

The Act also provided the regulatory board with criteria for evaluation of KEPCO management performance (with salary incentives awarded based on performance) under the scrutiny of a Public Enterprise Management Council, which reviewed all public enterprise performance. The act allows substantial incentives for superior performance and stresses evaluating management, not company, performance. The effects of this new regulatory structure were striking. Between 1983 and 1988, KEPCO operating costs declined in real terms by some 34 percent. This reduction was achieved despite rapidly rising real wage costs and after taking account of changes in the conversion efficiency of new generating plant as well as reductions in fuel costs during that period. In addition, technical measures on the supply side and demand management policies, such as mandatory time-of-use tariffs, are estimated to have reduced peak load demands between 1977 and 1987 by about 800 MW, or some 7 percent of actual 1987 peak demand. Another characteristic of the new regulatory policies was that over time tariffs were regularly adjusted to cover actual costs, including a substantial portion of capital investment costs. The performance statistics of KEPCO, based on 1988 data, speak for themselves:

Consumers/employee	311
Average reserve	7.6 US¢/kWh
Rate of return	8 percent
Debt service coverage ratio	2.2
Electricity produced/capita	1,906 kWh
Nuclear capacity factor	69%
Total system losses	6%

Here it will be argued that the most cost-effective route to significant reductions in environmental pollution is, first, to increase the operational efficiency of existing plant, equipment and delivery systems; and, second, to extend these improvements to all new plant and equipment that will be built in the future.

Table 4 provides a stylized example of the likely economic and environmental benefits to be obtained from such improvements. They are based on a comparison of a "typical" thermal-power-based LDC utility and on an "improved" one, with the latter reflecting "normal" operational and financial performance standards that can be found throughout the developed world as well as in a number of LDCs. Only those potential improvements have been identified that would have a direct and clearly measurable effect on environmental pollution loads. The various parameters assumed by the estimates are based on data and information from several internal World Bank studies and are quite within reasonable ranges. All of them would have high pay-offs in economic terms. It should be noted that none of the indicated improvements would depend on any specific, environmentally only designed activity or investment. They would solely be the result of policies and strategies designed to improve the technical, economic, and financial performance of a typical, under-performing utility to acceptable world standards. In other words, the resulting reduction in pollution loadings would be an additional and costless benefit of the policies adopted.

Box 6: Natural-Gas-Fueled Combined-Cycle Units Cause Less Environmental Damage and Are More Economic than Coal-Fired Conventional Steam Units

Large (150-200 MWe), efficient (35 percent) gas turbines are available and can be arranged as combined-cycle units (500-600 MWe) to provide gas-fueled baseload generating capacity on the power systems of those developing countries that have proven natural gas reserves. Combined-cycle units are formed with two or more gas turbines exhausting into waste heat boilers that supply steam to a steam turbine. In addition to causing less environmental degradation by burning "clean" gas, combined-cycle units are lower in capital cost, higher in efficiency, and can be constructed in stages over a shorter construction period than coal-fired conventional steam units, as shown by the following comparison.

Emissions/kWh	Coal-fired Steam Cycle, with Scrubbers	Natural Gas Combined Cycle
CO_2 (grams)	830	380
CO (mg)	75	34
SO_2 (mg)	600	0
NO_2 (mg)	600	350
UHC (mg)	0	18
Waste water (g)	15	0
Ash (g)	34	0
Rejected heat (MJ)	4.3	2.6

Source: Haupt, Joyce, and Kuenstle (1990)

As can be seen from Table 4, the largest environmental benefits would result from reductions in generating plant heat rates, combined with improved load dispatch, and from adjustments in tariffs to cost-recovering levels.[12] The latter, of course, is a reflection of the large potential for more efficient electricity use on the demand side, an issue that has not been addressed specifically in this paper.

[12]The assumed price elasticity reflects the results of a number of recent World Bank studies in South Asia.

Table 4

Illustration of Potential Environmental Benefits from Improved Power Utility Performance[a]

	"Unimproved" Utility	"Normal" Utility	% Reduction in Pollution Load
Heat Rate (Btu/kWh)[b]	12,500	10,000	20
Technical losses[c]	15%	7%	6
Non-technical losses[d]	10%	1%	4
Share of auto-generation due to utility outages[e]	15%	1%	7
Tariff levels as percentage of total systems costs[f]	60%	100%	20
Net decrease in pollution loads			57

a Assumes an all-thermal system
b Assumes improvements in both plant-specific performance and in systems scheduling (plant stacking)
c Adjusted for improved heat rate
d Assumes 50 percent long-term load recovery in form of paid consumption
e Assumes net pollution load per kWh of auto-generators to be 50 percent above that of utility-operated plant
f Assumed price elasticity of demand = 30%

Environmental benefits from reductions in nontechnical losses, at 6 percent, appear to be relatively modest, in part because of the assumed conversion of 50 percent of formerly illicitly obtained electricity into paid-for consumption (see Schramm 1988). In countries with non-technical loss rates of, say, 25 percent, the environmental benefits from their elimination would be much larger, approaching 20 percent.

The overall conclusion that can be drawn from this simple presentation is that policies designed to bring about essential and economically advantageous improvements in utility performance are bound to have rather large and essentially zero-cost environmental benefits, amounting to reductions in pollution loads of more than 50 percent from levels produced before such improvements.

Conclusions

In order to support projected economic growth in general, electric power supplies in the developing world have to grow at rapid rates, estimated at in excess of 6 percent per annum at least throughout this decade and likely beyond. This growth will require huge new capital expenditures, estimated to amount to around $100 billion annually, with a foreign exchange share of some $40 billion per year. These huge capital requirements cannot be met, because of the poor financial and operational performance of the power utilities themselves and the poor credit ratings of their owners, the respective governments of these countries.

Attracting capital will require improving the operational and financial performance of the utilities. They will have to become financially self-supporting so that they can attract the necessary funding from sources other than their own governments. Their operational performance must improve equally well, in order to increase their supply reliability and reduce their operational and capital costs.

There is clearly a wide margin available for both financial and operational improvement. There is also room for increasing tariffs to cost-recovering levels. Electricity users have proved again and again that they are prepared to pay considerably more than what they are being charged now, provided they are assured that electricity will be available to them reliably if and when they need it.

The performance indicators of the majority of LDC power utilities are rather poor and well below accepted standards elsewhere in the world. Technical measures to improve performance are well known and, theoretically, highly cost-effective, far more cost-effective than the addition of new plant and equipment, the route usually taken by LDC governments and utilities when existing equipment performs badly.

An important side benefit of making such performance improvements would be the reduction in environmental pollution resulting from the prevention of unnecessary losses and of outright waste both on the power supply and consumption side. Reductions of more than 50 percent of existing pollution loads appear quite feasible. They would be essentially costless, because the improvements would be the result of economically fully justified measures taken to improve performance.

However, while the set of technical, financial, and operational measures to be taken is well known, efforts based on bringing about the required changes have not been very successful in the past. What is needed, first and foremost, are changes in the institutional, managerial, and regulatory environment in which these utilities operate. At present, most of them are run essentially as government departments, subject to a wide range of political and social objectives that have little to do with their primary mission--to provide electricity safely, reliably, within defined safety and environmental parameters. and at least cost. There must be a clear understanding between utilities and government that this is their mission, and basically their only mission.

There must also be a clear understanding that electricity is a commercial good and that users will have to pay the full costs of providing it to them.

Utility management must be chosen on the basis of technical competence and not political expedience; and utility management must be able to operate autonomously, with full authority over operational, staffing,

and investment decisions within the framework of the overall regulatory compact that defines its rights as well as its responsibilities.

Only if these conditions are met is it likely that the other set of physical, financial, and other institutional reform measures that are needed will ultimately be successful and sustainable. Only if they are will the power sectors in the LDCs fulfill their role as an essential and critically important catalyst for economic development.

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ANNEX
1988 PERFORMANCE INDICATORS OF POWER SECTORS FOR 100 DEVELOPING COUNTRIES

Country	GDP PER CAPITA (US$)	ENERGY CONSUMTION PER CAPITA (kgoe)	ENERGY IMPORT AS % OF MERCHANDIS EXPORT	ELECTRICITY PRODUC PER CAPITA (kWh)	PUBLIC UTILITY: TOTAL SYSTEM LOSSES (%)	GENERATION: CONSUMERS PER EMPLOYE	GENERATION: CAPACIT FACTOR (%)	GENERATION: AVERAG REVENU (USc/kWh)	RATE O RETUR (%)	CASH GENERATION (%)	DEBT SERVIC COVERA (times)	ACCOUNTS RECEIVABLE, (months)
Algeria	2,181	1,018	2	587	13	-	41	5 64	(1)	(48)	1.0	8
Argentina	2,640	1,350	4	1,685	21	175	37	4.49	7	3	0.1	2
Bangladesh	177	54	24	63	39	39	29	6.07	2	2	1.1	5
Barbados	6,010 a/	1,043	-	1,878	9	172	41	13.45	6	100	2.1	1
Belize	1,461 a/	333	-	428	17 d/	66 d/	40	21.50 d/	-	-	-	-
Benin	389	38	72	63	15	52	10	19.10	2	60	3.1	-
Bolivia	616	225	3	269	15	210	35	3.55	8	-	-	-
Botswana	1,617	415	-	390	9	8 f/	-	4.37 f/	4 c	(3) c	1.7 c	-
Brazil	2,241	915	13	1,473	17	146	49	5.37	6	62	0.5	-
Burkina Faso	221	19	7	15	11	41 f/	25	17.26 e/	-	-	-	-
Burundi	188	17	8	26	16	13	32	8.65	-	-	-	7
Cameroon	1,152	177	1	214	6 g/	70 g/	45	14.14 b/	13 g	32 l/	-	-
Cape verde	680 a/	68	-	88	21	49	23	14 83	-	-	-	-
Cent. Afr. Rep	360	24	14	31	26	14	35	14.50	5	14	2.9	15
Chile	1,725	817	4	1,321	19	-	48	3.06	6	90	2.7 c	1
China	340	580	2	497	12	396	54	2.10	5 j/	50	9.0	1
Colombia	1,221	676	4	1,198	26	180 c/	60	2.24	16 c	(5)	0.7 c	-
Comoros	440 a/	41	-	32	27	25 b/	32	39 27	-	-	-	-
Congo	1,024	249	5	139	19	97 g/	22	8.85 b/	-	-	-	-
Costa Rica	1,722	390	12	1,183	11	103	40	3.21	7	1	0.9	3
Cote d'Ivoire	683	158	12	587	14	-	28	15.80	2	(21)	0.7	4
Cyprus	6,261 a/	2,060	-	2,317	17	165 b/	52	9 20	11	74	2.2 d	1
Djibouti	-	249	-	548	19	29	26	21.00	6	21	2.4	7
Dominica	1,680 a/	244	-	354	13 b/	106	41	17.96	-	-	-	3
Dominican Rep	671	292	36	760	28	95	41	4.66	(4)	0	0.1	6
Ecuador	1,022	584	3	558	23	92 b/	37	2.85	2	-	-	-
Egypt	684	574	4	815	19	-	43	2.04	3	0	0.7	9
El salvador	1,087	215	14	398	15	188	34	3.50	4	5	0 3	-
Ethiopia	105	17	59	17	17 b/	50 d/	27	13 50 b/	2	10 d	0.7 d	-
Fiji	1,520 a/	284	-	574	11	65	24	14 92 b/	11	(27)	0 9	-
Gabon	3,018	803	1	797	12 d/	64 d/	50	12.56 c/	-	-	-	-
Gambia	200 a/	77	-	54	22	-	46	-	-	-	-	4
Ghana	374	132	15	344	22	41	48	1.69	9	66	2.5	1
Guatemala	933	136	14	261	17	69	32	0.10	6	(39)	0.7	11
Guinea	470	63	-	102	15	-	36	10.58	2	-	-	-
Guinea Bissau	190 a/	48	-	30	32	26	37	10.75	-	-	-	-
Haiti	351	35	13	74	39	62	35	15.30	2	18	1.4	3
Honduras	804	131	14	440	17	74 b/	43	7.70 b/	9	(3)	1.0	-
Hungary	2,642	2,791	15	2,756	15	107 g/	49	4.64 b/	-	11 f/	1.3 e	-
India	292	211	20	292	22	49	43	15.40	6	(155)	1.4	6
Indonesia	476	197	14	241	17	181	32	5.10	0	15	2.0	1
Jamaica	1,342	670	22	992	17	155	37	12.21	5	17	2.0	2
Jordan	1,000	693	42	1,054	14	92	43	4.20	4	(39)	0.9 d	2
Kenya	329	67	41	127	15	33 b/	56	6.15	5	34	1.9	-
Korea	4,079	1,740	10	2,150	6	311	46	7.61	8	63	2.2	-
Lao P.D.R.	128	25	-	202	24	30	51	2.70 b/	39 d	100 d	2.9 d	6
Lesotho	165	-	-	-	12	-	-	6.86 b/	-	-	-	-
Liberia	413	110	12	348	25	24 g/	29	15.00 e/	-	-	-	-
Madagascar	172	41	45	47	14	55 d/	27	-	4 c	0 c	0.7 c	-
Malawi	135	29	9	74	17	17	35	3.85	7	32	1.6	2

