Infrastructure Maintenance in LAC:
The Costs of Neglect and Options for Improvement

Volume 2
The Power Sector

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June 1992
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This report was prepared by Luis E. Gutiérrez, Senior Energy Economist (ESMOD). The peer reviewers were David P. Hughart (LATDR), Hossein Razavi (ESMOD), Gunter Schramm (ESMOD), and Vatsal Thakor (ASSIE). Rafael A. Moscote (LATIE) and OLADE’s staff actively assisted with comments and suggestions the elaboration of the document. Gerardo Corrochano and Yolanda Tayler assisted in the preparation of the Case studies.
MAINTENANCE IN THE POWER SECTOR: The Costs of Neglect and Options for Improvement

EXECUTIVE SUMMARY

INTRODUCTION

1. In spite of the substantial growth in installed generating capacity over the past decades in LAC, poor technical performance plagues every aspect of the power sector operations in several LAC countries. Shortcomings include power plant operating inefficiencies, low generating unit availabilities, high transmission and distribution losses, and service interruptions.

2. Lack of funds for proper maintenance and the inefficient use of the available resources have contributed to the rapid deterioration of the capital infrastructure in most countries. This has had serious implications for the region's economic growth, impairing the prospects for economic recovery and the comparative advantage of the LAC countries by increasing overall costs and reducing overall economic activity. The shortfalls in funding are caused by the scaling down of public sector expenditures to match available resources, by deterioration of LAC economies, and by the rigors of adjustment.

3. It appears that the dimensions of the infrastructure O&M (operations and maintenance) problem are not well understood by decisionmakers within and outside the sector (for a résumé of the causes of improper O&M, see Box 1).

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**Box 1: O&M are Closely Related Functions**

The effects of O&M are difficult to separate. In thermal generation, inefficient heat rates and lower availability can result from the following causes:

- Shoddy practices, such as operating beyond technically defined parameters
- Poorly trained operators and a "generate or bust" mentality that prevents timely maintenance at preplanned intervals
- Poor preventive maintenance (such as improper calibration of turbines)
- Substandard repair of broken equipment

In power transmission and distribution, losses can result from the following causes:

- Phase overload (unbalanced operation)
- Overload of equipment
- Inadequate load dispatching
- Insufficient conductor capacity
- Faulty commercial practices
- Inadequate clearing of trees from lines
- Deficient upkeep of system, transformers
- Improper calibration and faulty meters

Poor operating practices are frequently found together with inadequate maintenance, making it difficult to separate the consequences of improper operation from those of improper maintenance—a reason why O&M, even though clearly distinct functions, are so intimately related. Moreover, failures in both functions have a common ultimate cause—poor management.
The costs of improper O&M practices are substantial. For example, thermal generation costs could be reduced from the present US$17 per MWh to no more than $14.50 per MWh with adequate upkeep—a saving of US$360 million per year (data provided by countries in the Region and not verified by the World Bank). Yet losses in LAC have been increasing—in 1989, losses were 15 percent of total electricity supply, compared with 13 percent in 1980. In contrast, loss ratios in developed countries are typically below 10 percent. The significance of these losses and the importance of reducing them are highlighted by putting the problem in financial terms: for every percentage point reduction in losses in the LAC countries as a group, the annual savings in investment and operation costs would amount to US$368 million. Infrastructure degradation in LAC also causes pervasive power interruptions and voltage fluctuations, and reliability losses amount to about US$6,428 million.

4. The power sector is very important in all LAC countries. The installed generating capacity in 1989 amounted to 140 GW, representing about US$ 168 billions at replacement value, and more than $300 billions when considering transmission and distribution facilities. Electricity service coverage in 1989 extended to about 295 million people out of population of 420 million in the region; i.e., 70% of the population had access to electricity. In spite of the significant efforts carried out in most LAC countries to increase electricity service coverage, the levels attained are still far from those of developed countries. If population grows at 1.88% p.a. during the first half of the 1990s and at 1.65% during the second half (as forecast by the World Bank), by 1999 around 12 million new residential customers will have to be connected to the system just to maintain the current 70% level of service coverage. The investments required for this exclusive purpose would be about US$62 billion. However, if service coverage is to increase to around 80%, close to 23 million new residential customers would have to be connected, and the corresponding investments would be about US$120 billion. Thus, the challenges ahead are great for the utilities and governments of the region.

5. Given the close association between electricity supply and economic growth, it is not surprising that the deterioration of the power sector infrastructure caused by the decline in maintenance and rehabilitation expenditures in LAC was triggered by the generalized economic crisis. The GDP levels of LAC in 1980 were not surpassed until 1985. The seriousness of the economic crisis is underlined by the fact that GDP per capita in 1971-80 (expressed in 1989 US dollars) increased from $1,726 to $2,389 (average annual growth rate of 3.7 percent), whereas GDP per capita dropped in 1980-83, reaching a minimum of US$2,140 in 1983. Per capita GDP has rebounded since 1984 but was only $2,255 in 1989, still below the 1980 level.

6. The World Bank, aware of the scope of the problem, undertook this study in collaboration with OLADE to examine the main issues, causes, and measures to overcome maintenance neglect. The study outlines for decisionmakers the
Dimensions of maintenance neglect; its economic, financial, and social costs (see Box 2); and the quantitative and qualitative benefits of adequate maintenance. In addition, the study identifies the causes of deterioration (e.g., institutional, operational, financial, management, and inappropriate policies). Finally, it examines the economic, institutional, policy, and operational changes required to improve the rehabilitation and maintenance of the power sector infrastructure and presents an analysis of the options with lessons drawn from a sample of selected LAC countries. This study is the first stage of a three-part strategy to address the backlog of maintenance and rehabilitation tasks in the power infrastructure of the Latin America and Caribbean Region.

Costs of Maintenance Neglect

7. Maintenance should be understood in the conventional sense of the term—upkeep of equipment and property—but it also should be conceived of as an ensemble of physical, managerial, and corporate activities that will allow the infrastructure to function efficiently and according to design. Operations and Maintenance (O&M) are actually distinct but complementary facets of the task of providing economic and reliable service.

8. The main manifestations of inadequate maintenance in power systems arise from the use of existing capacity outside of its design specifications: (a) higher
fuel costs caused by inferior thermal efficiency and lower available capacity; (b) additional investment required to compensate for the lower availability of the installations and premature aging; (c) higher generation costs caused by excessive losses in transmission and distribution; (d) additional outage costs stemming from lower reliability of the equipment; and (e) additional pollution in thermal systems from poorly kept and operated equipment.

9. Governments in LAC have frequently reacted to periods of inflation and economic stagnation by holding energy prices below cost-recovery prices and by managing public utilities according to noncommercial criteria. This has compromised the capacity of the utilities to carry out proper maintenance and to operate and expand efficiently, with far-reaching consequences for economic recovery and sustained growth.

10. Box 3 presents key maintenance practices and problems as found by the survey of LAC countries. A common feature underlying maintenance problems is the absence of sound tariffs. Electricity tariffs should cover operating and maintenance costs, leaving a net margin for investment in capacity expansion. Tariffs at all supply levels should reflect the marginal cost structure to promote energy conservation and provide managers the proper signals about what to produce and when to expand (i.e., to promote an optimum allocation of resources), whereas the tariff level should be set according to cash flow needs to ensure proper cost recovery and an economic return on assets.

11. The economy bears the brunt of the costs of maintenance neglect in the form of higher fuel costs, reduced investment in power-dependent productive sectors, output foregone, decline in trade competitiveness, and so on. These costs far exceed the financial savings to the power sector from deferring or neglecting investment and necessary maintenance. Preventing the additional
economic costs of more than US$10 billion per year would have required
spending less than one-third of that figure on rehabilitation and maintenance (see
the breakdown in Box 4).

Generating Costs

12. Generating costs in LAC countries, taken as a group, are unacceptably high
compared with the costs of similar equipment in developed countries
(Diewart 1990). These costs can be reduced with proper maintenance and
rehabilitation of current facilities. Estimates suggest that savings of US$360
million per year in generating costs are possible. The costs of building additional
facilities to compensate for the decline in available capacity of the equipment are
substantial. The investment costs in generation, transmission, and distribution
is $1,750 on average for LAC countries to increase by 1 kW of capacity.

Electricity Losses

13. Electricity must be harnessed from a primary energy source, transformed
to higher voltages and transmitted over large distances, and stepped down to
distribution voltages for consumers. In this process, some electricity is
inevitably lost. Moreover, the cost of reducing losses to the absolute physical
minimum may exceed the benefits. Still, excessive losses are avoidable.

14. High levels of power loss reflect design failures; aging of facilities; repair
and replacement delays; and failure to prevent illegal connections and frauds,
to implement good reading and commercial practices, and to monitor all uses
of electricity. Losses above 10 to 12 percent of energy requirements (net
generation plus purchases) are excessive. Although a substantial share of the
industry's capital is in distribution, this is where maintenance cutbacks are first
felt, not necessarily in terms of a decline in the rate of connections (this has
political appeal) but in asset maintenance and replacement. When resources are
limited, they are usually allocated first for electrification programs and
expanding generating capacity, taking care of the public image of the utility and

1. There is always an acceptable economic level of losses. This level varies from
country to country, depending on supply conditions and the structure of relative
prices. The level is reached when the cost of reducing losses by 1 kWh is larger
than the long-term marginal cost of supplying it (Gutiérrez 1989).
of public officials. This explains why losses reached extremely high levels in LAC countries during periods of financial difficulties, especially during the debt crisis of the 1980s. Indeed, loss levels in various LAC countries exceed 20 percent, of which the greatest share was distribution losses.

Service Reliability

Along with the increase in loss levels, the quality of the service rendered by utilities has deteriorated. Consumers in some countries suffer constant interruptions and voltage fluctuations. It is estimated that up to 5 percent of total electricity demand in LAC is not satisfied because of power outages, a level that could be halved with adequate maintenance of existing supply infrastructure. This represents about 11 TWh of unserved energy or some $580 million of lost sales revenue per year for the power utilities and 5 to 10 times that amount for users.²

Environmental Impact

Policies designed to raise O&M efficiency are bound to have a significant and essentially a zero-cost environmental improvement. Improvements in the generation heat rate, reduction in losses, and improvement in service reliability lead to a lower pollution load, amounting to reductions of up to 37 percent in thermal systems from previous levels. 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 at about 49 percent of the total from all sources (WRI 1991). Generation based on fossil fuels is estimated to contribute about 30 percent of the total energy’s share, or about 15 percent of all greenhouse gases (British Petroleum Corporation 1990).

CAUSES OF MAINTENANCE NEGLECT

Several factors have contributed, often in a synergistic way, to the poor state of most power infrastructure and the deterioration of service in LAC. An assessment of the factors that led to the current situation is important to examine alternative options to overcome the problems. These factors are grouped in Box 5 to facilitate discussion, but most of them cut across boundaries.

International lending and donor agencies have, at times, sent the wrong signals or encouraged less-than-optimal investments. They have neither

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² The value of an electricity outage varies depending on whether it is planned or a random interruption. The outage value here refers to random interruptions, which are higher than planned shortages. The National Energy Commission in Chile uses for long outages of up to 20% of consumption between $120 to $230 per MWh (1991), figures which are four times the average tariff.
provided adequate support for the removal of long-standing maintenance problems nor promoted adequate maintenance programs before new construction projects were supported. World Bank appraisal and sector reports do make reference to problems of maintenance, and most of them have a standard maintenance clause, yet few have attempted to quantify and assess the costs of this neglect. Loan operations with a rehabilitation component also suffer from this omission. Several rehabilitation and loss-reduction operations would have benefitted from a more comprehensive analysis of the maintenance and operation problems that led to their need, so as to prevent these problems from recurring. In the final analysis, rehabilitation, power loss, and outage reduction projects are essentially corrective measures required by improper O&M.

OPTIONS TO OVERCOME MAINTENANCE NEGLECT

19. Overcoming the present degradation of the power sector infrastructure in the region to provide adequate support for economic growth and development is the challenge facing policymakers and development institutions during this decade. Many lessons can learn from the errors of the past. Disregard of programmed intervals for maintenance increases generation costs and impairs the thermal efficiency and availability of the units. Keeping prices below cost-recovery levels has overstimulated demand and required greater quantities of
already-scarce resources for generation. Thus, low prices have induced higher demand, lower revenue for O&M and expansion investment, less preventive maintenance and replacement investment, higher operating costs, shrinking operating margins and government contributions, politicized management and unions, and so on. Avoiding a repetition of the maintenance neglect of the 1980s is paramount to an economic and reliable electricity supply, key inputs for regaining and sustaining economic growth in the region.

20. The power sector needs sound pricing policies, adequate and robust expansion plans, and alternatives that consider the risks entailed in existing facilities, foreign exchange availability, maintenance staff capabilities, and training needs. Electricity prices should reflect the present and future costs of supply, and they should signal consumers how much it costs to supply them to induce promote rational consumption patterns and discourage waste. Sound electricity pricing also encourages efficiency in supply by providing utilities with market signals in sync with the opportunity costs of operation and expansion. A sound pricing policy is necessary to improve the internal funding of the sector and provide adequate preventive and corrective maintenance.

21. The main cause behind the weak finances of the sector, the poor operating practices, the lack of proper maintenance, and the unreliable service is the institutional setup—the lack of corporate autonomy of the utilities, the myriad government departments and agencies overseeing the sector, and the general lack of clear objectives. Inadequate O&M has been compounded by the perception that electricity is a service Government is obligated to supply without consideration of cost. The institutional and regulatory framework needs revamping. The power sector has to open up to competition, a priority because of many factors: the need for efficiency associated with competition; the perception by the people—and often by governments—that government-run companies are inefficient; and the inability of the governments to fund investment programs.

22. As summarized in Box 6, most of the power sectors in the region face major investment requirements in the 1990s, especially if the economic adjustment and macroeconomic programs materialize. To face this challenge, the power sectors in the region need to mobilize resources, taper demand through sound electricity pricing, establish an adequate institutional framework, provide regular preventive maintenance, reduce investment requirements through rehabilitation of existing infrastructure and loss reduction programs, and attract private sector participation. The critical fiscal situation of most LAC governments and the existence of other
pressing priorities impel them to consider harnessing the resources of the private sector.

ELECTRICITY TARIFFS

23. Adequate cost recovery policies are fundamental for the long-term financial health of the utilities and to enable adequate maintenance for a least-cost and reliable supply of power, essential inputs for economic recovery and sustained growth. The power sector demands large investments in generation plants, transmission lines, and distribution networks. Given the long lead times of electricity supply projects, assuring a reliable supply requires the commitment of scarce investment funds several years in advance. Electricity prices influence demand, and demand in turn influences investment. Consequently, inefficient pricing policies fail to send the right signals to consumers and promote a misallocation of resources, yielding suboptimal development patterns with far-reaching consequences. Thus, rational electricity pricing is vital to sound maintenance policies and, ultimately, to a competitive economic base for renewed and sustainable growth (see Box 7).

• Price is the best inducement for energy conservation. Industries will invest in energy conservation to the point where the cost of saving an additional unit of energy is the same as the purchase price of that energy.

• The benefits for the country of subsidizing energy consumers are less than the benefits of allocating the equivalent subsidy to infrastructure, social, and human capital formation.

• Proper prices lead to better financial situations for the sector utilities which in turn lead to maintenance expenditures and replacement investments to improve operative conditions and the quality of supply (i.e., reduce costs, improve availability and reliability of supply).

• Adequate prices are necessary for an efficient and reliable maintenance policy, to lower forced outage rates, raise efficiency and availability factors, lower losses and improve reliability of supply.

• Sound electricity pricing also encourages efficiency in supply by providing utilities market signals for an efficient operation and power investment program.

• Sound electricity pricing improves the chances for private sector participation.