1988 PERFORMANCE INDICATORS OF POWER SECTORS FOR 100 DEVELOPING COUNTRIES

Country	GDP PER CAPITA (US$)	ENERGY CONSUMTION PER CAPITA (kgoe)	ENERGY IMPORT AS % OF MERCHANDIS EXPORT	ELECTRICITY PRODUC PER CAPITA (kWh)	PUBLIC UTILITY: TOTAL SYSTEM LOSSES (%)	GENERATION: CONSUMERS PER EMPLOYE	GENERATION: CAPACIT FACTOR (%)	GENERATION: AVERAG REVENU (USc/kWh)	RATE O RETUR (%)	CASH GENERATION (%)	DEBT SERVIC COVERA (times)	ACCOUNTS RECEIVABLE, (months)
Malaysia	2,052	938	5	1,018	16	108	37	7.10	12	64	1.5	1
Mali	270	24	31	27	22	37	31	20.30	15	46	2.4	5
Mauritania	472	535	6	68	23	-	13	-	-	-	-	-
Mauritius	1,455	274	9	581	16	112	27	11.40	1	0	0.9	2
Mexico	2,111	1,331	1	1,313	14	186	45	3.67	1	0	1.2	2
Morocco	916	241	17	373	14	80	45	9.82	8	109	3.0	13
Mozambique	74	86	43	28	14	99	1	3.87	10 j/	-	-	4
Myanmar	-	45	5	57	13	30 e/	26	9.68 e/	-	-	-	-
Nepal	159	18	29	33	28	34	34	5.92	6 j/	3	1.7	3
Nicaragua	883	211	42	329	18	76	35	6.63	-	-	-	2
Niger	329	19	15	22	18	40	20	20.62	4 j/	51	1.8 c	3
Nigeria	267	125	2	114	33	62	20	1.56	(8)	44	(0.3)	15
Pakistan	320	199	27	348	25	38	61	3.84	14 j/	21	1.7	3
Panama	2,364	1,627	57	1,191	19	57	33	11.94	7	96	1.6	5
Papua New Guin	915	207	9	161	12	18 e/	41	15.50	13	40	2.3	-
Paraguay	1,510	164	12	725	16	136 g/	8	-	9 g	-	-	-
Peru	1,222	463	1	666	18	116	39	1.71	-	-	-	-
Philippines	655	231	16	435	17	172	46	8.70	10	99	1.0	2
Poland	1860 a/	3,[illegible]22	15	3,205	19	-	53	2.15 b/	-	-	-	-
Portugal	4,049	1,503	21	2,183	8	-	37	8.23 b/	8 b	(59) b	1.2 b	11 b/
Romania	-	3,300	-	3,273	7	-	39	-	-	14 d	2.6 d	-
Rwanda	345	21	63	36	17	28	45	10.50	2	-	-	12
Sao Tome & Prin	490 a/	101	-	143	29	24	65	-	-	-	-	-
Senegal	711	87	18	122	18	86	46	19.62	4	24	2.6	-
Seychelles	3 800 a/	618	-	1,221	18	-	43	20.61 g/	-	-	-	-
Sierra Leone	326	53	11	29	35	23	10	12.17	4	0	0.2	6
Solomon Islands	630 a/	165	-	97	13	29	26	16.57	5	0	2.8	2
Somalia	164	49	20	44	30	50 d/	49	14.68 b/	6	-	-	3
Sri Lanka	386	113	25	169	15	40	26	5.40	8	26	2.4	5
St. Lucia	1,540 a/	379	-	717	13	105	55	14.91 b/	-	-	-	3 b/
St.Vincent & G	1 200 a/	170	-	286	20	92	37	21.11 b/	8 g	-	-	2 b/
Sudan	472	44	37	45	20	31	27	8.87 b/	9 c	41 c	1.6 c	-
Switzland	810 a/	-	-	506	12	-	27	3.92 b/	5 c	67 d	1.4	-
Syria	1 289	771	18	699	12 b/	97	31	3.21	6 i/	-	-	-
Tanzania	111	27	44	36	25	105 d/	23	7.86	7 b	0 b	0.6	-
Thailand	1,063	399	14	685	14	99	55	5.00	13	41	1.7	3
Togo	1,360	79	6	14	24	49	4	18.20	2	100	25.8	6
Tunisia	1,119	512	10	615	12	150	38	6.02	(2)	18	1.0	-
Turkey	1,196	871	24	893	13	-	42	6.22	8	35	1.5	2
Uganda	244	20	14	37	40	34	42	1.50	-	0 f/	2.8 f/	-
Uruguay	2,155	597	10	1,775	19	81	41	6.30	5	43	2.1	4
Vanuatu	850 a/	184	-	190	10	-	29	22.93 e/	-	-	-	-
Venezuela	3,391	2,484	0	2,828	19	113	33	2.32	-	0	0.9	-
Western Samoa	640 a/	252	-	289	12	50	31	13.00	3 b	-	3.0 b	-
Yemen Arab Rep	695	155	-	98	25	60	23	10.75	0	1	0.5	4
Yemen, P.D.R	350	15	1	277	17	43	31	13.30	1	5	7.5	7
Yugoslavia	2,615	[illegible],749	18	3,713	13	116 g/	48	2.92	-	10	2.2	3
Zaire	194	42	2	233	12	33	28	1.80	-	44	-	6
Zambia	526	174	6	1,116	7	29	40	1.01	6 g	18 g	1.1 g	-
Zimbabwe	608	488	5	891	10	60 b/	47	3.68	21 j/	25	0.8	-

NOTE: a/ GNP per capita. b/ 1987 data. c/ 1986 data. d/ 1985 data. e/ 1984 data. f/ 1983 data. g/ 1982 data.
h/ 1981 data. i/ 1980 data j/ ROR based on unrevalued assets

IMPLEMENTING POWER SECTOR SOLUTIONS IN DEVELOPING COUNTRIES

STOCKHOLM INITIATIVE
ON
ENERGY, ENVIRONMENT AND SUSTAINABLE DEVELOPMENT
(SEED)

Stockholm

November 13-15, 1991

by

DR. DAVID J. JHIRAD

U.S. Agency for International Development
Washington, D.C.

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INTRODUCTION

In the electric power sector, developing countries face the triple-bind problem of inadequate capital mobilization for power development, deteriorating financial, institutional, and technical performance of their electric utilities, and increasingly severe environmental constraints, both local and global. Only about $20 billion of the projected $100 billion per year required for developing country power system expansion in the next decade will be available from all external and internal sources.

An effective response to the challenge of this triple bind must include innovative approaches on all fronts. Neither policy reform, institutional improvements, nor technological innovation alone can solve the triple bind problem and provide reliable delivery of electricity services in developing countries. A multifaceted approach will be necessary, posing a difficult challenge for the international community. This brief paper presents some aspects of this approach for consideration by the Participants to the consultative meeting entitled the *Stockholm Initiative on Energy, Environment and Sustainable Development (SEED): Strategies for Implementing Power Sector Efficiency.*

Developing countries are emerging as the major growth centers of energy demand. Figure 1 shows their dramatic rise in primary energy demand from 16 billion per day of oil equivalent (mbdoe) in 1970, or 15 percent of the World total, to 45 mbdoe by 1990, or to 27 percent of a world total. Under growth rate scenarios of 5 to 6 percent annually, their primary energy demand could exceed 200 mbdoe in 2025, or about 60 percent of the world's total. However, as depicted in Figure 2, the per capita energy consumption of developing countries in 2025 would still be only 10-20 percent of the comparable figure in the OECD countries. To maintain an acceptable level of economic growth, electric power growth rates in the developing countries will have to be considerably higher than those in the OECD countries.

Innovative approaches that are mandatory for meeting power sector demand include the following:

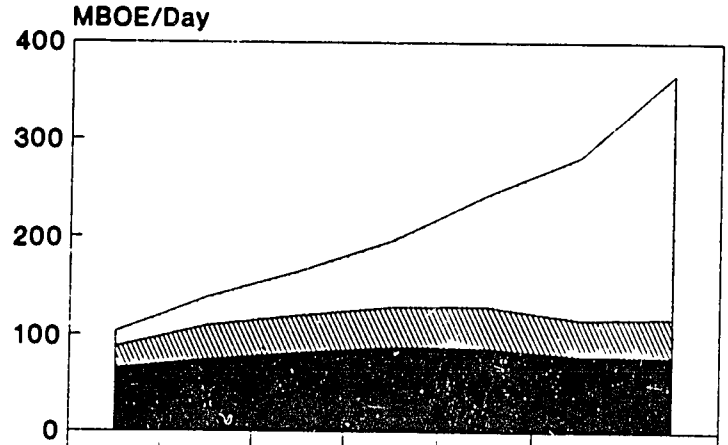
- Major collaborative initiatives among donors, lending institutions, governments, and power utilities. Harmonizing of donor policies will be essential to ensure both economic efficiency and the fiscal soundness of power institutions.

- Major institutional changes that allow power utilities to function as autonomous commercial institutions instead of political patronage organizations, and regulatory changes to permit efficient delivery of electricity services to the consumer.

- Innovative financing approaches to foster major improvements in operations, maintenance, and end-use efficiency.

- Innovative technology cooperation programs between developed and developing countries, focusing on the role of private sector entities.

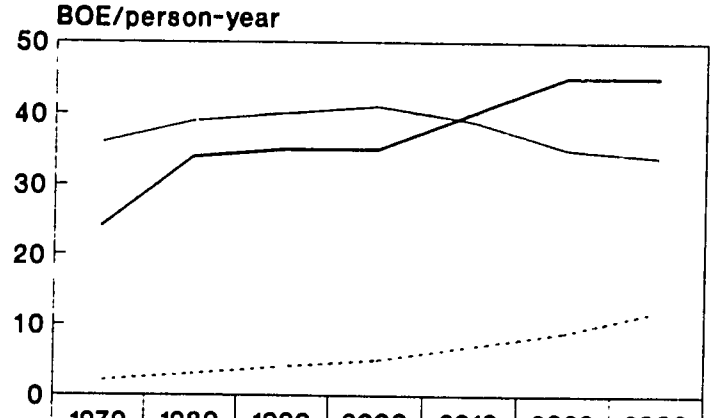
Fig. 1 An Energy-Efficient Demand for the Period 1990 to 2030



	1970	1980	1990	2000	2010	2020	2030
LDCs	16	29	45	68	113	166	249
E. Europe/USSR	23	35	38	41	43	38	40
OECD	65	75	82	88	87	79	78

Source: Denis Anderson, May 1991
"Energy and the Environment"
The Wealth of Nations Foundation

Fig. 2 Energy-Efficient Demand Scenario Per Capita Primary Energy Consumption For The Period 1990 - 2030



	1970	1980	1990	2000	2010	2020	2030
LDCs	2	3	4	5	7	9	12
E. Europe/USSR	24	34	35	35	40	45	45
OECD	36	39	40	41	39	35	34

Source: Denis Anderson, May 1991
"Energy and the Environment"
The Wealth of Nations Foundation

FACING A TRIPLE BIND

Capital Shortages

Developing country utilities are finding that "business as usual" energy strategies are falling seriously short of providing the electricity services required for economic development. Figures 3 and 4 show "World Bank estimates for regional additions to capacity during the 1990s and the capital expenditures required. The total estimated capital expenditure (in current dollars) for all regions is $100 billion. Of this annual requirement, $40 billion is needed in foreign exchange. However, only $7-$10 billion is available from all external sources, including both official bilateral and multilateral agencies, as well as private creditors.

There are also serious local financing gaps. Developing countries have little capacity to mobilize the local currency required by these energy expansion plans. Tariffs are often insufficient to cover current operating costs, much less system expansion. The average developing country already spends one quarter of its public budget on the power sector. Other sectors, such as health and education, are competing for the same scarce resources.

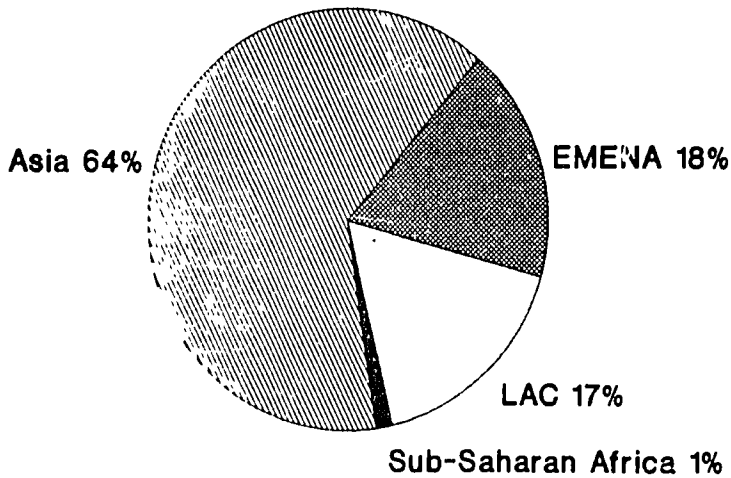
Developing countries are quite aware that this power related financial crisis will become more severe as debt mounts and new loans become more difficult to secure, and that economic disruption and political instability could ensue. Deteriorating utility performance and the consequent unreliability of delivered power already exact a heavy toll on economic growth. The adverse economic effects of power supply interruptions can be from five to one hundred times the average electricity tariff. In India, for example, the value of lost industrial output caused by power shortages is estimated at $6 billion a year (10 percent of total annual industrial output).

Declining Institutional Performance

The financial performance of many utilities in developing countries is considerably lower than their industrialized country counterparts, and the situation is rapidly worsening. Poor maintenance, operations, accounting, billing, and planning practices (stemming in large part from a lack of management autonomy) limit the ability of utilities to deliver adequate electricity services for sustained growth. As depicted in Figure 5 transmission and distribution losses in developing countries typically amount to 20-25 percent of electricity generated, compared with 7-8 percent in the industrialized countries. In the developed world losses are primarily technical, while in developing countries technical losses are often dwarfed by uncollected revenues and theft.

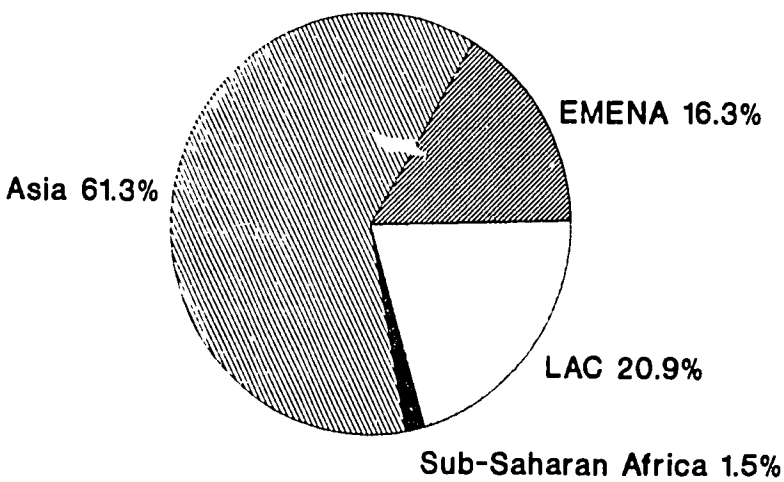
Due to this poor performance, government-owned utilities in developing countries often show a negative return on assets. Figure 6 shows a steady decline in the Financial rate of return over the period 1965 to 1984. From 1966 to 1987 the rate of return on assets fell from 9.2 percent to 4.4 percent; debt service coverage rose from 2.0 to 2.6; and the investment self-financing ratio dropped from 24 percent to 19 percent.

Fig. 3 Expected Generating Capacity Additions By Region in the 1990s
(384 GWe Total)



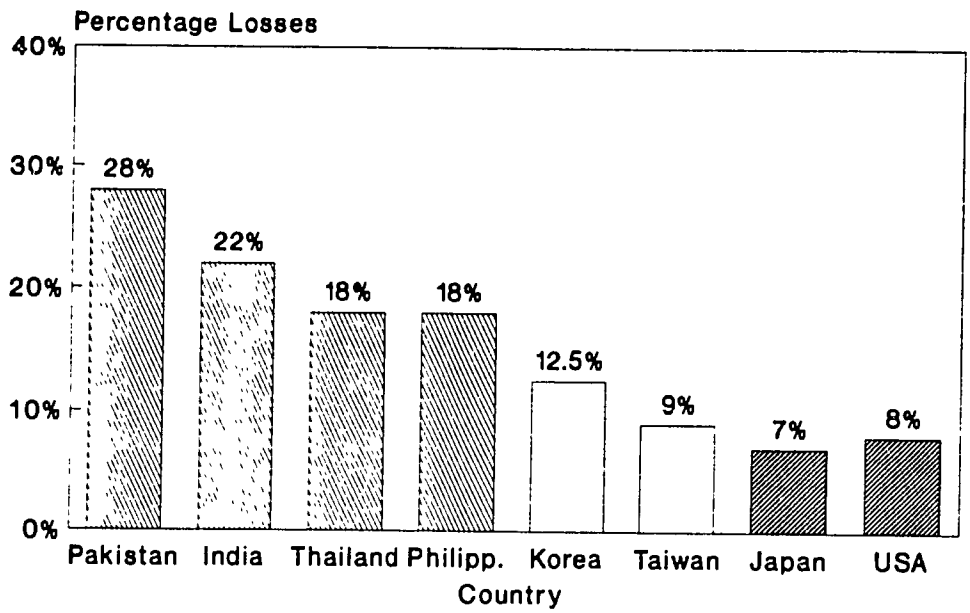
Sample Size: 70 Countries
Source: World Bank (1990) ESP #21

Fig. 4 Breakdown by Region of Capital Expenditures Required for Power in the LDCs in the 1990s
($742 Billion Total in 1989 US$)