Box 7: Benefits of Sound Electricity Pricing
MANAGERIAL AND INSTITUTIONAL

24. With some exceptions (e.g., Chile, Bolivia, and Venezuela), most of the electric utilities in LAC are government owned. The regulations inherent in management of a public company are a frequent obstacle to the necessary actions for efficient maintenance, purchasing of spare parts and labor policies. These regulations establish lengthy and relatively complex purchasing and credit request procedures. If foreign goods or services are to be acquired, then the public utility must previously have access to foreign exchange, which raises the possibility of new restrictions and procedures. In some countries, legislative approval is required for foreign exchange purchases. In addition, civil service regulations control salary levels, overtime work, and outside contracting, which limits the utility's ability to bid for the best talent and services.

Recent case studies in 17 developing countries determined the causes of poor power plant performance, measured the economic and financial costs of poor performance, and identified programs to address these problems. The following principal contributing factors were identified:

- lack of managerial autonomy for the utility;
- conflicting utility objectives, such as being required to earn a profit while providing power at subsidized rates;
- lack of utility management accountability;
- insufficient technical and managerial training;
- unavailability of internal utility resources;
- poor management quality;
- lack of financial transparency;
- insufficient revenues;
- lack of timely access to foreign exchange; and
- inappropriate donor policies and procedures of official financing agencies.


Box 8. Institutional Causes of Poor Power Plant Performance in Developing Countries

25. When public companies are plagued by excessive government and political intervention the almost inevitable results are low electric tariffs and maintenance neglect, financial restrictions, excessive staffing, drainage of qualified personnel away from the sector and inefficient operation of the equipment. The end result is degradation of facilities, deterioration of service, and mounting social and economic costs for the consumers.

26. Different approaches are currently being tried in the LAC countries to remove the managerial and institutional barriers. In Chile, the policy includes the decentralization or segmentation of the sector into smaller units concerned with only one component of the electric system: generation, transmission, or distribution. It also includes the independence of the utilities from government intervention, the application of efficient tariffs related to marginal costs at generation, transmission, and distribution levels. In Colombia and Venezuela, major restructuring efforts are under way to induce competition and private sector participation in generation and distribution.
27. Performance contracts are being examined in Bolivia and Panama. The goal of the contracts is to raise overall efficiency by providing the power companies more management freedom and corporate independence. A performance contract is signed between the government and the public utility, where pecuniary incentives are established if the utility achieves the agreed goals. Agreements are formalized to give the utility flexibility in acquiring goods, contracting services and managing its salary levels.

28. An alternative approach is to establish contract plans with private companies. These contracts would help to remove some of the institutional barriers to efficiency, specially when maintenance is hampered by foreign exchange restrictions, funding constraints and shortage of qualified personnel. Private contractors can overcome, better than a public utility, the foreign exchange restrictions, and get in a timely manner spare parts and/or trained personnel. The contractor provides the utility the necessary equipment or services to reduce costs or to increase revenue, typically, a loss reduction program, generation efficiency improvements or increased availability program. In return, the utility agrees to pay the contractor an amount equal to a fraction of the net gains achieved (Yates 1988). This approach has yet to be tried to improve the performance of the power sector in a developing country.

29. Power sector utilities must be granted increased autonomy. The necessary actions should include: (a) limit the relations of the utilities to one or two government entities; (b) establish expenditure and investment approval procedures equivalent to those of the private sector; (c) ease access to foreign exchange; (d) apply electric tariffs related to forward marginal costs considering financial restrictions, to promote an efficient allocation of resources, to allow a financial margin and the generation of funds for new investment; (e) establish a sound adjustment mechanism of tariffs to maintain real value in the presence of cost inflation; (f) allow the public power sector to set competitive salary levels in order to attract and retain qualified staff (Saunders and Jechoute 1985).

Labor Training

30. The critical issue for ensuring availability of qualified personnel for proper O&M is the civil-service constraint on salary levels paid by public utilities. Where such constraints seriously impair hiring and retention of qualified personnel, utilities should be granted flexibility in setting competitive salaries, pecuniary incentives, and performance evaluation procedures. LAC countries with smaller and less developed power sectors and labor pools also may require training programs to upgrade the skills of maintenance crews and specialists, and improved investment planning to identify robust economic solutions that consider potential maintenance risks.
Private Sector Participation

31. In the quest for improved services and cost effectiveness of O&M, it is important to dispel apprehensions that might be in the minds of the public and sector officials about private sector ownership in the power sector. The experience in many countries such as Spain, United States, Great Britain, New Zealand and in the LAC Region, notably Chile, clearly shows that this participation can be productive and effective. In these countries private firms have demonstrated that they can provide many services more efficiently than public utilities, because of their better management, greater flexibility and accountability, and stronger ability to retain more skilled personnel.

32. Many of the power sectors in the LAC region operate under institutional frameworks that originated when the government was considered an optimal vehicle for pursuing social and economic development. At present, however, governments are considered best suited to this role only when the private sector does not choose to take the lead. Typically, governments are concentrating on their inherent role of policymaker.

33. The private sector can also participate in the maintenance of the power sector by bidding for maintenance, specially in the case of major overhauls of generating units. The private sector can also provide additional financial resources if a clear legal framework exists to facilitate it. The productive participation of private sector financing in the power sector—particularly as it transpired in the UK and Spain—should be emulated in LAC. However, the institutional frameworks need updating to mobilize the managerial and financial capabilities of the private sector.

34. Box 9 highlights several activities of a utility that are amenable to private sector participation. In fact, it is quite common for collection to be carried out through private sector banks. Again, provided these activities are contracted through competitive bidding, they should be beneficial to the utility. Except in the poorest LAC countries it is unlikely that the local private sector does not have the necessary expertise and the tools (hardware and software) for the job. It might also be that in these cases the magnitude of the task, and therefore the rewards, are too small to interest an international company. It is also very clear that the key activity of disconnecting those clients that do not pay in time (especially the administration), cannot easily be transferred to the contractor. The social and political price of disconnecting non-payers is normally incommensurate with the expected profit, although this is the key to reducing accounts receivable.

35. An O&M service contract with the private sector can of course include a loss-reduction program, generation efficiency improvements, an increased availability program, and so on. A service contract requires supervision by well-trained staff to solve in a the timely manner the problems that may arise
in performing the obligations under the contract. Timely payment of contract obligations is paramount to a successful contract.

36. The precondition for success for any of the available institutional options in LAC is political will. Performance-based contracts appear to be needed to advance the utility to the point where private sector participation might become a viable option. The achievement of a minimum level of performance is required by the utility and a minimum set of conditions to be fulfilled by the country, before the private sector develops the necessary confidence to participate in the above mentioned schemes. Paradoxically, that threshold might require that an adequate tariff level, as well as a suitable billing and accounting system be in place and that the utility generate and collect enough funds to cover its costs. Without this, no reasonable participation will be obtained from the private sector. Indeed, even when these conditions are met, an escrow account might be needed to guarantee payment and attract the private sector. At the country level, a fair regulatory system, a bona fide process for settling differences and a mechanism that allows access to foreign exchange are also needed. Some utilities in particular bad shape will need to cross the performance threshold through performance related contracts with other utilities and/or consulting firms. The Bank and other donors can provide assistance in establishing a trustworthy regulatory system and in addressing the foreign exchange problem. Finally, an arbitration procedure in a neutral country might be necessary in order to provide a credible process for resolving disagreements. However, political will is also the precondition for a successful participation of the private sector.

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<th>Box 9: Areas for Effective Private Sector Participation in Power Sector O&amp;M</th>
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<td>- Collection of service payments</td>
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<td>- Maintenance and repairs of equipment</td>
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<td>- Maintenance and repairs of distribution grid</td>
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<td>- Maintenance and repair of house connections</td>
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<td>- Data processing centers</td>
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</table>
1.1 The electricity supply industry is very important in all LAC countries. Installed generating capacity in 1989 LAC amounted to 140 GW, representing about US$168 billions at replacement value, and about twice that much when considering transmission and distribution facilities. About 295 million people in 1989—out of a population of 420 million in the region—had access to electricity. These levels are still far below those of developed countries. If the same current 70% coverage level is maintained throughout the decade, by 1999 around 12 million new residential customers will have to be connected. The investments required for this exclusive purpose would be about US$62 billion. However, if service coverage is to increase to around 80%, close to 23 million new residential customers would have to be connected, and the corresponding investments would be about US$120 billion. Thus, the challenge ahead is great for the utilities and governments of the region.

1.2 Maintenance of the power sector infrastructure is generally understood as crucial for an economic and reliable supply of power and to save scarce investment resources. The importance of an economic and reliable supply of power for economic growth is generally accepted, but the nature of its influence needs to be examined. This study sought to explore the relationship between the power sector and the macroeconomy and to examine the consequences of uneconomic and unreliable supply of power. The study emphasizes the crucial role of adequate upkeep of the power infrastructure in providing an economic and reliable supply of electricity for economic recovery and in sustaining growth and promoting awareness of the dangers of undermining the power sector's capacity to operate and expand efficiently.

ENERGY, ELECTRICITY, AND ECONOMIC GROWTH

1.3 That there is a relationship between the power sector and economic growth is generally taken for granted, but the importance of that relationship in developing economies is often understated. The present examination suggests three important conclusions that reemphasize the relationship: First, in developing economies, the use of electricity in comparison with other energy sources is growing with economic growth. Second, electricity demand has grown even during macroeconomic downturns; and third, in the LAC region in particular, economic and reliable supplies of electric power are fundamental to regaining and sustaining competitive growth.

1.4 The performance of the economy has a predominant influence on energy consumption. When the economy grows, commercial energy consumption also grows. Concomitantly, when the economy shrinks or slows down, total energy consumption follows it closely. The energy consumption model is explained by incomes, population, energy prices, and by the stock of energy-using equipment, weather, tastes, and other variables. To simplify the analysis and provide a
general idea of the relationship between the energy sector, the power subsector, and the economy, we have estimated a reduced form of the above model. Through a regression analysis, two curves were estimated between GDP per capita—as a proxy for the physical well-being of the population—and, on the one hand, commercial energy consumption per capita (first curve) and, on the other, electricity per capita (second curve). Estimation of the two curves allows for comparative analysis of any significant behavioral changes in demand. The data corresponds to 1988 for a representative sample of 50 countries throughout the world, including 21 LAC countries (World Bank 1990).

1.5 The results indicate that as income per capita grows, per capita consumption of energy also increases, albeit at a lower pace than the former. The estimated elasticity of 0.84 between commercial energy consumption and GDP—both in per capita terms—is very significant. This is compatible with the facts that the stock of energy-using equipment and appliances can only vary in the long run and that each generation of equipment tends to be more energy efficient than the previous. The income elasticity for electricity consumption, using the same countries in the sample, is somewhat higher (0.96). Underlying this higher elasticity value might be the higher user value of electricity—along with natural gas—in developed countries relative to other fuels in the energy mix.

1.6 The same approach for LAC produces even higher income elasticity values. Using the 21 LAC countries in the sample, the income elasticity for energy is 1.61, which suggests that energy is more responsive to economic growth in less developed countries. The income elasticity for electricity demand is 1.51, which is higher than the previous estimate for the 50 countries worldwide, but lower than the estimate for energy. This is explained in part by the fact that the greater the degree of development the more important a reliable supply of electricity is, and because power supply in LAC may not be as reliable as the levels prevailing in developed countries. (This observation is also based on the fact that outage levels are higher in LAC countries than in developed countries). Another explanation is that the elasticity results for total energy may be biased by not considering the traditional energy forms in developing countries.

1.7 Figure 1 shows the relationship between energy consumption per capita and GDP per capita for the countries in the sample and the estimated regression

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3. The term elasticity refers to the proportional change in the dependent variable over the proportional change of the independent variable. It can be applied to any set of variables. In this document we refer to various types of elasticities, such as the income elasticity of energy consumption (the proportional change of energy consumption to the proportional change in income) and the GDP elasticity of the electricity coefficient (the proportional change of the electricity coefficient to the proportional change in GDP).
line. Countries with a high share for the services sector in their GDP formation, such as Italy and Switzerland, are outliers below the regression line, whereas those with a high industrial share, such as Norway, are above the line. Another factor at play is the availability of cheap energy resources. Thus, Japan with high levels of industrialization and without indigenous energy resources is highly energy efficient and, thus, below the regression line. LAC countries also fall in this pattern. Trinidad and Tobago, Venezuela, and Argentina, which have high GDP per capita (US$3,667, US$3,391, and US$2,522, respectively), also have high energy consumption per capita (5,255, 2,354, and 1,523 kg of oil equivalent, respectively), whereas Haiti, Bolivia, and Guatemala, which have lower income per capita (US$397, US$625, and US$931, respectively), also have lower energy consumption per capita (57; 249, and 168 kg oil equivalent, respectively).

Box 10: Sources of Economic Growth

The process of economic growth can be described in many ways. However, common to all definitions is that economic growth entails a sustained increase of incomes and outputs over time. Thus, economic growth can be brought about by:

- augmenting or improving the capital stock;
- enhancing the productive abilities of the population, and
- straightforward productivity gains.

Productivity growth results from the substitution of an expensive input for a lower-cost one and by technological change. The historical record shows that technical change tends in the direction of energy intensive and electricity intensive technologies. Thus, countries at a more advanced stage of economic development tend to have higher levels of energy as well as of electricity consumption.

Figure 1
1.8 As a general rule, total commercial energy consumption in lower-income countries grows faster than the economy, whereas the opposite is true for high-income countries. The rate of growth of energy consumption in developed countries, both in the 1970s and the 1980s, was lower than the rate of growth of GDP. In the case of the LAC countries taken as a group, energy consumption grew faster than GDP. There are several reasons that explain this behavior, among which the most important is that high-income countries tend to consume energy more efficiently than less developed countries (i.e., less energy per unit of output, generally because of a continuous shift to energy-intensive industries and better conservation, coupled with pricing policies based on economic costs).

1.9 Table 1 shows that electricity consumption in LAC has grown consistently faster than GDP. Based on the evidence, it can be concluded that (a) economic growth must be accompanied by an increasingly economic and reliable supply of electricity; (b) electricity tends to grow faster than other forms of energy; and (c) electricity demand grows even during periods of macroeconomic deterioration.

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<td>0.8%</td>
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<td>kWh per capita</td>
<td>7.3%</td>
<td>7.7%</td>
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1.10 Figure 2 shows the relationship between electricity consumption per capita and GDP per capita. The points above the regression line are countries with strong industrial sectors, particularly those dominated by high-electricity-intensity industries such as aluminum and paper. For example, among developed countries are Norway, Sweden, and the United States; among the middle-income countries are Yugoslavia, South Africa, and Venezuela; among the developing countries are China and India. The points below the regression line are countries with predominant services and primary sector activities: Switzerland and Italy among the developed countries; Bolivia and Guatemala among the developing countries, with Haiti as a significant outlier.

1.11 Twelve countries in LAC are below the regression line (Bolivia, Ecuador, El Salvador, Guatemala, Haiti, Honduras, Jamaica, Mexico, Nicaragua, Panama, Paraguay, and Peru), and nine are above it (Argentina, Brazil, Chile, Colombia, Costa Rica, the Dominican Republic, Trinidad and Tobago, Uruguay, and Venezuela). This grouping reflects the approximate division of LAC countries into industry-oriented and service- or agriculture-oriented countries. Because most of the LAC countries fall on the lower left of the graph, it is evident that electricity supply in the region is likely to increase with economic growth toward levels comparable with those of developed countries.
ENERGY AND ELECTRICITY INTENSITIES

1.12 As Figure 3 shows, the energy coefficient (energy/GDP ratio) tends to decline with development. This means that the incremental energy-GDP ratio declines with increases in income per capita. The analysis confirms this point. Based on the same 1988 data for the 50 countries, we found a negative elasticity of the energy coefficient to per capita GDP of -0.16, which implies that the higher the level of income per capita in the country, the higher the efficiency in the use of energy.

1.13 The energy coefficient for the LAC region during the same year is positive 0.62, which means that there is great scope to improve energy conservation and efficiency in consumption. Implicit in the above results is the fact that energy prices in LAC have been on average below their opportunity costs, while energy prices in the developed countries in the sample are more in line with opportunity costs.
Sound energy pricing is thus important, not only to promote efficiency on the supply side but to foster energy conservation on the demand side.

1.14 Figure 4 shows the electricity coefficients for 1989 for the LAC countries along with the estimated regression line. The countries above the regression line combine two features: low electricity prices (low energy conservation) and a larger industrial share of GDP. For instance, Venezuela (above the regression line) is less efficient in the use of electricity and has lower tariff rates than Mexico (below the line).

![ELECTRICITY INTENSITY AND GDP](image)

**Figure 4**

**EVOLUTION AND PROSPECTS OF ELECTRICITY CONSUMPTION**

1.15 As we have seen, there is a strong association between electricity consumption and economic growth. The official demand projections for the region, as prepared by the individual countries, are on the conservative side when compared to the historical record. Total electricity sales for the region are forecast to increase from 466 GWh in 1990 to 823 GWh in 1999, implying a demand growth of 6.5% p.a. However, if the same relationship between GDP and consumption during the 70s and the 80s holds during the 90s, this forecast would mean a GDP growth of only 2.3% per year during the same period. Even when accounting for energy conservation, the forecast growth in electricity demand is too conservative. Using the World Bank GDP forecast for the region of 4.2% p.a., and assuming the same relationship between economic growth and power demand as in the past, electricity sales would grow by about 8% per annum.
1.16 Up to now we have only compared different countries at the same moment in time. In this section we examine the evolution through time of these relationships based on regression analysis on time-series data for 27 LAC countries from 1971 to 1989 (the data was not available for Cuba, Grenada, and St. Lucia). The data includes GDP (in constant prices of 1989) and electricity consumption. To account for movement in other explanatory variables, the equations used in the analysis incorporate a time trend variable.

1.17 The results show that as GDP grows, so does electricity demand. The countries with higher levels of GDP per capita require higher levels of per capita electricity consumption. A significant elasticity of electricity consumption to GDP of 0.78 was detected for LAC as a whole. Furthermore, since the time-trend variable T is significant, we can conclude that electricity consumption has grown due to the action of the other explanatory variables—at an average annual growth rate of 5 percent.

1.18 The regression results for the individual LAC countries proved significant at the 99 percent confidence level for the 27 countries examined. Figure 5 presents a ranking by elasticities of the 27 LAC countries. Seven had elasticity values higher than or equal to unity. Haiti was the only significant outlier, at 2.60, and was excluded from the graph. Seven countries had elasticity values below 0.5. The elasticity values of the remaining 13 LAC countries clustered between 0.5 and unity. The estimated coefficient for the independent variable—electricity consumption—indicate that the elasticities of 20 countries were significant and higher than 0.5, which confirms—once we consider the positive time variable—that to guarantee continuous economic growth, the availability of electricity must grow at a higher rate.

### AVAILABILITY AND QUALITY OF SUPPLY

1.19 To effectively foster and support economic growth, electricity supply must be reliable and available at the lowest possible cost. Reliable components in the electric generation, transmission, and distribution systems are keys to assuring affordable and continuous service to the end-user, in particular because the ever-present threat of random outages means that utilities must have adequate margins of reserve capacity. If design and implementation of maintenance and
Increasing energy prices and curtailing the growth of energy inputs affect overall economic growth via two main channels. First, there is a direct effect associated with a decline in the supply of inputs. Suppose, for example, that gross output is produced with three factors of production, capital, labor, and energy under constant returns to scale. Capital and labor are primary factors, while energy is intermediate. We can decompose the rate of growth of gross output in the economy, \( q \), into a weighted average of the rates of growth of these three factor inputs, \( k, l, \) and \( e \) and, perhaps, an additional term for technical progress, \( m \), where the weights \( w_k, w_l, \) and \( w_e \) are the shares of capital, labor and energy in gross output (equal to the respective elasticities of output):

\[
q = w_k k + w_l l + w_e e + m.
\]

Reducing the growth of energy inputs by \( de \) reduces the rate of growth of output by \( w_e \, de \). Economies with high energy intensities (i.e., relatively large values of \( w_e \)), and/or with relatively high rates of energy input growth (i.e., relatively large negative \( de \)), other things being equal, will tend to suffer relatively large direct effects from curtailment of energy usage.

Factor share weights may shift as a response to more expensive or less reliable energy. The nature of the shift depends on the degree of substitutability between capital, labor and energy. At one extreme, suppose that substitution is impossible. Then the share of the fastest growing input would drop to zero, and output would grow at the slower of the two rates—presumably the energy input growth rate—plus the rate of technical change. At the other extreme of perfect substitutability, the share of the slowest growing input would decline to zero and long-run output growth would be unaffected.

Another avenue in which growth may be affected is through induced changes in the rates of growth of other inputs. One way is when capital and energy are complements. Thus, reduced energy inputs lower the return to capital which, if saving and investment are sensitive to returns, would lower saving and investment growth. Another way is redistribution of income among groups with different saving propensities could also affect saving and investment, as could changes in the terms of trade associated with fuel price changes. The direction and size of these effects depend on the structure of the economy. Recent research also raises the possibility that increases in energy prices cause lower rates of productivity growth (i.e., a decrease in \( m \)).

Box 11: Growth Effects of Declining Energy Usage

repair policies are not up to standard, the need for adequate reserve capacity may require further investments in new capacity. But it is substantially more costly to add new capacity than to maintain existing capacity: in fact, adding only 10 MW of new capacity is more costly than maintaining 10,000 MW of existing capacity.

1.20 Utilities much reach a balance between the cost of electricity, reliability of supply, and levels of expenditures for maintenance. As components in the electric system deteriorate with use and the simple passage of time, additional spending on maintenance is needed. Postponing such expenditures, although sometimes tempting as a cost-saving measure, leads to problems of availability and reliability and then forces building of an additional margin of capacity to maintain the quality and continuity of the supply of electricity to end-users. Considering the premium on building new capacity, deferrals of needed
maintenance raise the cost of electricity and damage the competitive base of the economy.

1.21 Among the conditions necessary to achieve an economic supply of electricity are (a) high availability of the least-cost plants so that they can operate most of the time; (b) efficient conversion of hydrocarbon fuels into electricity (low heat rate); and (c) control of electricity losses (both technical and nontechnical).

1.22 An unreliable supply of electricity results in short-run economic losses when production (or consumption) processes must be interrupted or postponed. Medium-term losses occur when users install equipment to provide emergency power supply, to continue producing during power shortages. Neglect in maintenance not only reduces the reliability of the system components but also (a) reduces the amount of the installed capacity available for operation; (b) reduces thermal efficiency in generation; (c) increases losses in transmission and distribution; and (e) reduces reliability of supply.

1.23 The electric utilities then face a number of trade-offs: capacity additions (in generation, transmission, and distribution); maintenance and rehabilitation of the equipment (to enhance its reliability and efficiency); conservation and load management (increase the load factor, loss reduction, etc.). Efficient corporate policies consist of allocating resources and efforts in the areas of maximum benefits per dollar of expenditure until the marginal benefit in the alternative allocations is the same. However, the only efficient implementation of corporate policies is under an institutional framework of autonomy, competition, commercial regulation, and adequate pricing.
II. STATUS OF THE POWER SECTOR INFRASTRUCTURE IN LAC

2.1 Six countries (Brazil, Mexico, Venezuela, Argentina, Colombia, and Chile) account for 91.3 percent of total electricity consumption in the LAC region. The largest electric system is Brazil’s, with 44.5 percent of total electricity supply in the region. The remaining 21 countries with small- and medium-sized electric systems account for 8.7 percent of the region’s consumption.

2.2 Given the differences between LAC countries, it is difficult and risky to make sweeping generalizations about the conditions of electricity sectors and the quality of services. In addition, statistics on reliability and maintenance levels of the power sectors are available here only for the countries in our sample: Argentina, Bolivia, Chile, Guyana, Honduras, Jamaica, and Venezuela. Nevertheless, cross-country comparisons are needed to appreciate the relevance of particular issues. Thus, with consciousness of the data limitations, this chapter attempts to describe the conditions of the power sectors in the LAC countries.

THE POWER SECTORS IN LAC

2.3 The greater the industrialization, the more important it becomes to ensure economic and reliable supplies of energy: economic to support competition, and reliable to provide the continuous supply of ancillary services (telecommunications, banking, etc.) and to avoid outages and productivity losses. Hence, the more industrialized a country, the more it needs to prevent deterioration of its power sector infrastructure. Similarly, the larger the thermal share in generation, the more important it becomes to ensure adequate maintenance to prevent higher fuel consumption, forced outages, decline in available capacity, and decrease in the useful life of the plant. Hydro plants also require maintenance, of course, but the requirements are not as large.

2.4 The continuously growing demand for electricity in LAC has resulted in increases of slightly more than four times the total electricity requirements since 1970. The sheer size of the growth in demand provides an idea of the magnitude of the effort made by the countries in LAC to provide electricity in support of the region’s economic development, particularly the investment resources required to build the electricity supply facilities. Given the scarcity of capital and the intensity of electricity supply, adequate maintenance is fundamental to derive the maximum benefit from these installations.

Electricity Uses and Sources

2.5 Electricity production in LAC increased from 1971 to 1989 at 8.1 percent annually, from 134 TWh in 1971 to 541 TWh in 1989, and electricity sales increased at the slightly lower annual rate of 8.0 percent, from 113 TWh
to 449 TWh. The difference between these rates is explained by the rapid increase in electricity losses, from 19 TWh to 81 TWh, an 8.5 percent annual increase on average. In the late 1980s, the composition of electricity use was, on average, 20 percent residential sales, 9 percent commercial sales, 43 percent industrial sales, 1 percent bulk sales, 11 percent other sales, and 16 percent losses and own consumption.

2.6 The evolution of the structure of electricity supply in the region shows the rapid growth of hydroelectricity during the last two decades (see Figure 6). The amount of hydro generation increased by 8.6 percent annually, from 82 TWh in 1971 to 364 TWh in 1989. Thermal generation, on the other hand, increased only by 6.3 percent annually, from 52 TWh to 156 TWh.

2.7 Maintenance requirements are higher in thermal than hydro-based systems. The LAC region is fortunate in that regard, because overall supply is predominantly hydro. The structure of electricity supply in the late 1980s was 68 percent hydro, 27 percent thermal, 1 percent geothermal, 1 percent nuclear, 2 percent other, and 1 percent purchases. The predominance of hydro resources helped the sector to reduce fuel consumption (one of the objectives of the policy of energy self-reliance) but increased capital investments (one of the reasons for the funding problems of the sector). The countries with the highest share of hydro generation are Paraguay (100 percent, including Itaipu); Honduras (98 percent); Brazil (96 percent, including Itaipu); Guatemala (94 percent); Peru (92 percent); and Costa Rica (89 percent). Some countries in LAC showed substantial increases in their hydro share: Argentina (8 percent in 1971 and 45 percent in 1987); Ecuador (42 percent in 1971 to 86 percent in 1988); and Guatemala (19 percent in 1977 and 94 percent in 1989). Mexico behaved differently, as hydro generation declined from 50 percent in 1971 to 22 percent in 1989 because of the availability of cheap oil and the unavailability of new and viable hydro sites.

**Installed and Available Capacity**

2.8 The power sectors of LAC experienced a rapid increase in generating capacity from 1971 to the present (see Figure 7). However, the availability of that capacity has decreased during the same period. The main reasons for the decrease have been poor operating practices and neglect of maintenance.
2.9 There is insufficient hard data to provide accurate statistics on available capacity. However, the availability of installed capacity appears to have declined from the beginning of the decade to about 80 percent today. For example, the installed thermal power generation capacity in Costa Rica totals 144 MW, but the maximum available capacity varies between 50 and 70 MW. The Dominican Republic provides another example. In 1987 the installed thermal capacity was 823 MW of which only 356 MW were effectively available (Figure 8).

2.10 A manifestation of an improvement in the use of installed capacity occurs when installed capacity grows less than electricity demand. Installed generating capacity grew at an 8.4 percent annual average, going from 33 GW in 1971 to 140 GW in 1989. During the same period, installed hydro capacity increased at an annual average of 9.2 percent, from 19 GW to 93 GW, and installed thermal capacity at 6.3 percent, from 14 GW to 42 GW. In LAC, although there has been no deterioration in the load factor, and hydro regulated capacity has increased during this period, installed capacity has outgrown (4.2 times from 1971 to 1989) total electricity production (4 times since 1971), which suggests a deterioration in the availability of existing capacity, reflecting the need for substantial improvement.

2.11 In the late 1980s, the average composition of installed capacity (see Figure 7) was 65 percent hydro, 32 percent thermal, and 3 percent other. In 1988, Brazil (41,700 MW), Mexico (23,912 MW), Argentina (14,642 MW), and Venezuela (16,861 MW) accounted for around 75 percent of the region’s installed capacity, and these four countries together with Chile (3,075 MW), Colombia (7,394 MW), and Peru (2,808 MW) accounted for about 85 percent of the region’s public service installed capacity. The countries with the largest share for hydro installed capacity were Paraguay (98 percent), Brazil (89 percent), Costa Rica (83 percent), Honduras (74 percent), Peru (74 percent), and Colombia (74 percent). In many of these countries, the share for hydro increased substantially: In Paraguay, from 70 percent in 1980, and in Honduras, from 60 percent in 1971. However, in Peru, it decreased from 80 percent in 1980.
In Dominican Republic, there is enough installed capacity to satisfy maximum system demand. However, in practice—because of high forced outages and low availability—there is insufficient capacity to satisfy demand all of the time, leading to huge energy deficits. Of the 823 MW of thermal capacity in 1987, only 72 percent was in working conditions and available for only 60 percent of the time, given an effective available capacity of 356 MW. The generating capacity of the public utility CDEE (Corporación Dominicana de Electricidad) amounted to 1,029 MW in 1987, of which 823 MW corresponds to a total of 30 thermal units concentrated in 12 plants. Five of these units had more than 20 years of use, 18 had between 10 and 20 years of use, and only 7 had fewer than 10 years of operation. The large number and variety of small plants, together with the poor operating practices, fuel problems, insufficient maintenance, and improper maintenance procedures, has meant that several plants are out of operation and others cannot reach nameplate capacity and efficiency.

Figure 8

Electrification

2.12 One of the reasons for the significant growth of electricity demand has been the increase in the rate of electrification (or electricity service coverage). Regardless of the degree of development, electrification rates have increased substantially in most LAC countries during the last two decades. Electricity coverage in Mexico increased from 50% in 1971 to 86% in the late 1980s, in Bolivia, it went from 15% to 29%. For the region as a whole, the electrification rate went from 42 percent in 1971 to 70 percent in 1989 (see Figure 9). The population with electricity increased at 5.3 percent annually, from 117 million to 295 million, while the total population increased at a 2.3 percent annual average, from about 279 million to 420 million. Between 1971 and 1989, the number of total customers almost tripled (2.8 times), from 25 million to 70 million, residential users accounted for most of the increase, from 21 million to 60 million.
2.13 As a rule, the more developed a country, the higher the level of electricity coverage; whereas the poorer the country, the lower the coverage. This association can be seen in Figure 10, where the rates of electrification in the LAC countries are ranked according to level of income per capita. Some of the exceptions are Brazil and Panama, with lower electrification rates relative to their per capita income levels.