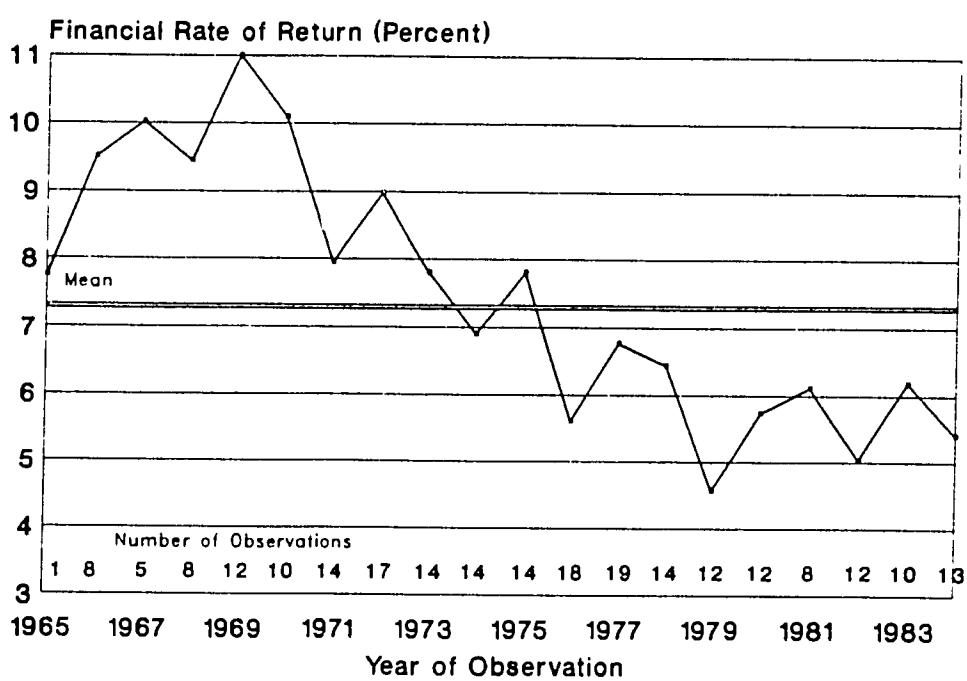
Sample Size: 70 Countries
Source: World Bank (1990) ESP #21

Fig. 5 Transmission and Distribution Losses in Several Countries (Average for 1981 - 1985)



Source: Lawrence Berkeley Laboratory

Fig. 6 Rate of Return on Assets



Source: M. Munasinghe, World Bank (1989)

Inadequate tariffs are a major factor in poor financial performance. Studies undertaken by the World Bank indicate that average tariff yields in LDCs should be about 10 U.S. cents/kWh (1989 prices). However, in most countries, tariff levels have generally been well below long-run marginal costs and even below average operating costs. In these cases, governments provide partial subsidies to cover the shortfall, and the operational performance of utilities suffers from the insufficiency of funds.

Environmental Degradation

Increasing concern over environmental degradation complicates the power expansion plans of developing countries. Energy activities are the most significant contributors to local air and water pollution, as well to greenhouse gas emissions that affect climate change. Fossil fuel combustion is thought to be responsible for 65-90 percent of total carbon dioxide emissions. Although developing countries account for only a quarter of the global CO_2 emissions from commercial energy, increased emissions from these countries will accompany the rapid development of their power sectors. Emissions of SOx and NOx compounds and particulates will also increase, thus contributing to acid precipitation and a general decline in air quality, particularly in urban areas.

Adding new environmental control equipment will cause an increase in the initial capital cost of new pulverized coal-fired power plants. When fully commercialized, however, the greater efficiency of integrated coal gasification combined cycle technology is expected to compensate for much of their higher capital cost. While economic benefits will accrue in other areas, the power sector will have to bear the brunt of the capital cost for environmental improvement. Innovative solutions will involve new technology, including renewables, a major expansion in natural gas use, and the widespread implementation of energy efficiency in supply and demand.

SOLVING THE TRIPLE BIND

Collaborative Power Sector Appraisals

Donors could collaborate with developing countries in performing energy/environment sector assessments. The assessments would define a coherent donor/government strategy for power sector lending programs over the medium and long term. The primary objective of the assessments is to identify and prioritize the principal policy, institutional, and economic constraints to environmentally sound power sector development , and to identify ways to remove these constraints. The assessments should include recommended policy packages, resource mobilization strategies, investment priorities, and likely economic and environmental benefits.

The country-specific assessments should address the power/energy planning process under capital constraints, and propose system efficiency and demand-side management options in addition to supply expansion. The assessments should also investigate the environmental impacts of power development, and

the scope and potential for natural gas and renewable energy supply options. All assessments should be conducted in close collaboration with private and public institutions in developing countries.

Capital Investment in End-Use Efficiency

The capital mobilization problem in developing countries demands that capital investments in end-use efficiency be compared with investments in new supply. Of major interest is the capital saved on the supply-side per dollar invested in demand-side energy efficiency; this is referred to as the capital multiplier.

Figure 7 shows the results of a recent assessment in India conducted by the Government of India, USAID, the Overseas Development Administration (ODA) of Britain, and the World Bank, which concluded that implementation of eleven key end-use measures can dramatically reduce the capital required to deliver electricity services. The best measure has a capital multiplier of 12.5, and the average of eleven key measures has a capital multiplier of 5. A national end-use efficiency program that implements the key measures would require an investment of about 20 percent of the cost of new supply to deliver the same level of electricity service.

India's power sector has an installed capacity of over 65,000 MW, which generated 241,000 GWh in 1990. Approximately 60 percent of generation is coal-fired and 35 percent is hydroelectricity. The balance is oil- and gas-fired generation and a small amount of nuclear electricity. Since 1981, supply has increased from 31,000 MW and 114,000 Gwh.

Despite this impressive growth, shortages amount to about 20 percent of peak power and 10 percent of energy demand. Power shortages are exacerbated by inefficient end-use of electricity, resulting from low subsidized tariffs, technological obsolescence of end-use equipment, processes and systems, and inadequate commercial incentives for efficiency. The Government of India plans to install 110,000 MW of additional capacity by the year 2000 - the largest power expansion undertaken anywhere outside of the USA. This would reportedly cost about $200 billion (1989), or about 30 to 40 percent of total public investment over the period. Implementing such an ambitious program will strain India's public finances and pose unprecedented managerial and technical challenges for the sector.

The major findings of the end-use efficiency assessment are:

- good planning must address the central problem of limited capital resources and inadequate investment mobilization. Current power sector planning fails to include system rehabilitation and demand-side options.

- As shown in Figure 8, power end-use efficiency has the potential to save 38,000 - 61,000 MW in peak generation and 103 - 170 billion Kwh in energy savings by 2004-05. The corresponding reduction in capital expenditures from capacity savings could be over $30 billion, or a fifth of the projected capital requirements of $150 - 200 billion.

Fig. 7 Costs & Benefits of End-use Energy Efficiency Improvements in India

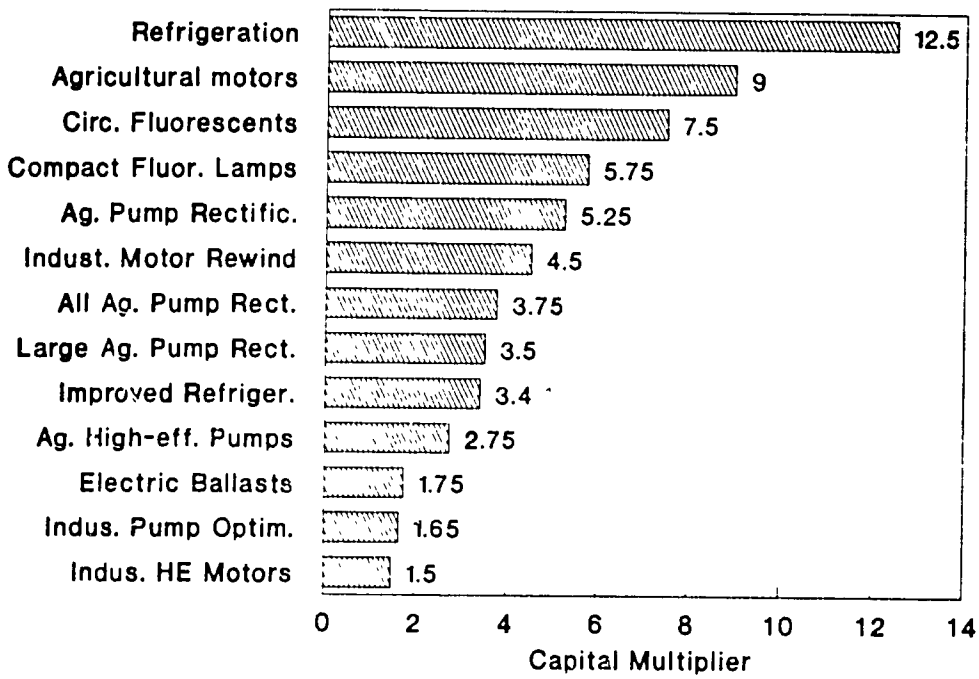
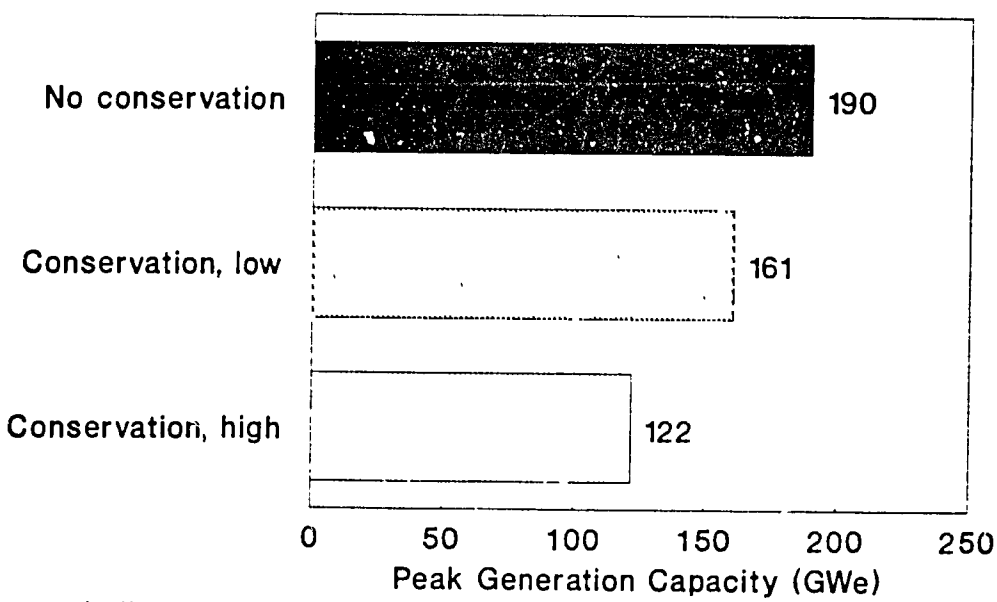


Fig. 8 Conservation Potential for 2004-2005 in India: Improved End-use Electricity Efficiency



Source: India - Long-Term Issues in the Power Sector (USAID, 1991)

Capital Investment in Operations and Maintenance

Generating capacity reserve margins in over 70 developing countries are excessive and average 43 percent instead of 20-30 percent in well planned and operated systems. There was an excess capacity of 43,000 MW in the developing world in 1989 on a total system load of 331,000 MW, assuming a 30 percent reserve margin.