2.14 The analysis points out that GDP size is more relevant than population for the level of service coverage. More developed countries have higher electrification rates than developing countries. Thus, the GDP elasticity of service coverage (the proportional change in service coverage to the proportional change in GDP) was estimated from a cross-section analysis of LAC countries for 1971, 1980, and 1989. The results indicate that this GDP elasticity of service coverage declined from 0.78 in 1971 to 0.66 in 1980 and 0.63 in 1989, meaning that as the size of the economy grows, service coverage increases also but at a declining pace. Another reason for the decline in the elasticities of service coverage was the progressive macroeconomic deterioration experienced by the LAC countries from the 1970s to the 1980s.

4. A regression between electrification rates for 24 LAC countries and their per capita income levels verifies this point. The value of the regression coefficient (elasticity value) was significant. The regression gave the following equation:

\[
\ln ER89 = -6.19 + 0.57 \ln GDPPC
\]

\(R^2 = 0.42\) \(F = 17.89\) \(DW = 1.94\)

where \(ER89\) stands for electrification rate in 1989.
COSTS OF MAINTENANCE NEGLECT

2.15 Inadequate maintenance leads to the deterioration of the electricity supply infrastructure, which in turn affects the utilities and consumers. To determine the status of the infrastructure of the power sector, it would have been useful to have data on equipment availability, maintenance needs, energy not delivered, and energy rationed because of lower availability and equipment outages. These figures were available for only four countries in LAC, however.

2.16 On the supply side, the costs of the neglect in maintenance are (a) additional variable operating costs caused by inferior thermal efficiency (higher fuel consumption for electricity generation) and lower available capacity; (b) higher investment requirements to compensate for the decline in availability of existing capacity and in their lives; (c) higher generation costs and income not collected by the utilities because of excessive losses; and (d) excessive pollution loads on the environment due to lower thermal heat rates, higher electricity losses leading to higher generation requirements, and inferior service reliability leading to higher autogeneration.

2.17 On the demand side, the deterioration of the power infrastructure results in substantial costs to the users of the service. These costs can have the form of productivity losses caused by sudden power interruptions and/or voltage or frequency drops. Or, industrial or commercial users may invest and spend in operating expenditures on emergency supply equipment to guarantee the timely availability of adequate amounts of electricity or equipment to control the quality of electricity supplied. Households and small businesses experience costs associated with leisure or time lost and the shorter economic life of appliances attributable to outages and frequency or voltage variations.

Availability

2.18 Most thermal plants in LAC countries operate below their design capacities and efficiency levels. In addition, the proportion of plant downtime is significantly greater than in most industrialized countries. In some LAC countries, plants cannot be operated at more than 80 percent of their rated capacities. The availability of many thermal power plants averages less than 60 percent, compared with an industry standard of over 85 percent in industrialized countries.

2.19 Typical heat rates for thermal plants in LAC countries often exceed 13,000 BTU of fuel per kWh of output, compared with 9,000 to 11,000 BTU per kWh for efficient plants. Heat rates declined from design ratings as a result of inadequate maintenance and improper plant operation, delays in correcting minor plant defects have increased the likelihood of breakdowns between scheduled maintenance work.
Failure to consider in the investment decision the risks of importing materials, spare parts, technical services and maintenance equipment can lead to a false sense of reliance on the proposed equipment, equipment which will not be properly maintained and that soon will fall into disrepair.

Dominican Republic has suffered from low availability of generating facilities for most of the 1980s. This low availability is consequence of several factors, among which the diversity of the generating plants is an important culprit. There are several different types of plants (fuel oil fired; coal fired; gas turbines; internal combustion diesel units, and slow speed diesel); fifteen out of twenty thermal units are more than twelve years of age (based on 1987 data). Foreign exchange shortages reduce the availability of spare parts for preventive maintenance and repairs.

In general the following relationships hold:

- The higher the number of plant types, the larger the stock of spare parts and the technical services needed for timely and proper maintenance and repairs.
- The higher the generating diversity, the higher the O&M budget required.

Box 13: Generation Investment Should Consider O&M Risks and Requirements

2.20 Equipment availability depends on technology, age, operating conditions, and availability of spare parts. Thermal generation plants are usually the most critical element in an electric system in regard to availability, so that adequate maintenance is fundamental in power sectors with a predominant thermal share. Age of equipment is important too; availability declines with wear and tear and the passage of time. Power infrastructures in LAC aged rapidly during the 1980s because of funding shortages. In Argentina, for example, 11 percent of existing substations and 15 percent of all transformers have more than 30 years of service. The average age of generating plants in Argentina is 14.3 years, of substations 15.6 years, and of transmission lines (500 kV) 9 years.5

2.21 The conditions in the sample of six LAC countries are heterogeneous. Unusually low availability values for thermal generating equipment are present in Argentina, Jamaica, and Guyana. Honduras and Venezuela also show low availability levels of thermal equipment; the only difference is that in these two countries it does not constitute a critical factor given their excess capacity, mainly in hydroelectric plants. Only Chile presents a good record of availability, above 85 percent for thermal and 97 percent for hydroelectric plants. The distribution systems of Argentina, Honduras, Jamaica, and Guyana were found in poor operating condition; those of Chile and Venezuela were in better condition.

2.22 Because of poor plant availabilities, data on total installed generating capacity can be a highly misleading indicator of actual capability in some

5. Figures weighted by MW for generation, MVA for substations, and km for transmission lines.
countries. In several countries the installed capacity is considerably higher than maximum demand. The difference is not unused capacity, but just an apparent margin of reserve. The real margin of reserve—or excess capacity—is the difference between the available capacity and demand (see Figure 11).

2.23 The amount of system reserve required may be as low as 10 percent, on a multiplant all-hydro system with huge storage reservoirs, or as high as 100 percent on a small diesel system, where allowance has to be made for one unit to be out of service at any time. When plant availability is low because of poor upkeep of facilities, extra generating capacity is required to maintain deliverability of supply. In well-managed systems, a 20 to 30 percent reserve margin is more the rule than the exception. Higher margins are justified in some cases by seasonal, hydrologic or temperature conditions.

2.24 Several countries in LAC suffer from low utilization of their power production facilities caused by maintenance neglect. For example, the average reserve margin from 1987 to 1989 was higher than 50 percent for the LAC countries as a group, which is not serious considering the predominant share of hydro capacity in the region. However, the margins of reserves of several individual countries with predominantly thermal generation (more than half) were above 80 percent—Jamaica, Argentina, Guyana, and Trinidad-Tobago—which is significant.

2.25 Providing proper O&M in LAC costs less than 2 percent of investment requirements, US$24 per kW or 0.6¢ per kWh. Because investment in capacity expansion generally costs about $1,200 in LAC, and excess capacity is about 14
percent of installed capacity, there is an over-investment of $168 per kW of peak load, or about 4.4¢/kWh of electricity generated.

2.26 Adequate maintenance is a sound economic proposition and provides a higher return than adding new generating capacity. Ironically, the IDB and the World Bank probably contributed to the excess capacity in the power infrastructure of LAC countries because for many years borrowing for "recurrent costs and working capital," including foreign exchange for foreign spare parts and services, was not allowed.

Additional Generating Costs

2.27 The available data for LAC present wide variations in the costs of thermal generation. These differences are caused by (a) the different fuel compositions of the thermal capacity among LAC countries and (b) the fuel pricing distortions—many countries charge consumers less than the international opportunity cost. For example, the thermal generation cost is higher than US$60 per MWh in Brazil, Dominica, Costa Rica, and Honduras. Most other countries have generating costs between $20 and $60, whereas most oil-exporting countries in LAC have generating costs below $20. Figure 12 presents the ranking of countries by generating costs.

2.28 High heat rates of thermal generation equipment, unavailability of equipment, and excessive losses result in increased operating costs because of the additional generation required and the consumption of more expensive fuels. It is conservatively estimated that about 20 percent of the generating capacity in LAC is in need of rehabilitation because of maintenance neglect. Thermal generation costs in LAC are estimated at US$17 per MWh at domestic fuel prices, which can be reduced to a conservative figure of $14.50 per MWh with adequate upkeep—that is, a saving of US$365 million per year.6

6. No attempt was made to correct distorted domestic fuel prices for international prices.
Proper O&M increases the availability and reliability of existing generating capacity, reducing system reserve requirements. Improved O&M in LAC to increase unit availability and reduce the reserve margin to 30% could save US $26 million initially and about $5 billions annually after the fourth year in terms of future generating investment.

Electricity supply systems need a margin of generating capacity above the system's load to serve demand when some units are out of service due to scheduled maintenance or forced outages, or because demand underestimation, or due to variability in water stream-flows in hydro systems, etc. On well planned, operated and maintained systems the required system reserve is typically 20-30 percent above system's load.

The average reserve margin in LAC is more than 50%. Given the 1989 demand of 91 GW and an assumed 30% target reserve margin, there was an excess capacity margin of 22 GW. The average investment cost in generation in LAC is about $1,200 per kW of installed capacity, which would imply investment savings of $26 billions. The 22 GW of capacity would cover the forecast increment in demand for the next 3.6 years.

<table>
<thead>
<tr>
<th></th>
<th>1988</th>
<th>1989</th>
</tr>
</thead>
<tbody>
<tr>
<td>Generating Capacity (GW)</td>
<td>131</td>
<td>140</td>
</tr>
<tr>
<td>Demand (GW)</td>
<td>87</td>
<td>91</td>
</tr>
<tr>
<td>Generation (GWh)</td>
<td>510100</td>
<td>538724</td>
</tr>
<tr>
<td>System load factor (%)</td>
<td>44.4%</td>
<td>44.0%</td>
</tr>
<tr>
<td>Reserve Margin (%)</td>
<td>51.4%</td>
<td>54.2%</td>
</tr>
<tr>
<td>Reserve Margin (GW)</td>
<td>44</td>
<td>49</td>
</tr>
<tr>
<td>GW Savings with 30% Reserve Margin</td>
<td>19</td>
<td>22</td>
</tr>
<tr>
<td>Investment Savings (US$ billions)</td>
<td>22</td>
<td>26</td>
</tr>
<tr>
<td>Annual Savings after 1993 (US$ billions)</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Total O&amp;M cost (US$/MWh)</td>
<td>$22.92</td>
<td></td>
</tr>
<tr>
<td>Generating O&amp;M</td>
<td>$6.23</td>
<td></td>
</tr>
<tr>
<td>Transmission &amp; Distribution O&amp;M</td>
<td>$16.69</td>
<td></td>
</tr>
</tbody>
</table>

Box 15: Proper O&M Increases Availability of Existing Capacity and Reduces Reserve Requirements

Electricity Losses

2.29 Electricity losses are of two types: technical and nontechnical. Technical losses (TLs) consist of energy produced and lost through transmission, transformation, and distribution. All power systems, regardless of efficiency, have some TLs, which arise intrinsically from the resistance of conductors and equipment to electrical current. TLs represent added production costs to the utility. On the other hand, nontechnical losses (NTLs) consist of energy
consumed but not paid for. NTLs arise mainly from theft and fraud and, to a lesser extent, from uncalibrated and broken meters, errors and problems with meter reading, poor invoicing and collection, and so on. NTLs translate into less sales revenue to the utility.

Box 16 Considerable Savings due to proper O&M in Dominican Republic

2.30 Losses are caused not only by maintenance neglect but by design and operative problems, such as inadequate design of components, phase and equipment overloads, poor load dispatching, and insufficient conductor capacity. Losses from improper and insufficient maintenance are caused by insufficient clearing of trees from lines, deficient upkeep of transformers and system components, and uncalibrated and faulty meters. However, in practice, the consequences of poor operation are difficult to disentangle from those of inadequate maintenance. Thus, although operations and maintenance are distinctly different functions, they are closely interrelated; ultimately, failures in both areas are caused by poor management.

2.31 The electricity loss ratio (ELR) refers to total electricity losses relative to available electricity. This ratio is greater if the transmission and distribution systems are old and inefficient. It is estimated that losses in LAC during 1989 amounted to 81,042 GWh. Given an available supply of electricity of 541,392 GWh in the same year, the ELR was 15 percent. However, experience with many systems indicates that the TLs of an efficiently run system are between 7
and 10 percent of available energy. NTLs arise from theft, fraud, unregistered consumption, underreading, metering breakups, and errors. Although there are no comprehensive data for LAC countries, a conservative estimate would be 2.5 percent of NTLs and 2.5 percent of technical.

2.32 Figure 13 presents the evolution of the ELR (ratio of total electricity losses to available electricity) for the region, showing clear deterioration from 1980 onward. However, the loss ratio is biased by the weight of the big electricity producers in the region. Thus, we have also estimated and presented in the graph the simple average of the ELRs of the LAC countries. The picture is even more dramatic: the trend is erratic, and the deterioration begins as early as 1978.

2.33 The weighted ratio varies within a range of 12.5 percent to 15.0 percent for the entire 1971-89 period. However, for the individual LAC countries the data is more heterogeneous: twelve countries show an increasing tendency during the 1980-89 period, whereas only four countries—Chile, Dominica, St. Lucia, and St. Vincent—show the opposite tendency. The remaining countries show an erratic trend.

2.34 As Figure 14 shows, the loss ratios during 1989 were very heterogeneous for the LAC countries. Seven countries (Guyana, Haiti, Honduras, Panama, Colombia, Dominican Republic, and Paraguay) had losses above 20 percent. Although most developed countries have losses of less than 10 percent, only two LAC countries, Barbados and Costa Rica, had comparable figures.

2.35 Reducing technical losses requires replacement and rehabilitation investments and expenditures on maintenance to ensure the availability of proper capacity in the transmission and distribution networks and, of course, to sustain proper operating and maintenance practices. During the last two decades,

These TL are average figures for the whole system, which include urban and rural distribution grids. TLs in urban grids, with densely packed populations, are lower than in rural distribution grids with consumers dispersed over larger areas.
investment and maintenance expenditures in distribution in LAC have not been
commensurate with investments in generation. This imbalance was exacerbated
during the years of financial strain, because the reduced level of available
funding was oriented mostly toward completing ongoing generation projects, on
the principle that suspending them would be more costly to the economy. As
a result, the distribution infrastructures of many power sectors in LAC
deteriorated, diminishing their reliability and increasing their losses.

Power system losses in Colombia began
to increase dramatically in the late 1970s.
The ELR increased to 20 percent in 1980
and stayed above that value for the rest of
the decade. How did this come about?
The main reason for the rapid increase in
the ELR was the “nontechnical” losses.
Technical losses stayed roughly the same,
around 12 percent of net energy supply
during both periods, but NTLs increased
rapidly, from about 6 percent during the
1970s to double that during the 1980s.

Figure 15

2.36 The economic benefits of power loss reduction projects (PLRPs) for
technical losses are, first, a reduction in generation requirements, leading to
lower operating and expansion costs. Second, PLRPs improve and expand
available capacity, which in turn improves reliability of supply for existing
users. Third, the reduction of power losses releases capacity for new users who
previously could not be connected with a given standard of reliability. Fourth,
rehabilitation may reduce expenditures on maintenance and emergency repairs,
especially in old and deteriorated systems. Finally, reduced unit costs reflect
(vis-à-vis the without-project situation) greater investment resources, lower
tariffs, or both, resulting in an increase in supply and demand. It should be
pointed out that a number of the above-mentioned effects have significant
financial benefits for the power utility, either in the form of lower costs or
increased receipts. 8

2.37 Costs of repair and maintenance of distribution networks are a function of
age, operating practices, wear and tear, and previous neglect. Distribution
networks most in need of rehabilitation are generally old, designed according
to noneconomic criteria, use multiple nonstandardized technical specifications,

8. In an optimum pricing environment, all of the above economic benefits improve
the financial position of the utility. However, when tariffs are below marginal
costs, an increase in supply leads to added financial losses to the utility.
and are designed for smaller loads than those they are presently serving. In many cases, equipment, even though overworked, receives little or no maintenance and thus often breaks down. Conductors are also often overloaded and therefore overheat, becoming brittle and shatter-prone. Poles are neither uniform nor safe and very often consist merely of tall sticks, generally leaning and supported by cables. Many poles, located near public highways, are knocked over by vehicles. Hence, proper design of distribution grids can reduce operation and maintenance costs, in situations in which many of the expenditures are for repairs, because properly designed installations improve or avoid almost all of the above-mentioned problems.

2.38 Significant savings in investment for new generation plants can be obtained if electricity losses are reduced to technically acceptable levels. There is no reason why losses should not approach the 10 percent level typical of efficient systems, or even less, in some countries. A 5 percent reduction from the typical 15 percent level in LAC would mean about 27,070 GWh of electricity and about 5,618 MW of capacity. If we assume that half of the difference is attributable to technical losses (the remaining being nontechnical), the corresponding 2.5 percent would amount to 13,535 GWh of electricity and 2,809 MW of capacity. The investment costs in generation, transmission, and distribution saved by this loss reduction would amount to $6.2 billion valued at a conservative overall unit investment figure of $2,200 per kW. However, to estimate the annual savings—not only of investment but of operating costs—we can use the LRMC for LAC estimated at $68 per MWh. Thus, the annual savings from this loss reduction would be approximately US$920 million.

2.39 NTLs are a form of consumption that is not charged by the utility because of poor commercial practices. Thus, the reduction of NTLs constitutes a major objective for electrical utilities, because the utility has to generate more (which is costly) and receives less revenue. Nontechnical loss reduction projects (NTLRPs) vary according to the type of NTL. Hence, it is important to determine the origin of the losses to design optimum PLRPs. NTLs can stem from user frauds or from inefficiency of the utility. The primary fraudulent causes are illegal connections, tampered meters, deceitful underreporting of true
consumption by personnel of the utility, and resale to third-party users of energy by customers with fixed tariffs (no meter).

2.40 Utility inefficiency losses stem from technical imperfections in the meters or from management carelessness, inefficiency, or both. These include inaccurate estimation of consumption, defective meters, improper hookups to the grid or unsuited equipment for measuring the user loads, fixed-charge users who overconsume, nonmeasured public consumption (such as public lighting in several countries); inadequate billing and collection, and management system discrepancies in power generated, transformed, and recorded at consumption.

2.41 The greatest share of NTLs in LAC countries is from theft and fraud, which frequently account for three-quarters of NTLs. A common feature of NTLs is that the tariff on marginal consumption is zero, leading to excess demand.

2.42 The makeup of NTLRP varies along with the main type of NTL and the characteristics of the electricity supply system. Where theft is deep-rooted, more investment is needed in distribution equipment relative to expenditure on meter reading, billing, and collection.

2.43 When rising energy theft and fraud are not quickly controlled, the practice rapidly spreads and becomes socially acceptable. Fraud becomes a game in which everybody wants to participate, a politically acceptable way of subsidizing low-income groups, and a practice in which better-off users increasingly participate. In Dominican Republic advertisements in newspapers regularly offered illegal connections at modest rates during the late 1980s. Private sellers—illegally connected to the network—offer power at rates below official tariffs. Personnel for meter reading offer customers lower readings in exchange for gratuities. In Haiti, the local attitude—"volez l'Etat ce n'est pas
voler"—fosters illegal use of electricity. In such situations, eliminating fraud becomes unpopular and difficult, as normal administrative measures, police activities and disconnections of illegal users are rapidly outflanked by new forms of fraud and reconnections. Here, the cost of NTLRP is higher because expensive techniques are required to inhibit fraud, such as triphase cables and meters in strongboxes or mounted on posts.

2.44 There are two types of benefits of NTLRP: economic and financial. The economic benefit is the resource savings in generation, because a share of the energy previously consumed free will no longer have to be produced. Another economic benefit consists of the increase in willingness to pay (WTP) resulting from the reduction in tariffs or an improvement in long-term reliability. This is the case where existing users cross-subsidize unpaid consumption. Thus, the reduction in NTLs benefits the former by preventing unnecessarily high tariffs. Of course, there is a reduction of WTP for the consumers of the NTL. The financial benefit occurs when the utility covers part or all of the cost of NTL. Then, the improved financial position resulting from the loss reduction and the increase in sales revenue enables it to keep investment and maintenance work on schedule, thereby preventing unnecessary cost and tariff increases.

Reliability Costs

2.45 Two of the most relevant components of reliability of supply are protection from interruptions in service (power cuts) and from voltage and frequency variations. Maintenance neglect impairs the reliability of service, with consequent costs to the economy in terms of direct and indirect economic losses experienced by industrial, commercial, residential, and other users.

9. To steal from the State is not stealing.
2.46 The quality of supply depends on the security and homogeneity—lower voltage and frequency variations—of the kWh delivered. Reliability is high when the number of interruptions is low. Likewise, the fewer the variations in voltage, the greater the homogeneity of power supply. The unserved energy cost (UEC) is the cost to the economy of a reduction in the reliability of the supply. This cost has two components—direct and indirect. The direct component is measured in terms of what users suffer as a result of the interruption in supply. The indirect component involves the effects on the economy at large from the damage to consumers. In practice, a breakdown in supply affects not only users but other sectors of the economy through the multiplier effects of the reductions in incomes and outputs.

2.47 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 several studies, the UEC, 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. Naturally, UEC is not a constant figure. It varies according to the degree of development of the country; the stage of supply involved (generation, transmission, or distribution); the region (rural or urban); the type of users (energy-intensive industries, low-income households); the duration; the time the outage takes place; whether the outage is sudden or expected; the availability of substitutes (e.g., self-owned standby generation); and whether it takes the form of a power cut or a voltage variation. In estimated cost per kWh, the UEC 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 (see Sanghvi 1991). Table 2 presents estimates of the average outages cost by consumer types for three LAC countries.

Table 2: Outages Values 1989 US$/kWh

<table>
<thead>
<tr>
<th>Type</th>
<th>Argentina</th>
<th>Dom. Rep.</th>
<th>Brazil</th>
</tr>
</thead>
<tbody>
<tr>
<td>Residential</td>
<td>1.30</td>
<td>0.40</td>
<td>1.40</td>
</tr>
<tr>
<td>Industrial</td>
<td>5.33</td>
<td>2.50</td>
<td>5.00</td>
</tr>
<tr>
<td>Commercial</td>
<td>0.50</td>
<td>0.40</td>
<td>2.00</td>
</tr>
</tbody>
</table>

Sources: IDB, Various economic analysis; AR-0205, DR-0117, BR-0308.

2.48 The forced shutdowns of generating plants last longer than transmission or distribution equipment outages. The frequency of outages in distribution is higher than those in transmission or generation, however. The depth (i.e., the number of consumers affected) outages in generation is greater than in transmission and distribution. In general, the costs of supply interruptions to industrial users are generally higher than for residential users, and the UEC in high-income neighborhoods is higher than in low-income ones. An outage early in the morning is less damaging than one in the afternoon, when more users are consuming power. A power cut lasting a minute may be insignificant, but an hour's interruption may be very costly. A power failure generally occurs suddenly—when the maximum demand cannot be met because of lack of capacity—whereas an energy failure (e.g., caused by low water levels in the reservoirs) can be managed. When users are aware that an interruption is going to occur they make the necessary preparations and thereby minimize the impact. In other words, the cost to users of an unexpected interruption in supply is greater than that of an anticipated one. Similarly, the cost of a service interruption is greater than that of a voltage reduction, because in the first case, no energy is delivered, whereas in the second some is, even if less than normal.

2.49 It is estimated that up to 5 percent of total possible electricity consumption in LAC is not delivered because of power outages, a level that could be at least halved with adequate maintenance of existing supply infrastructure. This represents about 11 TWh of unserved energy or some $580 million of lost sales revenue per year for the power utilities and at least 10 times that amount for users.

Environmental Implications

2.50 It is beyond the scope of this report to review the various environmental consequences of infrastructure neglect and the poor operating practices in
electricity supply in LAC. However, policies designed to raise O&M efficiency are bound to have a significant and essentially zero-cost environmental benefits, amounting to reductions in pollution loads of more than 30 percent from levels produced before such improvements. 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). Generation based on fossil fuels is estimated to contribute about 30 percent of the total energy’s share, or about 15 percent of all greenhouse gases (British Petroleum Corporation 1990). Given the more rapid growth of electricity compared with other energy sources, this share is bound to grow, particularly in the developing world.

2.51 The regional and local effects of pollution emanating from thermal power plants are more pressing in the sense of the immediate impacts (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).

2.52 Control technologies to mitigate environmental effects are available and widely used in developed countries. However, they are costly, adding significantly to the capital costs of generating plants and to the running costs by reducing net energy outputs and increasing operational complexity. Hence, few LAC countries have made efforts to adopt these technologies.10

2.53 Proper O&M is the most cost-effective option to reduce environmental pollution. 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

10. Very few LDCs have used these technologies. The available information suggest that so far only one LDC country has a coal-fired power plant with operational flue-gas desulfurization equipment, the TATA-owned Trombay plant in Bombay. 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$c/kWh in 1987 US$ for coal, heavy oil, and natural gas steam plants, respectively (Moore 1991).
designed to improve the technical, economic, and financial performance of a typical, underperforming 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.

Table 3: Potential Environmental Improvement From Improved Performance

<table>
<thead>
<tr>
<th></th>
<th>Unimproved Utility</th>
<th>Normal Utility</th>
<th>% Reduction in Pollution Load</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heat rate (BTU/kWh)</td>
<td>12,500</td>
<td>10,000</td>
<td>20%</td>
</tr>
<tr>
<td>Technical losses</td>
<td>15%</td>
<td>7%</td>
<td>6%</td>
</tr>
<tr>
<td>Non-technical losses</td>
<td>10%</td>
<td>1%</td>
<td>4%</td>
</tr>
<tr>
<td>Share of auto-generation due to poor reliability</td>
<td>15%</td>
<td>1%</td>
<td>7%</td>
</tr>
<tr>
<td>Tariff levels as percentage of system costs</td>
<td>60%</td>
<td>100%</td>
<td>20%</td>
</tr>
<tr>
<td>Net decrease in pollution loads</td>
<td></td>
<td></td>
<td>57%</td>
</tr>
</tbody>
</table>

Notes: Calculations based on the following assumptions: a) an all thermal system; b) improvements in plant efficiency and merit order dispatching (plant stacking); c) a 50% load recovery of non-technical losses in the form of electricity sales; d) net pollution load per kWh of auto-generators 50% above that of utility-operated plant, and e) a price elasticity of demand of -30%.


2.54 As illustrated in Table 3, the largest environmental benefits would result from improvements in the heat rates, combined with better dispatching of the units, and from adjusting tariffs to reflect cost-recovering levels. Environmental benefits from non-technical loss reduction at 4 percent, appear relatively modest, in part because of the assumed conversion of 50 percent of formerly illicitly obtained electricity into paid-for consumption (see Schramm 1988 and 1991). In countries with non-technical loss rates of, say, 25 percent, the environmental benefits from their elimination would be much larger, approaching 20 percent.
III. CAUSES OF MAINTENANCE NEGLECT

3.1 Many factors contribute in a synergistic manner to the lack of adequate maintenance (Box 20). Perhaps the main reason is institutional, stemming from the lack of tariff, financial, and corporate autonomy of power sector utilities and the unclear regulatory functions of the government. More often than not, tariffs are used as a policy instrument of the government—to fight inflation, to promote income redistribution, to win an election—rather than as a commercial instrument to raise revenues and make a reasonable return on assets, or as an economic instrument to promote the efficient allocation of resources. Thus, during periods of macroeconomic deterioration, tariffs are artificially kept below inflation, reducing the operative profit margin and shrinking O&M budgets proportionally more than other budgets. Confusions of priorities often result in poor managerial practices and more political interference. Political and professional reward has often played an important role on this trend, because new construction projects carry professional and political glamour, whereas maintenance has little visibility and hence little immediate attraction.

3.2 Noncommercial criteria and reduced management autonomy affect O&M. High losses are caused both by improper operational practices on the technical side and by poor commercial practices on the nontechnical side (the latter are frequently affected by political factors, such as instructions not to suspend service to some nonpaying users). In many countries, bloated personnel establishments cannot be reduced because of the political clout of sector unions. These factors reflect the absence of a degree of corporate independence that would isolate the sector from undue political interference and the lack of an institutional environment conducive to efficient commercial operation of the sector.

Even though the root cause of the maintenance neglect and the resulting degradation of service rendered (and the poor image of the utilities) in most LDCs power infrastructure is institutional in nature, lack of financial resources usually triggers maintenance neglect. Regardless of the institutional model—public ownership, mixed ownership, or entirely private—generally if there is money there is maintenance. To a large extent the maintenance neglect in less developed countries is the immediate result of the tariff distortions and shortages.

Box 19: Lack of Financial Resources Triggers Maintenance Neglect

3.3 The erosion in real tariffs has a number of causes, but probably the most important has to do with the oil crisis in 1973, when the price of oil quadrupled, resulting in large increases in costs for utilities with thermal generation. Several utilities were prevented by policy considerations from transferring these cost increases to the users. If the utilities had been allowed to do so, supply conditions, service quality, and reliability probably would have been better, and PLRP would not be needed. A good investment policy is merely the other side of a good pricing policy. The public service feature of electricity supply has
meant in many cases that governments have prevented utilities from charging the full cost of supply, especially in inflationary situations. Public utilities have been used as another policy instrument for fighting inflation and promoting equity objectives, giving rise to a cascade of problems: low relative tariffs stimulate consumption and raise generation costs; the utility then compensates by reducing preventive maintenance, expenditures on replacement investments, and real wages and by postponing necessary maintenance; supply efficiency and service quality then decline, equipment becomes less available, and operating expenses and losses increase; and, finally, costs to users accumulate in terms of increasing blackouts and load shedding.

3.4 Continuation of these financial, operational, planning, and institutional problems and the resulting degradation of service and infrastructure finally reach a point at which the required tariff increases to overcome the financial shortages are so steep that the political costs are deemed unacceptable— not only because of the magnitude of the increases but because the quality of the service that can be provided is so poor. When neglect and deterioration of facilities and the primary and secondary distribution networks have prevailed for a considerable time, and power utilities have lost key technical personnel, they may well require the design of specific projects to rebuild their institutional and commercial capacity.

PRICING AND FINANCIAL ISSUES

3.5 The immediate cause for maintenance neglect has been lack of financial resources. When tariffs are sufficient to cover costs and provide an adequate return on assets, maintenance is carried out. During the macroeconomic deterioration of the 1980s, tariffs in LAC evidenced a declining trend, which reduced operative margins. Data for the electric sector does not show any important reduction in the operating revenues in LAC. The total operating revenues in LAC grew at an average annual rate of 6.2 percent between 1980 and 1985, and at a rate of 10.8 percent between 1985 and 1988. However, operating costs grew faster at an average annual rate of 7.8 percent in the 1980-85 period, and at a rate of 11.3 percent a year between 1985 and 1988, shrinking steadily the operating margin. Before 1975 the operating margin in the LAC countries tended to be above 40 percent, dropping continuously to 35 percent for the 1975-79 period, 21 percent for the 1980-84 period, and 16 percent for 1985-88.

3.6 This declining trend in the operating margin of the electric sector led many sector utilities to develop an unhealthy dependency on the central budget for funds. This dependency increases the power of the government entities, making expenditure, investment and financial planning at the public utility level erratic and inefficient and, by reducing accountability, undermines all attempts, at the utility level, to improve O&M.
3.7 Maintenance expenditures are often the first ones to be cut because consumers do not perceive infrastructure and service deterioration until it is often too late. More often than not, the seriousness of these constant reductions—even though breakdown repair is eventually more costly than preventive maintenance—is not fully understood by management and government officials and when it is understood, these decision makers are often forced to defer maintenance because of competition from other priorities with immediate political appeal. To reduce maintenance expenditures without a proper cost-benefit analysis is invariably a misguided and costly decision. Maintenance expenditures are a negligible fraction of total operating costs and amount to less than 10 percent of the total life-cycle cost of a facility (investment included). However, as examined in the previous chapter postponement in maintenance has a substantial impact on the useful life, operating costs and on the productivity of the assets.