This excess capacity represents a capital investment of $50 billion, using $1,150/kW as a weighted mix of capital costs. Improved maintenance to increase unit availability and reduce capacity reserve could save about $50 billion initially and approximately $25 billion annually in future generation investments.

Strengthening Development Finance Institutions

The banking community in developing countries, including the Development Financing Institutions (DFIs), could incorporate energy efficiency in major energy investments. Industrial modernization should include technological advances that reflect lower energy consumption and environmentally sound production processes. DFI's could promote, in collaboration with donors, investment mobilization under capital constraints, least-cost investment portfolios, life-cycle financing of utility operations and maintenance, and preparation of specific operational and financial action plans.

Innovative Technology Cooperation Programs

A financing facility should be created for joint venture technology development and commercialization, involving firms from industrialized and developing countries. The primary concern expressed by firms from industrialized countries in technology development and commercialization ventures is the level of risk associated with product development and commercialization particularly when investing in developing countries.

USAID is promoting user-supported, market-driven research in critical technology areas through consortia which include electric utilities, manufacturers, universities, and national laboratories to tap the private sector for innovative technology. A hallmark of this approach is that developing countries participate directly in the development and adaptation of innovative technologies, and thus are able to influence the outcome so that innovative technologies are also appropriate to the developing country situation.

The Program for the Acceleration of Commercial Energy Research (PACER), an Indian/USAID collaborative science and technology initiative launched in 1987, is a good model of a successful consortium of this type. The purpose of PACER is to foster innovation in the Indian electric power sector, in part by establishing consortia that link the industrial, commercial, R&D, and government sectors.

Through PACER, new technologies for energy conservation and efficiency, renewable energy, clean coal technology for power generation, and improved transmission and distribution are being developed and

commercialized. Costs and risks are shared by USAID and private sector participants, which helps ensure that only viable, market-driven projects are supported. Since its inception, PACER has supported over 21 energy technology development projects and energy research studies in the private sector. An additional 14 projects are in various stages of formulation.

SUMMARY RECOMMENDATIONS

Harmonization of Donor/Government Actions

Donors and developing country governments should collaborate closely to:

Conduct power and environment appraisals to provide policy reform packages and investment priorities for public and private entities in specific developing countries.

Provide a country focused private and public capital mobilization plan.

Focus resources on countries and institutions with a strong commitment to improving sector performance.

Fostering Innovation in Policies and Institutions

Donors and multilateral lending institutions should promote new social arrangements between developing country governments and utilities to promote superior performance. This can be achieved through establishing an independent regulatory framework and a clear regulatory process that assures efficient delivery of utility electricity services.

Donors and governments should create a financing facility for joint ventures in environmentally sound energy technology development and commercialization.

Donors and governments should establish research, development, and commercialization networks among developing country utilities.

Fostering Innovation in Financing

Donors and governments should consider financing enterprises that deliver reliable electricity services on the basis of kilowatt-hours supplied rather than on the basis of generation, transmission, or distribution project costs.

Donors, governments, and utilities should dramatically alter their investment priorities in the power sector to finance operations, maintenance, and end-use efficiency as-well-as traditional investments in supply.

Donors and multilateral financing agencies should use their guarantee powers to encourage foreign and domestic private investment in the power sector of developing countries.

Promoting Global Energy and Environmental Management Network (GLEEM)

We propose that existing bilateral and multilateral donor networks in energy and environment be strengthened and expanded to link with developing country financing institutions and recognized centers of excellence in energy and environment. It is proposed that the SEED Meeting authorize a committee to explore the financing and institutional modalities of such a global energy and environmental management network. This committee is urged to conduct discussions with developing country participants, the private sector in developed and developing countries, the ESMAP Program, and other appropriate programs.

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ANNEX 1

SLIDE PRESENTATION

IMPLEMENTING POWER SECTOR SOLUTIONS IN DEVELOPING COUNTRIES

STOCKHOLM INITIATIVE ON ENERGY, ENVIRONMENT AND SUSTAINABLE DEVELOPMENT (SEED)

Stockholm

November 13-15, 1991

Power Sector Problems in Developing Countries - The Triple Bind

Developing countries need expanded power development to fuel economic growth, but face:

- ✓ Massive capital mobilization requirements
- ✓ Deteriorating financial performance
- ✓ Increasingly severe environmental constraints

The Three-Fold Solution: Fostering Multi-faceted Innovation

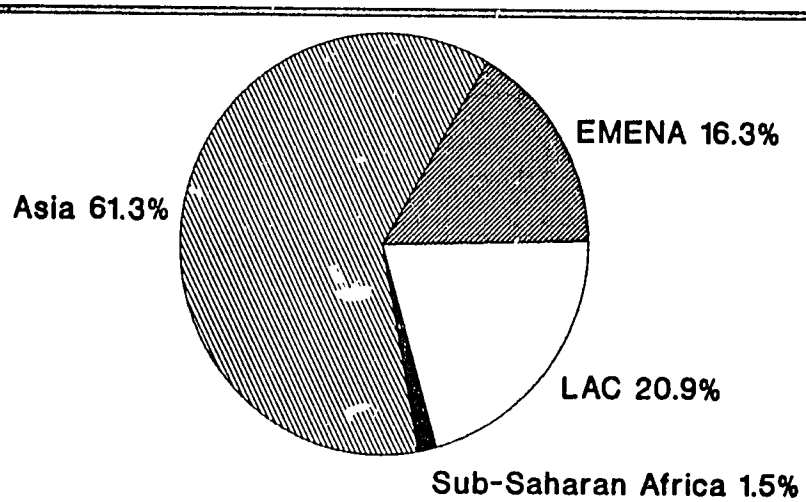
The three-fold solution requires fostering innovation in:

- ✓ Management and financing
- ✓ Technology
- ✓ Policies and institutions

Capital Requirements for Power Expansion (1990 - 2000)

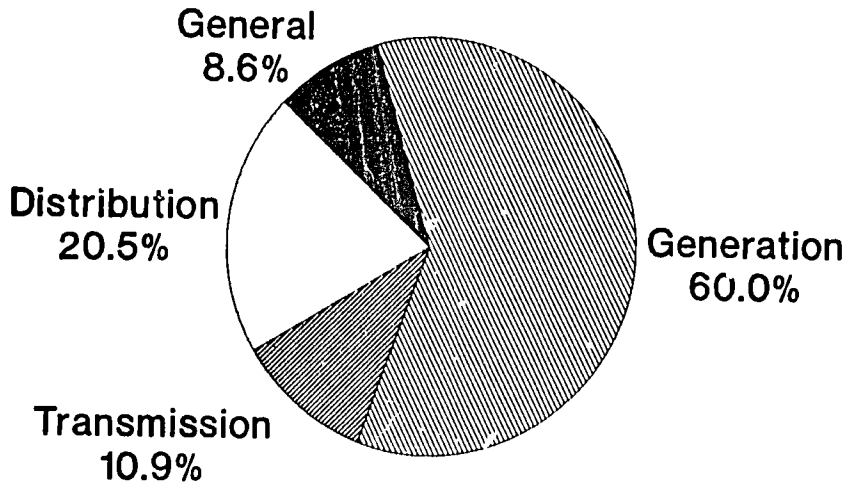
- US$ 760 Billion (1989$) or
- $1 trillion (nominal dollars)
- $100 Billion annually
  - ✓ $60 Billion local currency
  - ✓ $40 Billion foreign exchange

Breakdown by Region of Captal Expenditures Required for Power in the LDCs in the 1990s ($742 Billion Total in 1989 US$)



Sample Size: 70 Countries

Projected Capital Expenditures for LDC Power Generation in the 1990s ($742 Billion in 1989 US$)



Sample Size: 70 Countries

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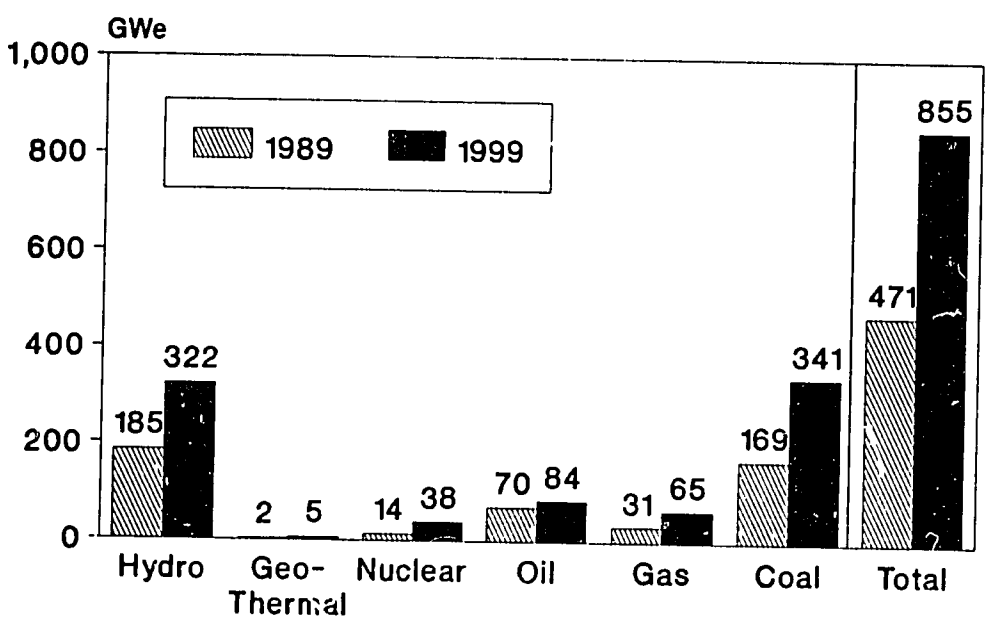
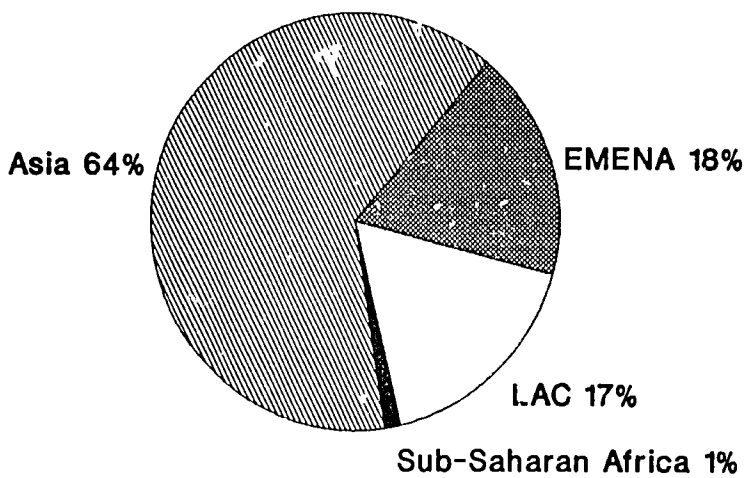
Comparison of 1989 and Projected 1999 Installed LDC Generating Capacities
(Sample Size: 70 Countries)

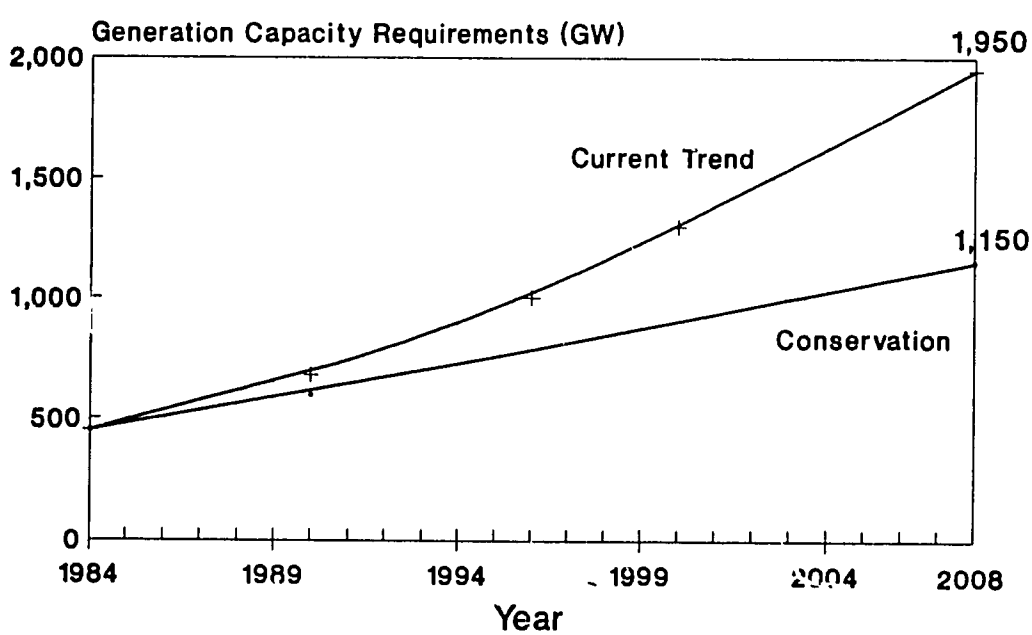


Expected Addition to Capacity By Region in the 1990s (384 GWe Total)



Sample Size: 70 Countries

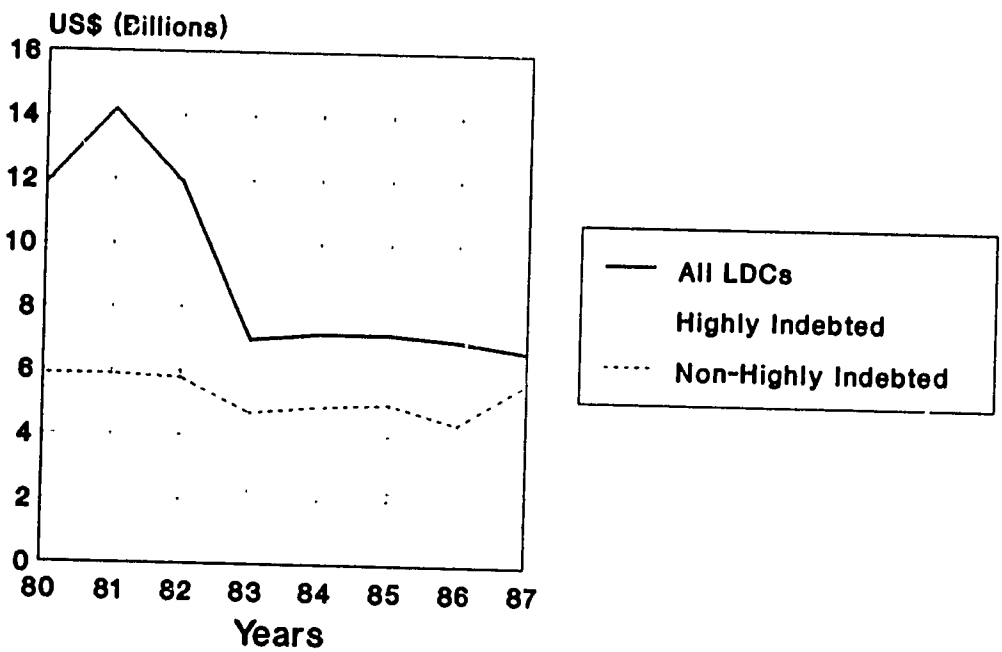
Electricity Generation Capacity Requirements in Developing Countries Current Trend & Conservation Scenarios



Capital Available for Power Expansion (1990 - 2000)

- $7-10 billion/year foreign exchange available
- $30 billion/year foreign exchange financing gap
- Serious local currency financing gaps

Trends in Total Power Commitments for Developing Countries



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Per Capita Electricity Use in Developing Countries (1968 - 1982)

- 7% annual increase from 280 kWh/capita to 530 kWh/capita
- Continued high growth rate necessary for economic development
- Indian per capita electricity consumption = 1/40 U.S. per capita consumption

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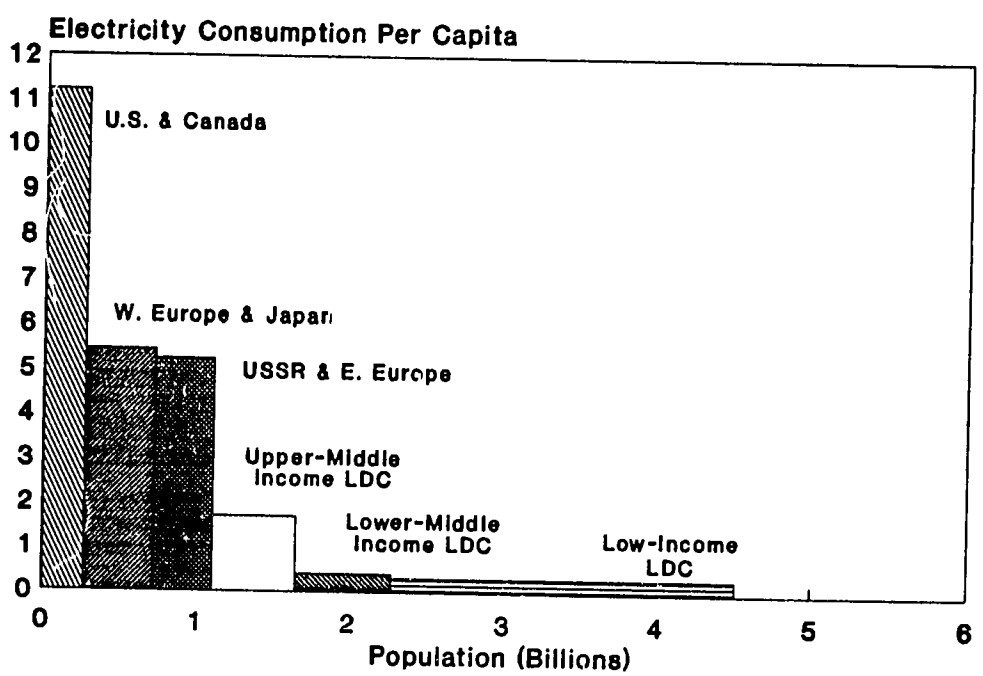
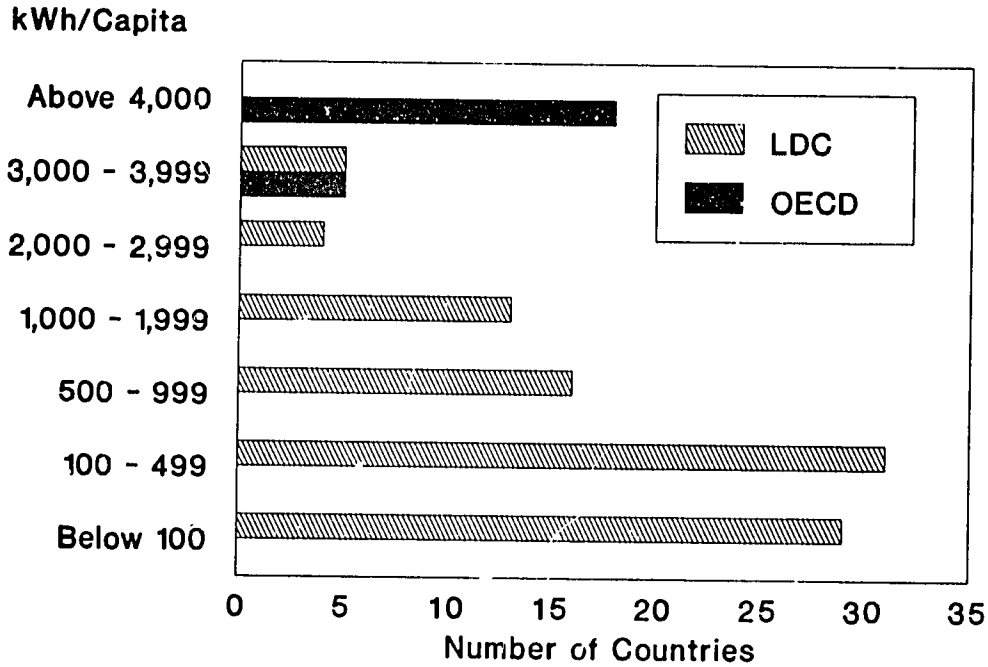
DJF-5C

Distribution of World Electricity Consumption (1984)