3.8 Service degradation is often justified by management by the poor finances of their companies caused by external factors over which they have little control. The poor financial conditions are in turn used as the excuse for maintenance neglect. Although there is some truth to this perception, the fact of the matter is that the poor financial situation of most sector utilities is aggravated by problems of their own. The insufficient cash flow, consequent upon the lower than adequate tariffs and poor financial management, is accentuated by electricity losses often exceeding 20 percent of total generation. More often than not, however, the misallocation of resources on nonpriority investment programs and the amount of revenues foregone by inadequate commercial practices can be, on absolute terms, larger than the funds needed for adequate maintenance. The solutions to some of these problems are well within the mandate of sector utilities.
Several factors have played a role in the poor maintenance and the ensuing degradation of most power infrastructure and the service in LAC. An assessment of these factors is important to examine alternative options to overcome the problems. The factors for maintenance neglect are arranged in three groups to facilitate discussion, however most of them cut across boundaries.

Institutional and Managerial

- Conflicting roles between government, regulatory agencies, and power utilities.
- Lack of corporate memory for pricing, expenditure and labor decisions (in some countries rate hikes have to be approved by congress) and political interference in the running of the industry.
- Lack of utility management accountability.
- Legal obstacles for private sector participation in the O&M function.
- Poor public image of maintenance activities and uncertainties about the benefits of adequate maintenance.
- Shortage of experienced managers and skilled technicians in some countries, aggravated by lack of formal training programs.

Operational

- Misplaced operating priorities, the "operate or bust" mentality which leads managers to operate equipment beyond technically recommended parameters and without proper respect for scheduled maintenance due to political priorities and lack of knowledge of the potential costs involved.
- Faulty and/or non-economic equipment designs.
- Poor control of operations, infrequent use of performance indicators and inadequate information on systems and costs.
- Inadequate maintenance of generating stations due to insufficient reserve margins.
- Deficient levels of maintenance expenditures.

Pricing and Financial

- Tariffs below operating unit costs and long-run costs of supply lead to insufficient generation of financial resources to cover costs and an oversupplied market demand.
- Deteriorating operating profit margins because of non-economic criteria for rate fixing and an unhealthy dependency on government capital contributions and social budgets.
- Lack of financial transparency.
- Lack of timely access to foreign exchange.
- Inappropriate donor policies and procedures of official financing agencies.

Box 28: Causes for Maintenance Neglect in LAC

Unit Prices and Costs

3.9 From the point of view of finance, the most important elements affecting the profit and return on assets of power utilities are prices and costs. Real tariff rates in LAC have experienced a steady decline since 1972. However, unit costs did not decline reducing the operative margin. The average tariff of electricity, expressed in 1989 prices, was US$56.7 per MWh for the LAC (data
were available for 16 of 30 countries) for the 1971-74 period. This average tariff decreased to US$50.8/MWh in average for the next five years (1975-79); and to US$43.8/MWh for the 1980-84 period. The trend was reversed increasing to an average of US$46.3/MWh for the years 1985-88.

3.10 Unit costs have more or less stayed constant between 1971 and 1988, with values ranging between US$33.0 to $38.9 per MWh. The net margin declined from US$16.4 per MWh in the first four years of the 1970s, to US$7.4 per MWh in the 1985-88 period. Figure 20 shows the steady deterioration of the financial condition of the electrical sector for the LAC region as a whole.

3.11 Electricity rates in the LAC region have not reflected supply costs or kept pace with inflation. Between 1972 and 1988, the unit cost of 1 MWh of electricity (in 1989 US dollars) increased from $36 to $41—that is, 1 percent p.a.—whereas the unit price of 1 MWh of electricity fell from $63 to $49—that is, 1.6 percent p.a. (Figure 20). As a consequence of the evolution of unit prices and unit costs during the last two decades, the difference between them left an operating margin for the region, in absolute terms, of US$8 per MWh in 1988, which was significantly less than the margin of US$27 per MWh in 1972 and explains in part the significant deterioration of the rate of return obtained by the sector.

3.12 The average tariff based on US dollars of 1989 fluctuated greatly in several countries. In Peru, it went from a peak of $68 in 1985 to $29 in 1988. The decline in the unit price between 1987 and 1988 (from $42 to $29) resulted in a reduction of revenues in 1988 of more than US$100 million for the Peruvian sector. In Jamaica, the unit price increased from US$66 in 1973 to US$208 in 1985 and then decreased to US$121 in 1988. In the United States, France, and Malaysia, the price of 1 MWh of electricity in 1988 was US$71, US$73, and US$76, respectively. At least half of the LAC power sectors had a price that was less than US$70 per MWh.

3.13 This deterioration of sector finances was not the result of inefficiency, because unit costs were held basically constant (see Figure 20). The main cause was the decline in tariff rates, testimony of the tendency of the governments in the region to use electricity prices as another policy tool.
3.14 Tariff rates have shown resilience for upward adjustments, especially during periods of macroeconomic duress. Governments in LAC held electricity prices down with the intention of dampening the effects of the economic crisis. However, the results of this misguided policy were mainly to hurt the prospects of economic recovery and sustained growth by promoting the wrong allocation of resources and fueling inflation by increasing government contributions to support the sector and to make the service more expensive and less reliable.

3.15 From an economic point of view, the major difficulty for efficient energy pricing in the power sectors is the absence of external competitive markets to provide efficiency signals based on international prices to guide domestic pricing. Overcoming this limitation requires marginal cost studies to measure opportunity costs. However, given that electricity supply cannot be stored, that projects have long lead times and operative lives, and that investments are lumpy, strict marginal cost pricing would lead to several tariff schedules—difficult to implement and to understand in practice. Thus, LRMCs are used to proxy short-run marginal costs for tariff design.

3.16 Electricity prices in the region have not reflected LRMC, which, as a surrogate of market forces, would promote an efficient allocation of resources. Whereas in the early 1970s the unit price of electricity for the region was close to the LRMC, the gap between both has been widening, as the price has been deteriorating, while the LRMC has been increasing.
Table 4: Average Incremental Costs and Electricity Tariffs
(US$ of 1989)

![Average Incremental Cost 1989-1999](image)

<table>
<thead>
<tr>
<th>Country</th>
<th>AIC US$/MWh</th>
<th>Tariff US$/MWh</th>
<th>(2)/(1) (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bolivia</td>
<td>56.70</td>
<td>66.60</td>
<td>118%</td>
</tr>
<tr>
<td>Chile</td>
<td>34.43</td>
<td>36.31</td>
<td>105%</td>
</tr>
<tr>
<td>Panama</td>
<td>111.99</td>
<td>117.59</td>
<td>105%</td>
</tr>
<tr>
<td>Dominica</td>
<td>163.12</td>
<td>169.68</td>
<td>104%</td>
</tr>
<tr>
<td>Colombia</td>
<td>41.57</td>
<td>41.04</td>
<td>99%</td>
</tr>
<tr>
<td>Costa Rica</td>
<td>64.60</td>
<td>61.94</td>
<td>96%</td>
</tr>
<tr>
<td>Guatemala</td>
<td>77.25</td>
<td>64.37</td>
<td>83%</td>
</tr>
<tr>
<td>Jamaica</td>
<td>193.92</td>
<td>159.86</td>
<td>82%</td>
</tr>
<tr>
<td>Trinidad-Tobago</td>
<td>43.93</td>
<td>35.11</td>
<td>80%</td>
</tr>
<tr>
<td>Barbados</td>
<td>169.92</td>
<td>133.18</td>
<td>78%</td>
</tr>
<tr>
<td>Dominican Rep.</td>
<td>107.36</td>
<td>80.50</td>
<td>75%</td>
</tr>
<tr>
<td>Brazil</td>
<td>83.27</td>
<td>62.30</td>
<td>75%</td>
</tr>
<tr>
<td>Venezuela</td>
<td>29.19</td>
<td>21.46</td>
<td>74%</td>
</tr>
<tr>
<td>Honduras</td>
<td>60.86</td>
<td>44.72</td>
<td>73%</td>
</tr>
<tr>
<td>Mexico</td>
<td>63.85</td>
<td>46.73</td>
<td>73%</td>
</tr>
<tr>
<td>Uruguay</td>
<td>109.05</td>
<td>75.77</td>
<td>69%</td>
</tr>
<tr>
<td>Argentina</td>
<td>66.05</td>
<td>43.16</td>
<td>65%</td>
</tr>
<tr>
<td>El Salvador</td>
<td>45.69</td>
<td>26.92</td>
<td>59%</td>
</tr>
<tr>
<td>Guyana</td>
<td>234.10</td>
<td>134.32</td>
<td>57%</td>
</tr>
<tr>
<td>Peru</td>
<td>145.30</td>
<td>66.42</td>
<td>46%</td>
</tr>
<tr>
<td>Ecuador</td>
<td>61.61</td>
<td>25.09</td>
<td>41%</td>
</tr>
<tr>
<td>LAC Weighted Avg</td>
<td>68.14</td>
<td>51.94</td>
<td>76%</td>
</tr>
<tr>
<td>LAC Simple Avg</td>
<td>93.51</td>
<td>72.05</td>
<td>77%</td>
</tr>
</tbody>
</table>

3.17 Based on cash flow and demand data and forecasts prepared by the electric utilities in the region, estimates of the average incremental costs (AICs) of electricity supply were generated for the LAC countries as a proxy for LRMCs. The AICs were then compared to the tariffs the utilities expected to charge in 1988. Figure 21, Figure 22, and Table 4 present the ratio of average tariffs in 1988 to incremental average costs in the LAC region and the AIC for each individual country. Based on this comparison, out of 21 LAC countries only four—Bolivia, Chile, Panama, and Dominica—had tariffs above average incremental costs. Two countries—Colombia and Costa Rica—had tariffs almost equivalent to AICs, while all the remaining countries have tariffs below AICs. In 1988, the AIC varied for the LAC countries, from a low of about 30US$/MWh for Venezuela to a high of 234US$/MWh for Guyana.

Due to the difficulties in estimating long-run marginal costs for each of the LAC countries, an indirect method based on financial projections prepared by the power utilities has been employed. The estimates are called average incremental costs and no attempt has been made to correct for any pricing distortions. The principles involved are straightforward and briefly illustrated for the LAC countries as a group.

| Total investment expansion program 1988-98 | $103,124 Million US$ of 1989 |
| Total capacity added 1990-99 | 69,186 MW |
| Increment system peak demand 1990-99 | 67,066 MW |
| Cost per kW additional peak demand | $1,538 US$ per kW |
| Average life new facilities | 25 years |
| Capital recovery factor for 12% over 25 years | 12.75% |
| Annual cost/kW peak demand | 196 US$/kW |
| Average system load factor | 68.0% 3,954 hours |
| Average capacity cost = 1000*(3196/5,954 hre) | $32.93 US$/MWh |
| Present value of fuel costs 1990-99 | $9,044 Million US$ of 1989 |
| Present value total generation 1990-99 | 3,980,848 GWh |
| Average fuel cost = $9 billion /3,981 TWh | $2.27 US$/MWh |
| Operations & Maintenance Cost | $22.10 US$/MWh |
| Average incremental cost of electricity | $57.30 US$/MWh |
| Average gross system losses | 16% |
| Average incremental cost of electricity sold | $68.14 US$/MWh |

Note: The figures for losses are those forecasted implicitly by the utilities; i.e., they include *non-technical* losses.

Box 21: Average Incremental Costs of Electricity in LAC
Operating Margin

3.18 The main reasons for the deterioration of the electricity infrastructure appear to be the financial constraints imposed on the power sector and the lack of sound planning. These financial restrictions result when electricity tariffs are maintained at artificially low levels relative to input costs. Under these conditions the electric sector is unable to collect the necessary revenues to pay for generation fuel, spare parts, salaries, and, finally, the borrowed capital. These subsidized rate levels inflate demand above economic levels, which requires additional generation and more costly inputs, shrinking further the operative margin. Given this shrinking budget, sound planning dictates the allocation of the available funds in a priority manner, where the priorities are determined by the main objective of the utilities: to provide a reliable service at the least possible cost while ensuring an acceptable return on invested capital. However, the practice in most LAC countries has been to set priorities differently, favoring the construction of generation projects at the expense of maintaining existing equipment.

3.19 The effects of the financial restrictions on the power sector depend on their duration. If the financial restriction is present for only a brief period, the results may lead to a postponement of maintenance, a temporary drop in the availability of installed capacity, and consequently, some load shedding and outages. When these temporary financial restrictions in the sector are the result of crisis in the entire economy, then these difficulties are usually dampened by the slower growth of electricity demand.

3.20 If, on the other hand, the financial restrictions are long lasting, the effects on the sector are major. A prolonged delay in maintenance results in permanent damage and premature aging of the equipment, permanent drop in available capacity, higher generation costs, a rise in electricity losses, increase in the frequency and duration of load shedding and outages, and finally, a drain of qualified personnel away from the sector and—in small countries with a reduced and little diversified labor market—out of the country. The Dominican Republic, Argentina, and Guyana, faced with long-term financial restrictions in the power sector, experienced a noticeable deterioration of their power infrastructure.
3.21 If the electric service is provided by companies differentiated geographically, or by level of activity, (generation, transmission, or distribution), then the financial restrictions will not necessarily be equally applicable to the entire electric sector. If such is the case, the degree of deterioration of the infrastructure might also vary or be limited to specific parts of the system. The data for Bolivia confirm that the financial restrictions faced by the electric sector in the 1980s did not affect equally all of the sector. The distribution companies were less hurt by the financial crisis, whereas the public utility responsible for generation and block supplies saw its collections markedly reduced during a longer period.

3.22 To examine the length of the financial strife, data on the net operating margin (difference between operating revenues and operating costs) for the LAC countries are studied for the 1971-88 period. Figure 23 ranks countries according to length of duration of negative operating margins. Eight countries showed periods of more than two years of operating deficits in the power sector: Argentina, Trinidad-Tobago, Dominican Republic, Guyana, Belize, Mexico, Peru, and Jamaica. Three other countries experienced this deficit for two years: Chile, Ecuador, and Uruguay. Four countries showed deficits for only one year: Bolivia, Brazil, Nicaragua, and Venezuela.

3.23 To examine on a comparative basis the net operating margins, the ratio between the net operating margins and total electric sales has been estimated. Figure 24 shows that this ratio has been declining steadily from 1971 to 1988. The average net margin for the group of LAC countries during the 1971-88 period is US$11.7 per MWh, with higher margins during the 1970s ($17.78) in comparison with those registered in the 1980s ($8.18). It is difficult to generalize about the right values of the net operating margin per unit of sales. However, figures in Spain and the United State suggest that a reasonable margin should be no less than US$10 per MWh. Only eight countries in LAC had net operating margins per MWh sold above US$20/MWh from 1971 to 1988: Honduras, St. Vincent, Panama, Haiti, El Salvador, Costa Rica, Barbados, and Brazil. Nine countries had ratios between $10 and $20 per MWh sold: Dominica, Paraguay, Surinam, Guatemala, Colombia, Jamaica, Uruguay, Nicaragua, and Chile. The remaining ten countries had an average weighted ratio below $10 per MWh, with four of
these—Guyana, Argentina, Trinidad-Tobago, and Dominican Republic—with negative ratios.