Source: United Nations

Distribution of LDC & OECD Electricity Production Per Capita

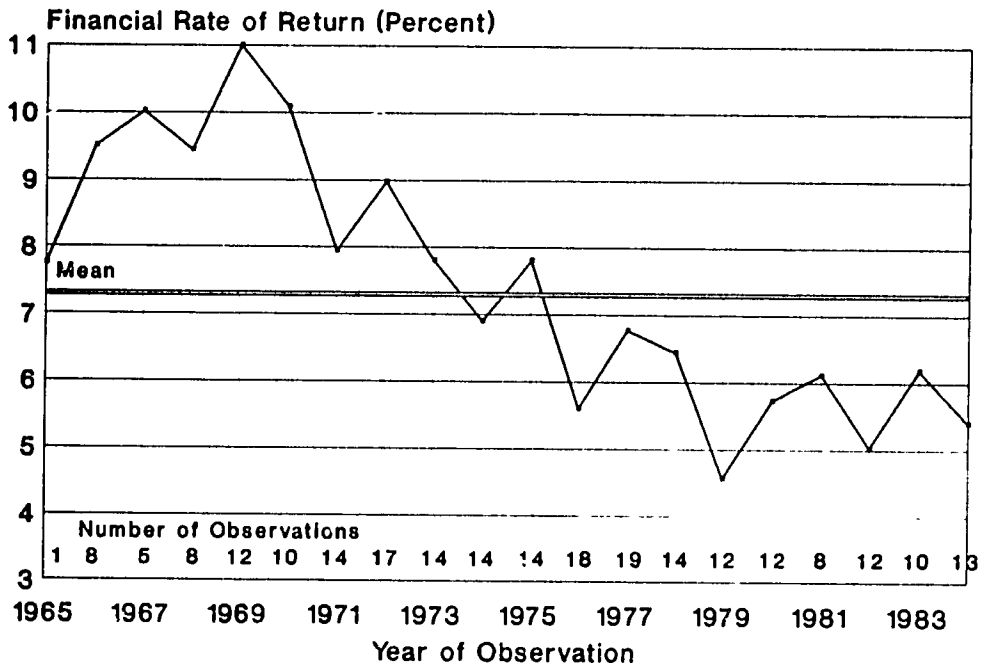


Deteriorating Utility Performance

'orld Bank review of over 300 Bank-financed projects shows:

- Steady decline in power sector performance
- High technical and non-technical energy losses
- Production costs consistently > prices
- Poor management and maintenance
- Over-optimism regarding costs and performance by neglect of institutional and management factors

Trend of Rate of Return on Assets



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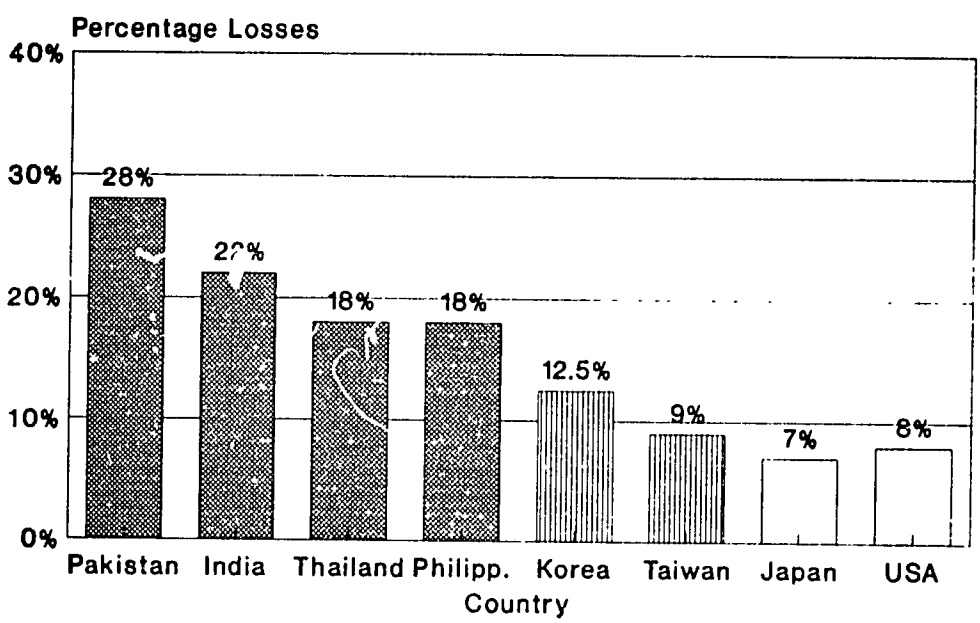
Source: M. Munasinghe, World Bank (1989)

Transmission & Distribution Losses in Several Countries (Average for 1981 - 1985)

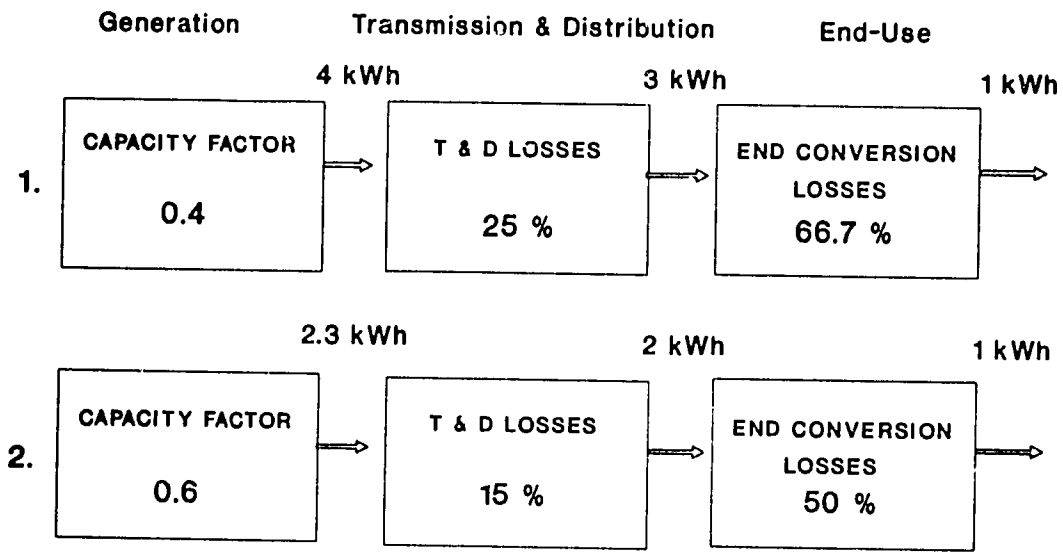


Source: Lawrence Berkeley Laboratory

Fostering Innovation in Financing and Management

- Financing delivery of reliable power rather than power plants
- Dramatic alteration of investment priorities: symmetrical treatment of new generation, O&M, rehabilitation, and end use
- Life-cycle rather than one-time financing
- Incentives for superior performance (salary, bonuses, career advancement)

Impact of Technical Improvements on Productivity of Capital in the LDC Power Sector

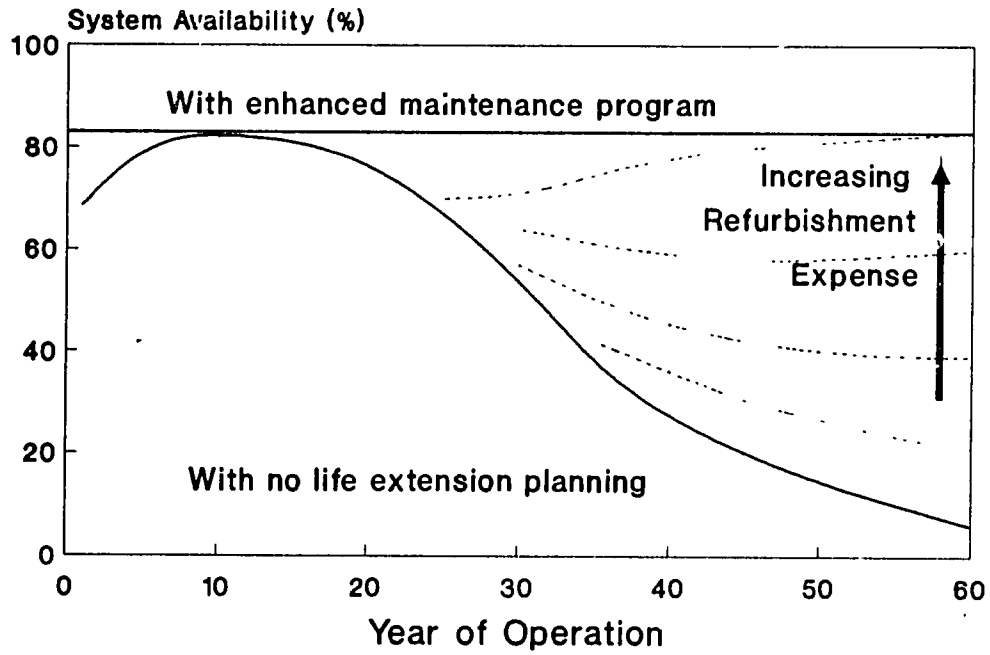


Case 1: $1,500/kWe installed
$15,000/kWe delivered

Case 2: $1,500/kWe installed
$5,700/kWe delivered

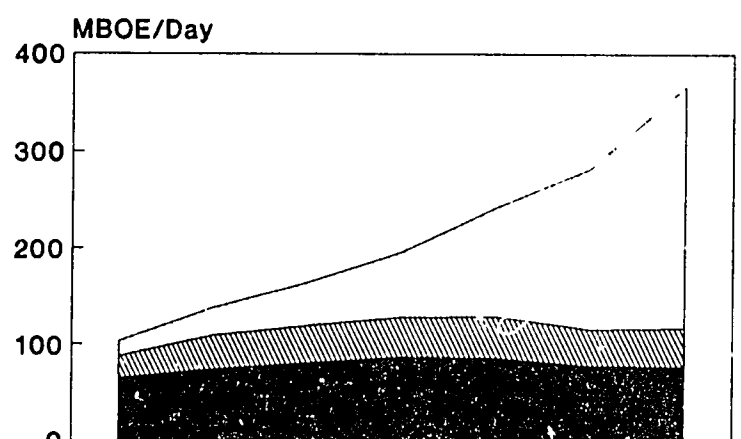
Source: David Jhirad (1987)

Management and Financing Innovation
Power Plant Life Extension Strategies



Source: EPRI

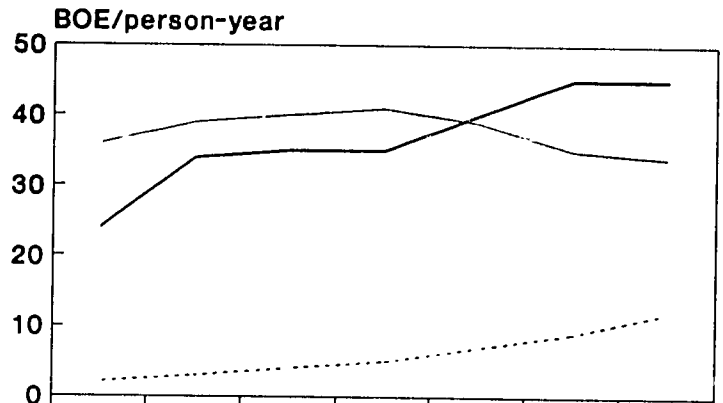
An "Energy-Efficient" Demand Scenario
Projections for 1990 to 2030



	1970	1980	1990	2000	2010	2020	2030
LDCs	16	29	45	68	113	166	249
E. Europe/USSR	23	35	38	41	43	38	40
OECD	65	75	82	88	87	79	78

Source: Denis Anderson, May 1991
"Energy and the Environment"
The Wealth of Nations Foundation

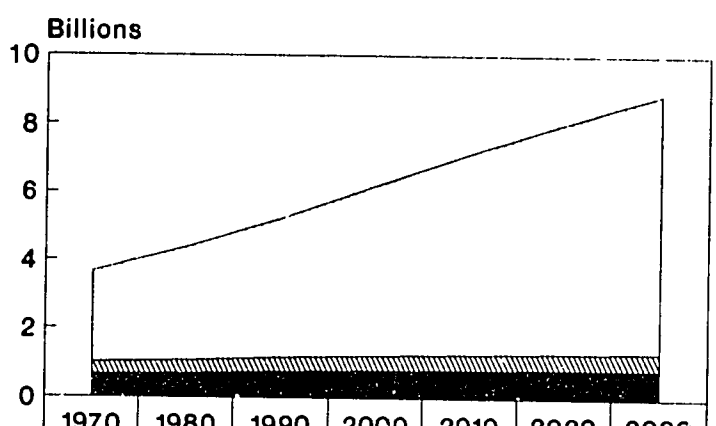
An "Energy-Efficient" Demand Scenario
Per Capita Primary Energy Consumption
For The Period 1990 - 2030



	1970	1980	1990	2000	2010	2020	2030
LDCs	2	3	4	5	7	9	12
E. Europe/USSR	24	34	35	35	40	45	45
OECD	36	39	40	41	39	35	34

Source: Denis Anderson, May 1991
"Energy and the Environment"
The Wealth of Nations Foundation

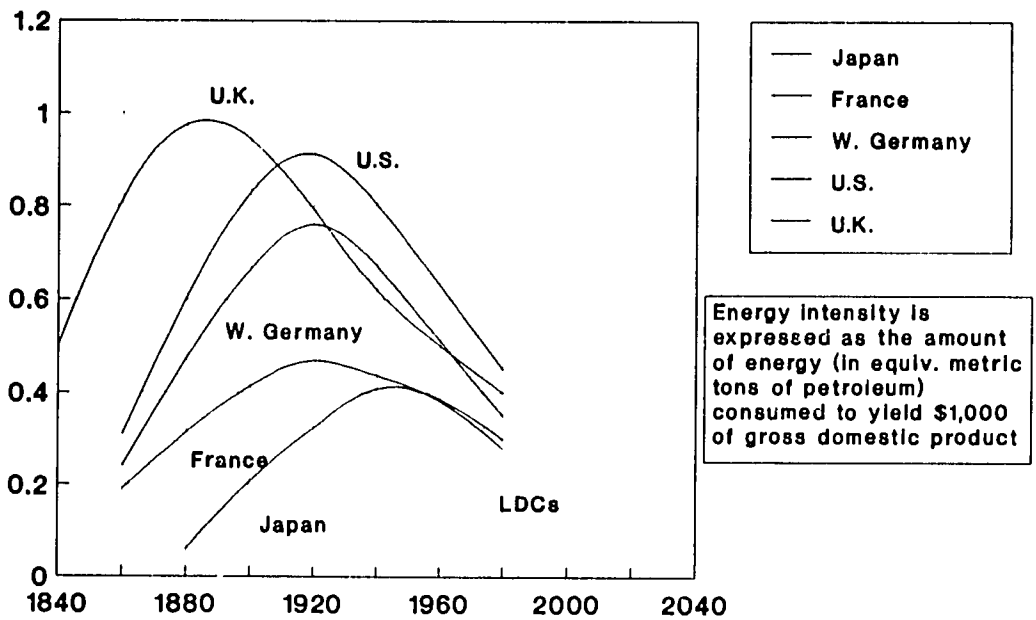
An "Energy-Efficient" Demand Scenario
Populations
Projections for 1990 to 2030



	1970	1980	1990	2000	2010	2020	2030
LDCs	2.65	3.31	4.085	5	5.9	6.75	7.575
E. Europe/USSR	0.345	0.375	0.402	0.425	0.45	0.47	0.485
OECD	0.66	0.7	0.756	0.79	0.81	0.825	0.83

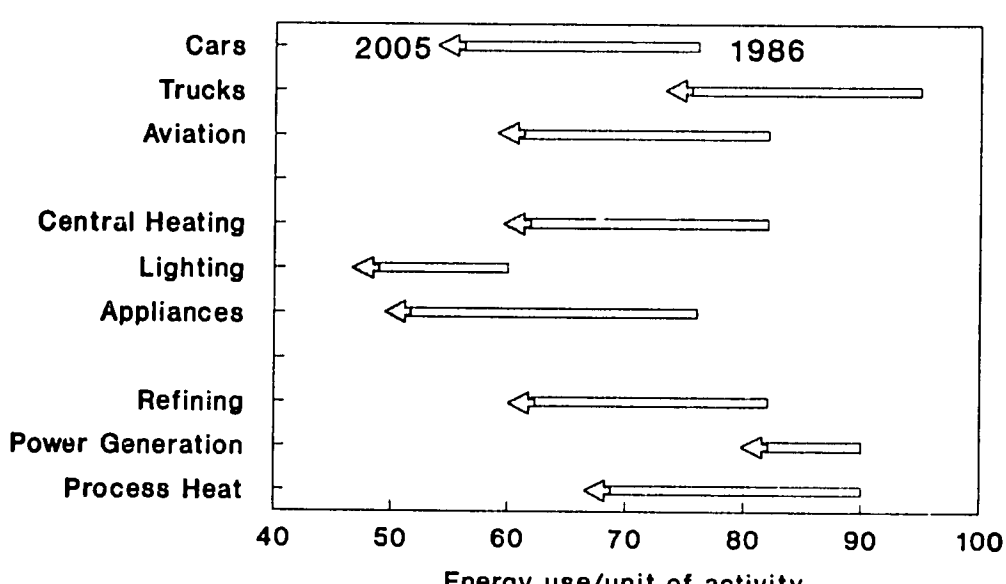
Source: Denis Anderson, May 1991
"Energy and the Environment"
The Wealth of Nations Foundation

Aspects of Energy Efficiency
Energy Intensity (Commercial Fuels)



Source: A.K.N. Reddy & J. Goldemberg
Scientific American, Sept. 1990

Potential for Efficiency Improvements Using Best Available Practice (OECDs)
(1986 to 2005)



Source: Davis (1989)

$50 Billion Investment Savings Through Maintenance Improvements

- Generating capacity reserve margins in 70 developing countries average 43 percent instead of 20-30 percent in well-planned and operated systems.

- Excess capacity of 43,000 MW on 1989 total system load of 331,000 MW assuming 30 percent target reserve.

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$50 Billion Investment Savings Through Maintenance Improvements

- Excess capacity represents $50 billion using $1150/KW as weighted mix of capital costs.

- Improved maintenance to increase unit availability and reduce capacity reserve could save about $50 billion initially and roughly $25 billion annually in future generation investment.

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Recommendations: Collaborative Action By Gov't.s, Donor/Lending Agencies, and Power Utilities

- *Focus Resources* on countries and institutions with a strong commitment to improving sector performance.
- *Conduct Power and Environment Appraisals* to provide policy reform packages and investment priorities for public and private entitities.
- Provide country-based private and public capital mobilization plan.

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Fostering Innovation in Financing

- Financing Enterprises that Deliver Reliable Electricity Services: Financing According to Kilowatts and Kilowatt-Hours Supplied, rather than Project Costs.
- Dramatic alteration of Investment Priorities: Financing Operations, Maintenance, Efficiency, as well as Supply.
- Financing Agencies Use Guarantee Powers to Encourage Foreign and Domestic Private Investment in the Power Sector.

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Fostering Innovation In Policies and Institutions

- Close Collaboration Among Donors, Lenders, Host Country Governments, and Power Utilities
- New Social Compact Between Government and Utilities to Promote Superior Performance: Establish Independent Regulatory Framework Between Government and Power Suppliers
- Establishing Global Research, Development, and Commercialization Networks Among Utilities

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Publications and Presentations

Stockholm Initiative on Energy, Environment and Sustainable Development (SEED): Strategies for Implementing Power Sector Efficiency.

Business Council for Sustainable Development (BCSD), Ms. C. Nystedt, BCSD

Core Report of the Electric Power Utility Efficiency Improvement Study, Mr. Gunter Schramm, World Bank

Donor Coordination in Energy Efficiency, Mr. S. Thomas, World Bank

Energy Management Consultation and Training (EMCAT) project, Mr. S. Padmanabhan, USAID/EPIC Program

Energy Efficiency and the Environment, Mr. G. Schramm, World Bank

Executive Summary, Conclusions, and Recommendations from the United Nations Seminar on Energy Conservation in Developing Countries, UNDTCD, September 1989

Global Environmental Facility (GEF), Mr. E. Ayensu

Group Areas of Activity for Discussion at SEED, Belgundi Group of Companies, India

Implementing Power Sector Solutions, Mr. D. Jhirad, USAID

Introductory Statement on the United Nations Conference on Environment and Development, Mr. B. Kjellen, Swedish Government, UNCED Prepcom

Introductory Address, Ms. D. Pastizzi-Ferencic, UNDTCD

Issues and Problems in the Power Sector, Mr. G. Schramm, World Bank

Press Release, United Nations Department of Public Information, November 6, 1991

Prospectus, Secretariat, October 25, 1991

Recommendations from the United Nations Seminar on Operation, Maintenance and Rehabilitation of Power Plants, UNDTCD, October 1988

Statement of Mr. Ji Chaozhu, Under-Secretary General, UNDTCD to the Consultative Meeting Stockholm Initiative on Energy, Environment and Sustainable Development (SEED): Strategies for Implementing Power Sector Efficiency, City Hall Address, Mr. Ji Chaozhu, UNDTCD

Statement by BITS at the Inaugural Session of the Stockholm Initiative on Energy, Environment and Sustainable Development (SEED), Ms G. Olofsson, BITS

Strategies for Implementing Power Sector Efficiency, Mr. M. Willingham, UNDTCD

United Nations Development Programme (UNDP), Mr. F. Pinto, UNDP