3.24 The power infrastructures of Trinidad-Tobago, Ecuador, Mexico, and Venezuela do not show the degree of deterioration that would be expected given the low operating margins registered. This is explained largely by the “oil syndrome,” which led to a relaxation of economic and financial prudence, while keeping investment up relative to maintenance expenditures. Even during the period following the fall in petroleum prices in 1982 with the associated foreign exchange shortages, import curbs, domestic inflation, and government’s refusal to allow the utility to adjust tariffs, there was probably greater reliance of the sector on Government contributions than elsewhere in LAC.

3.25 The relationship between the conditions of the power infrastructure and the financial crises of the sector is not easy to appraise based only on the operation margin to sales ratio. The information does not permit conclusive inferences in some instances. Bolivia and Nicaragua show average margins of about US$10.0 per MWh, but they also registered negative years with considerable variations from one year to other. Sixteen countries had on average during the 1980s a ratio above $10 per MWh, but their power infrastructure was in a poor state. Chile, for example, had a low weighted average ratio during the 1971-88 period but kept a good power generation and delivery infrastructure. Panama, on the other hand, with a high ratio, experienced a deterioration of the sector’s infrastructure. In conclusion, another indicator is needed to assess the relationship between maintenance neglect and financial shortages.

3.26 To better understand maintenance neglect and the financial conditions that give rise to it, it is convenient to examine the figures on Capital Stocks and Investment in the power sector in LAC. The first type of information available is the net annual increase in Working Capital (WK). That is the net difference between annual income and expenses, where income includes borrowing contracted, depreciation allowances and all other sources of income, while
expenses considers investment, debt service, and other operating expenses. This net flow of WK represents the actual yearly accumulation of surplus accruing to the power sector. The second type of information available is the stock of WK, the financial reserves accumulated by the power sector. The data comes from the sample of countries selected for this study.

Figure 26
3.27 Figure 26 attempts to shed some light on the region as a whole. After 1974, the first oil crisis, there was a steady deterioration in the WK stock in LAC with erratic net WK increases. The situation was not much better for the individual LAC countries. The results for six of these are presented in Figure 27 to Figure 32 below. Chile shows, by far, the best record both in terms of net annual increases of WK as well as the formation of WK Stock, which is in agreement with conditions of its power infrastructure. There are two short periods of financial difficulties—1971 to 1974 and 1979 to 1981—but financial conditions are favorable from then on. Argentina, on the other hand, shows the worst record with negative WK indicators from 1978 onward.

3.28 Bolivia and Honduras show a mixed record. Their performance up to 1984 was uneven, with negative figures on WK increases of approximately one out of every three years, which indicates the presence of slight financial constraints. After 1984, the WK performance improved for both countries. Jamaica also shows a very uneven performance on these indicators and for a longer period. Venezuela underwent important financial restrictions during the 1979-85 period, resulting from low tariffs and the huge investment requirements entailed by the construction of the “Guri” hydroelectric plant. The record improved somewhat since 1986, but unevenly for both the flow and the stock of WK.

Availability of Foreign Exchange

3.29 Failure to consider the risks and the difficulties in importing materials and spare parts and maintenance equipment can also lead to a precarious reliance on such equipment, which cannot be properly maintained and soon fails into disrepair. Shortage of foreign exchange during the 1980s was another difficulty facing the economies in the region and, consequently, their power sectors. The macroeconomic manifestations during the 1980-88 period were currency devaluations, external debt accumulation, negative current accounts, and net outflow of foreign exchange. The sectoral manifestations were delays in repairs and increases in equipment outages because of unavailability of foreign exchange for spare parts and technical services. The consulting firm of Stone and Webster estimated that in the Dominican Republic more than a hundred system components were out of service or had serious problems and needed replacement. However, replacement was impossible because of lack of foreign exchange, increasing the risks of outages and interruptions. Combined with problems such as bad investment planning, this shortage prevented the Dominican Republic’s system from conducting orderly operations and maintenance and forced it into operating on a day-to-day basis.

OPERATIONAL

3.30 Proper maintenance is the key to an economic and reliable power system, but maintenance practices vary widely among utilities in the LAC countries.
Maintenance practices can be classified as either planned (preventive) or unplanned (forced). Planned maintenance is necessary and should be carried out in accordance with equipment suppliers’ recommended procedures, but the required maintenance schedules are not carried out in many plants in LAC countries because of inadequate concern by managements or pressure to keep plants in production to avoid power shortages.

3.31 In many LAC countries, the majority of outages are forced and thus lead to unplanned maintenance work. The level of plant unavailability resulting from unplanned maintenance ranges between 5% and 50%, on an annual basis, compared with 3% to 15% in industrialized countries. Unplanned maintenance outage in many countries can be attributed to a combination of factors that include: lack of preventive maintenance, overloading of plant capacity, inferior fuels or materials, and lack of training of skilled operators. These outages are prolonged by poor inventories of spare parts, shortages of foreign currency for spare parts, and generally low productivity of maintenance staff. Utility managers do not give sufficient priority to proper O&M practices, nor do they set up incentive programs for their staff to improve operating performance and carry out preventive maintenance.

3.32 Maintenance of electricity facilities should be viewed as one phase in the design-construction-operation process. New equipment or facilities can and should be selected by seeking a robust economic solution, taking into account all the relevant risks associated with foreign exchange availability, personnel know-how, maintenance and repair needs, and so on. New facilities should be designed and built for ease of operation and maintenance, taking into account the know-how of personnel and realistic training programs. Timely repairs reduce long-term operating costs and ensure the full life expectancy of existing facilities and equipment. Innovative operations sometimes can add capacity for little cost and reduce maintenance needs. On the other hand, incompatibility of equipment, inadequate personnel know-how, and poorly trained staff often exacerbate maintenance problems. Such is the case with distribution workers, who take more time than normal—sometimes by a factor of ten—to fix a breakdown in the circuit. It is not uncommon to observe O&M crews in the field using improper procedures because of lack of training, improper tools, or inferior equipment or materials. Also, labor union contracts and regulations limit in some countries the range of activities of maintenance personnel, leading to low productivity and excess labor.

3.33 Maintenance personnel is seldom considered in project planning, and designers often are not knowledgeable about O&M requirements in the country. As a result, many facilities are built without due consideration of the local environment, the institutions, and the capabilities for a smooth operation and maintenance. Inappropriate designs select state-of-the-art equipment but fail to take into account the human resources and funding needed to maintain and operate it.
3.34 Management often sees maintenance as a series of problems to be handled as the situation demands instead of as a policy based on planning for future needs. The normal operational mode during the 1980s in LAC was management by crisis, with maintenance based on ad hoc decisionmaking. The enduring financial strife and the lack of autonomy of the power sector utilities in LAC have affected maintenance methods. For example, methods for issuing and tracking preventive and corrective maintenance are frequently inadequate. Preventive maintenance is not viewed as the cornerstone of the program but rather as "breakdown maintenance." Premature equipment failures and aging are the inevitable result.

**Evolution of Maintenance Expenditures**

3.35 Based on the study sample of six LAC countries (Argentina, Bolivia, Chile, Honduras, Jamaica, and Venezuela), one can appreciate a reduction in the level of maintenance work during the 1980s. During the 1970s, expenditures on personnel, materials, and support services rose more or less steadily in all LAC countries. Chile was the exception. Expenditures in 1971 were 14 percent higher than in 1980. The summary figures for the six countries show a slow increase in these expenditures until 1979, with a jump in the expenditures in 1980 most noticeable in Argentina and Venezuela. Between 1980 and 1984 the total expenditures of the six countries declined steadily. This drop in expenditures for maintenance, operation, and rehabilitation of the electrical systems was more noticeable in Argentina. Chile experienced a reduction in expenditures in 1980 and 1981 but continued growing from 1982 on. Honduras did not show any sign of decline during the entire period; its expenditures slowly but steadily grew during the 20 years examined because of the impact of El Cajón during the 1980s.
Maintenance Policies and Practices

3.36 The current conditions of maintenance policies and practices in the LAC countries where case studies have been carried out are briefly described in Box 22.

<table>
<thead>
<tr>
<th>Country</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Argentina</td>
<td>Planned maintenance is coordinated for two year periods with the participation of all companies in the National Interconnected System (NIS). Unfortunately this plan is seldom executed. The main restrictions to timely and adequate maintenance are: (a) Insufficient internal generation of funds to cover maintenance expenditures; (b) Scarcity of organizational and technical skills due to low salary levels in the power sector; (c) Labor union intervention to restrict outside contracting.</td>
</tr>
<tr>
<td>Chile</td>
<td>Planned maintenance is 90% implemented. The staff assigned is highly qualified. Given the decentralized structure of the sector with important private participation, the implementation of adequate maintenance is mainly controlled by the desire of each generation and distribution company to maximize profits. Regulations do exist regarding the quality and continuity of the service provided by distributing companies and the obligation of compensation payments by the generating companies in case of rationing.</td>
</tr>
<tr>
<td>Guyana</td>
<td>With only one public utility in charge of providing electric services, there is a Maintenance Unit in charge of planning and coordinating maintenance at the national level. The restrictions found in implementing maintenance are: (a) The lengthy withdrawal of a generating unit for a major overhaul is decided at high levels because of insufficient generation capacity; (b) Qualified personnel is scarce; (c) The lack of foreign exchange has led to scarcity of spare and cannibalization of other units.</td>
</tr>
<tr>
<td>Honduras</td>
<td>Maintenance is coordinated by the public utility responsible for providing electric service at the national level. Each generation plant has its own maintenance personnel and spare stock. Maintenance problems have been caused by delays in the approval of the annual budget by Congress which prevented the timely purchasing of services and goods.</td>
</tr>
<tr>
<td>Jamaica</td>
<td>There is a well-organized maintenance management structure in the power sector. There is a legacy of non-optimal selection of equipment, requiring large stocks of spare parts. Future distribution equipment needs standardization. The desire to avoid load shedding or to avoid approaching critical reserve marginal levels has led to postponing planned maintenance.</td>
</tr>
<tr>
<td>Venezuela</td>
<td>There are several public and private companies without coordination of maintenance activities at the national level, coordination which existed previous to 1984. There are different design criteria for distribution lines. The unusually large reserve margin has prevented supply problems, but these problems might arise if the lax attitude towards maintenance persists in the future.</td>
</tr>
</tbody>
</table>

Box 22: Current Maintenance Practices in Selected Countries in LAC

INSTITUTIONAL AND MANAGERIAL

3.37 In most LAC countries, governments are in charge of electricity supply through public enterprises. The role of the government is more related to policy aspects, regulation of services, and provision of some of the funds for investment and operations. Government-utility relations, therefore, play a crucial role in O&M. However, the regulatory function of government agencies has been, by far, ineffective in most countries in promoting efficiency of operations and in providing the parameters and criteria to support efficient investment planning decisions. Financial authorities—and in some cases Congresses—are charged with approving utility budgets. However, decisionmakers at the center are often too far removed from operational
realities, and therefore maintenance needs receive very little attention in the allocation of resources. The support and signals given by planning, finance, and congressional authorities have been erratic or contradictory at times with respect to maintenance policies, and new investment continues to receive most of the attention and support.

3.38 Policies intended to foster growth and equity through unrealistically low electricity rates—however well-intentioned—are misguided. Subsidies have been granted to build new generating capacity when there was clear evidence of high levels of losses and waste in consumption because of inadequate maintenance and subsidized tariffs. Little or no funding was allocated to redress the problems of loss and waste, and no actions were taken to align tariffs with supply costs. Although enacted in the name of social concern, investments in new capacity and artificially low electricity rates have deprived utilities of funds to maintain or expand services more economically. Hence, these practices have deprived the population—especially the poor, whose neighborhoods generally are the first disconnected during capacity shortages—of reliable service.

3.39 Institutional and managerial deficiencies often go hand in hand. It is not uncommon to observe ill-defined or overlapping functions in or across government departments and agencies, sector institutions and utilities. The lack of clear objectives and transparent rules reinforces this problem, and accountability is lost. Accountability is also lost when public administration of sector utilities intrudes on and obstructs utilities’ operational autonomy.

3.40 More often than not, inadequate management practices and uninspiring or inexperienced managers are a direct result of excessive government control and an important source of deficiencies in O&M. Most sector officials lack the necessary sectoral perspective to fully understand that poorly maintained and unreliable electric facilities are a drain on resources, that they hamper private sector productivity and economic growth. Many also fail to realize that poorly maintained electricity delivery systems have an important and undesirable impact on equity as the poor are the most vulnerable to deficient services.

3.41 The high turnover in management impairs institutional memory and long-term planning for maintenance. In-transit managers are not usually interested in developing and implementing maintenance plans, which bear fruit mainly in the long term. Noncompetitive salaries, politicized labor unions, personnel policies that fail to attract competent managers and technicians, and inadequate formal training all subvert good maintenance.
IV. THE CHALLENGE AHEAD AND AVAILABLE OPTIONS

4.1 The beginning of the 1990s finds the power sector infrastructures of many LAC countries in disrepair, the utilities' finances weak, and the governments unable to provide the funds to rescue them. The ambitious power investment programs of the 1970s faltered in the 1980s, when capital became scarcer and costlier. Internal funding declined because of a misconceived policy of curbing inflation through low public service prices, and this caused the utilities' operational margins to shrink. In turn, rates of return on investment fell below the cost of capital, and the availability of fiscal resources to the sectors declined, and borrowing became difficult. These factors were instrumental in causing most of LAC's power sectors in LAC to enter into a period of financial strife, burdening their national treasuries and cutting back on preventive maintenance and replacement investment. Shortages of funds, along with misguided priorities for expenditures, resulted in a backlog of maintenance work that negatively affected operating costs, plant availability, losses, system reliability, and environmental degradation with severe consequences for economies such as those of Argentina and the Dominican Republic, where energy shortages substantially hindered production and investment.

4.2 Overcoming the present degradation of the power sector infrastructure in the region to provide adequate support for economic growth and development is the challenge facing policymakers and development institutions during the 1990s. Many lessons can be learned from the errors of the past. Flouting of programmed intervals for maintenance increases generation costs, damages the thermal efficiency and availability of the units, and increases pollution loads. Keeping prices down overstimulates demand leading to greater resources for generation—resources in short supply. It was a vicious cycle: low prices induced higher demand, lower revenue for O&M and investment expenditures, less preventive maintenance and replacement investment, higher operating costs, shrinking operating margins, lower government contributions, more government intervention, politicized management and unions, and so on. Avoiding a repetition of the maintenance neglect of the 1980s is paramount to an economic and reliable electricity supply, key inputs for regaining and sustaining economic growth in the region.

4.3 The region's electric utilities estimate about US$19 billion annually in required investment (in constant 1989 prices) during the 90s to met an estimated annual demand growth in excess of 6.5% at least throughout this decade and likely beyond. However, they have projected only about $6 billion per year in net internal funding. Meeting the additional capital requirements is difficult because of the poor financial and operational performance of the region's utilities and the poor credit ratings of the LAC 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 service reliability and reduce their operational and capital costs.

4.4 The region’s power sector needs sound pricing policies, adequate and robust expansion plans, and investment alternatives that consider the risks entailed in existing facilities, foreign exchange availability, maintenance staff capabilities, and training needs. Electricity prices should reflect the present and future costs of supply, they should signal consumers how much it costs to supply them, to promote rational consumption patterns and discourage waste. Sound electricity pricing also encourages efficiency in supply by providing utilities with market signals in tune with the opportunity costs of operation and expansion. A sound pricing policy is necessary to improve the internal funding of the sector and provide adequate preventive and corrective maintenance.

4.5 The main cause behind the weak finances of the sector, the poor operating practices, the lack of proper maintenance and the unreliable service is the institutional setup, the lack of corporate autonomy of the utilities, the myriad of government departments and agencies overseeing the sector, and the lack of clear objectives. Inadequate O&M has been compounded by the perception that electricity is a service governments are obligated to supply without due consideration of cost. The institutional and regulatory framework needs revamping. The power sector has to open up to competition. The financial difficulties, the need for the efficiency associated with competition and the perception by the people and in many cases by the government of major inefficiencies in government-run companies, and the inability of the governments to fund investment programs has called in many countries for a strong participation of the private sector.

4.6 A great challenge lies ahead. Creative and innovative options have to be adopted and developed to face these new conditions. As explained in this report and summarized in Box 23, most of the power sectors in the region face major investment requirements in the 1990s, especially if the economic adjustment and macroeconomic programs materialize. To face this challenge, the power sectors in the region need to mobilize resources, taper demand through sound electricity pricing, establish an adequate institutional framework, provide regular preventive maintenance, reduce investment requirements through rehabilitation of existing infrastructure and loss-reduction programs, and attract private sector participation. The critical fiscal situation of most governments in the region and the existence of other pressing priorities impels the sectors to consider harnessing the resources of the private sector.
ELECTRICITY TARIFFS

4.7 Adequate cost recovery policies for electricity supply are fundamental for the long-term financial health of the utilities and to provide adequate maintenance for a least-cost and reliable supply of power, essential inputs for economic recovery and sustained growth. The power sector demands large investments in generation plants, transmission lines, and distribution networks. Given the long lead times of electricity supply projects, a reliable supply in the future requires the commitment of scarce investment funds several years in advance. Electricity prices influence demand, and demand in turn influences investment. Consequently, inefficient pricing policies fail to send the right signals to consumers and promote misallocation of resources, yielding suboptimal development patterns with far-reaching consequences. Thus, a rational electricity pricing policy is vital to achieving sound maintenance policies and, ultimately, to promoting a competitive economic base for renewed and sustainable growth.

MANAGERIAL AND INSTITUTIONAL

4.8 With some exceptions—such as Chile, Bolivia, and Venezuela—most of the electric utilities in LAC are government owned. The regulations inherent to management of a public company are frequently obstacles to efficient maintenance, purchasing of spare parts, and rational labor and personnel policies. These regulations establish lengthy and relatively complex purchasing and credit request procedures. If foreign goods or services are to be acquired, then the public utility must have easier access to foreign exchange. Honduras, for example, has to go to Congress for approval for foreign exchange purchases with the consequent delays and efficiency losses. There are also civil service regulations controlling salary levels, overtime work, and outside contracting that limit the utility’s ability to bid for the best talent and services.

4.9 When public companies are plagued by excessive government and political intervention the almost inevitable results are low electricity tariffs and maintenance neglect, financial restrictions, excessive staffing, drainage of qualified personnel away from the sector, and inefficient operation of the equipment. The result is degradation of facilities and deterioration of service, with mounting social and economic costs for consumers.

4.10 Different approaches are currently being tried in the LAC countries to remove the managerial and institutional barriers. In Chile, policy now decentralizes or segments the sector into smaller units concerned with only one component of the electric system: generation, transmission, or distribution. It also makes the utilities independent of government intervention and applies efficient tariffs related to marginal costs of generation, transmission, and distribution. Finally, it includes the privatization of the sector and the equity sale of state-owned companies. These actions are complemented by efforts to
After World War II and until the 1980s, the forecasting of electricity demand in LAC was rather simple: Demand could be counted on to grow at about 10% each year and, therefore, to double approximately every 7 years. Power planners believed that the elasticity of demand to price changes was minimal and that forecasting could be done based on simple trend extrapolation techniques. Forecasting was, as someone suggested, "like driving a car blindfolded and following directions given by a person looking out of the back window." The debt crisis and the slower economic growth of the 1980’s brought an end to the reliability of the blindfold "double-in-seven" formula.

The efforts to consider price and income as explanatory variables of demand in LAC have been mainly associated with the Bank and the IDB, especially the latter. The first paper, written by the IDB in 1979, put forward the recommendation that the same price-demand model used for demand forecasting should be used for estimating the benefits of electricity supply projects. A more recent study, also by the IDB, presented in 1989 the results of a survey of demand studies in the region.

A remarkable finding of the latter study is that price elasticities of demand across LAC countries vary within fairly narrow ranges: the long-run price elasticity of residential and commercial demand varied from -0.4 to -0.5, while that for industrial demand varied from -0.25 to -0.65.

Average electricity tariffs in most LAC countries are below LRMCo. Raising prices to marginal costs, in addition to eliminating economic losses associated with sub-marginal cost pricing, would in general tend to reduce power requirements. At what seems to be an empirical law for the long-run price elasticities of demand in LAC countries of about -0.5, increasing tariffs by about 30% (in real terms) would eventually reduce electricity demands by around 15%.

Sources: Gutiérrez and Westley (1979) and Westley (1989).

Box 24: Responsiveness of Demand to Tariff Changes

support the more deprived sectors of the population through direct subsidies. The underlying objective is to attain conditions of optimum allocation of resources according to Pareto criteria (Bernstein 1988).

Performance contracts, wherein the Government grants autonomy to the utility in return for measurable improvements in performance, have become very popular recently. But what does the experience show? Does a particular scheme yield better results? Is there a performance threshold which a utility must cross prior to becoming a suitable candidate for privatization?

In the absence of political will, performance contracts are merely formal documents that are periodically signed but produce few tangible results. In one case, in Guatema-Belice, the Government was so committed to the goals of the performance contract that it complied with its obligations prior to signature. In the majority of the cases, however, the Government has not fulfilled all its obligations and has therefore rendered the performance contract meaningless. Government practices with regard to tariffs, timely payment of its electricity bills and employment usually take precedence over the provisions of the performance contracts. They also limit authority and consequently impede transparency and accountability.


Box 25: Political Will is a Precondition for Performance Contracts

4.11. Performance contracts are being examined in Bolivia and Panama. The goal of the contracts is to raise overall efficiency by providing the power companies more management freedom and corporate independence. A performance contract is signed between the government and the public utility. Pecuniary incentives are established if the utility achieves the agreed goals.
Agreements are formalized to give the utility flexibility in acquiring goods, contracting services, and managing salary levels.

4.12 An alternative approach is to establish contract plans with private companies. These contracts would help to remove some of the institutional barriers to efficiency, especially when maintenance is hampered by foreign exchange restrictions, funding constraints, and shortage of qualified personnel. Private contractors can overcome, more easily than a public utility, the foreign exchange restrictions, and they can get spare parts or trained personnel in a more timely manner. The contractor provides the utility the necessary equipment or services to reduce costs or increase revenue—typically a loss-reduction program, generation efficiency improvements, or increased availability program. In return, the utility agrees to pay the contractor a fraction of the net gains achieved. This approach has yet to be tried to improve the performance of the power sector in a developing country.

There are several economic and sector benefits of a sound electricity pricing policy, among which the most important are:

- Price is the best inducement for energy conservation. Industries will invest in energy conservation to the point where the cost of saving an additional unit of energy is the same as the purchase price of that energy.
- The benefits for the country of subsidizing energy consumers are less than the benefits of allocating the equivalent subsidy to infrastructure, social, and human capital formation.
- Proper prices lead to better financial situations for the sector utilities which in turn lead to maintenance expenditures and replacement investments to improve operable conditions and the quality of supply (i.e., reduce costs, improve availability and reliability of supply).
- Adequate prices are necessary for an efficient and reliable maintenance policy, to lower forced outage rates, raise efficiency and availability factors, lower losses and improve reliability of supply.
- Sound electricity pricing also encourages efficiency in supply by providing utilities market signals for an efficient operation and power investment program.
- Sound electricity pricing improves the chances for private sector participation.

Box 26: Benefits of Sound Economic Pricing

4.13 Power sector utilities must be granted increased autonomy. The necessary actions should include (a) limiting the relations of the utilities to one or two government entities; (b) establishing expenditure and investment approval procedures equivalent to those of the private sector; (c) easing access to foreign exchange; (d) applying electricity tariffs related to forward marginal costs considering financial restrictions, to promote an efficient allocation of resources, to allow a financial margin, and to permit the generation of funds for new investment; (e) establishing a sound adjustment mechanism of tariffs to maintain

real value in the presence of cost inflation; and (f) allowing the public power sector to set competitive salary levels in order to attract and retain qualified staff (Saunders and Jechoutek 1985).

4.14 Another element in ensuring sound corporate policies is to provide the power utility with a wider public base to maintain automatic tariff adjustment policies and protect the sector through periods of political instability. This wider base can be attained either by consumer representatives allowed in the Board of Directors that controls the power sector or by means of the open-market sale of power sector equity.

Labor Training

4.15 Several LAC country utilities have not developed the necessary skilled manpower for managing power systems, and this situation remains one of the main constraints to sectoral development. Some utilities suffer from acute shortages of plant managers, engineers, geologists, hydrologists, financial managers, planners, computer specialists, and other skilled and semi-skilled specialists. Consequently, many utilities have had to rely on foreign consultants and expatriate staff to conduct planning and tariff studies and, in the weakest utilities, to fill key management positions.

4.16 Many utilities lack appropriate policies for staff training and professional development for their managerial and professional requirements. These utilities also lack the funds for training programs to develop skilled labor. Some utilities have relied on donors to support such training and made little training effort of their own.

4.17 Conversely, most LAC country utilities have an excess of unskilled labor which contributes to their low efficiency. This situation often arises from political pressure to create and maintain jobs in countries with a shortage of employment opportunities for unskilled labor. Nevertheless, there is a wide range of employment standards among these utilities as shown by comparative data on the ratio of the number of utility consumers per utility employee. For the best performing utilities—excluding those that only generate electricity but do not distribute it—which are generally in countries with sound adjustment policies, this ratio lies in the range of 100 to 300 (Bolivia and Mexico top the list with 210 and 187 respectively). The lowest ratios are below 70 and are typical of utilities in countries with unsound public sector policies (Panama and Guyana are at the bottom end of the list with 57 and 59 respectively).

4.18 The critical issue for the availability of qualified personnel for proper O&M is the low salary levels of public utilities that are subject to civil service regulations. The solution in those cases is to grant utilities flexibility in setting competitive salaries for qualified personnel as well as in setting pecuniary incentives and personnel performance evaluation procedures.
4.19 In the case of the LAC countries with smaller and less developed power sectors, it is important, in the short run, to support the maintenance of the power infrastructure by means of (a) training programs for technical personnel to upgrade the quality of maintenance crews and maintenance specialists and (b) improving investment planning to identify robust economic solutions that consider potential maintenance risks.

Private Sector Participation

4.20 In the quest for improved quality of services and cost effectiveness of O&M, it is important to dispel any apprehensions that public and sector officials may have about private sector ownership in the power sector. The experience in countries such as Spain, the United States, Great Britain, and in the LAC region itself (notably Chile) clearly shows that this participation can be productive and effective and that private firms can provide many services more efficiently than public utilities, owing to better management, greater flexibility and accountability, and an ability to retain more skilled personnel.

4.21 Many of the power sectors in the LAC region operate under institutional frameworks that originated when government entrepreneurship was considered optimal for social and economic development. At present, however, the government is thought best suited to entrepreneurship only when the private sector does not provide it; otherwise, the government should concentrate on policymaking.

4.22 The private sector can also participate in the maintenance of the power sector by bidding of maintenance, especially in the case of major overhauls of generating units. The private sector can also be a source of additional financial resources, provided, of course, that a clear legal framework exists to allow and encourage this participation. The positive experience of many industrialized countries, particularly France and Spain, with the participation of the private sector in the financing of the power sector should be emulated in the region. However, the institutional frameworks need updating to mobilize the managerial and financial capabilities of the private sector.

4.23 As Box 27 shows, several activities of the utility are amenable to private sector participation. In fact, it is common for collection to be carried out through private sector banks. Again, provided that these activities are contracted through competitive bidding, they should be beneficial to the utility. Except in the poorest LAC countries it is unlikely that the local private sector does not have the necessary expertise and tools (hardware and software) for the job. It might also be that in these cases the magnitude of the task, and therefore the rewards, are too small to interest an international company. It is also very clear that the key activity of disconnecting clients that do not pay in time (especially the administration) cannot easily be transferred to the contractor. The social and political price of disconnecting nonpayers is normally
incommensurate with the expected profit, although this is the key to reducing accounts receivable.

4.24 An O&M service contract with the private sector can of course include a loss reduction program, generation efficiency improvements, an increased availability program, and so on. A service contract requires supervision by well-trained staff to solve in a timely manner the problems that may arise in performing obligations under contract. Timely payment of contract obligations is paramount to a successful contract.

4.25 Successful O&M contracts with the private sector should span several years, usually not less than five, to elicit a good response from potential bidders and to allow and justify a reasonable investment and commitment on the part of the contractor. O&M contracts should pay particular attention to (a) a clear definition of contract objectives and delimitation of the area of service; (b) the obligations of the private company concerning standards and quality of service; (c) the procedures to adjust contract prices including revision thereof when service or cost parameters exceed preestablished limits; (d) the provisions for handover and continuity of service at the beginning and end of the contract; and (e) the handling of staff employed by the utility when service is taken over by the contractor.

4.26 To attract private sector participation in the property of the utilities and in the ancillary services, it should be recognized that private investors are guided by legitime profit opportunities; to achieve the desired objective of economic efficiency and reliability in the supply of electricity, a government agency must retain the responsibilities for regulating pricing and service quality. On the other hand, private firms should face the real possibility of losing the licenses because of inadequate performance. Equivalent incentives or sanctions generally do not exist for public agencies.

4.27 Finally, a precondition for the success for any of the available institutional options in LAC is political will. Performance based contracts appear to be needed to advance the utility to the point where private sector participation might become a viable option. There appears, however, to be a minimum level of performance to be achieved by the utility and a minimum set of conditions to be fulfilled by the country before the private sector develops the necessary confidence to participate in the above-mentioned schemes. Paradoxically, that
threshold might require that an adequate tariff level, as well as a suitable billing and accounting system, be in place and that the utility be able to generate and collect enough funds to cover its costs. Without this, no reasonable participation will be obtained from the private sector. Indeed, even when these conditions are met, an escrow account may be required to guarantee payment and attract the private sector. At the country level, a fair regulatory system, a bona fide process for settling differences, and a mechanism that allows access to foreign exchange are also needed. Some utilities in particularly bad shape will need to cross the performance threshold through performance-related contracts with other utilities or consulting firms. The World Bank and other donors can provide assistance in establishing a trustworthy regulatory system and in addressing the foreign exchange problem. Finally, an arbitration procedure in a neutral country might be necessary in order to provide a credible process for resolving disagreements. However, political will is also the precondition for a successful participation of the private sector.
BIBLIOGRAPHY


ARGENTINA

The total installed capacity of the power sector in Argentina in 1989 was 15,157 MW, 42.7 percent of which came from hydraulic plants, with the remaining 57.3 percent distributed among steam, diesel, gas turbines, and nuclear plants.

Table 5: Available Capacity and Demand

<table>
<thead>
<tr>
<th>Year</th>
<th>Effective Power (MW)</th>
<th>Peak Demand (MW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1987</td>
<td>12,212</td>
<td>7,843</td>
</tr>
<tr>
<td>1988</td>
<td>12,665</td>
<td>7,740</td>
</tr>
<tr>
<td>1989</td>
<td>13,080</td>
<td>7,436</td>
</tr>
</tbody>
</table>

Generation equipment in general is not in good operating condition. Table 5 presents the relationship between effective capacity and peak demand in the interconnected system, allowing for a generous reserve margin during the last three years.

Table 6: Unavailability Rates

<table>
<thead>
<tr>
<th>Year</th>
<th>Unavailability</th>
</tr>
</thead>
<tbody>
<tr>
<td>1978</td>
<td>11.9 %</td>
</tr>
<tr>
<td>1979</td>
<td>17.2 %</td>
</tr>
<tr>
<td>1980</td>
<td>13.7 %</td>
</tr>
<tr>
<td>1981</td>
<td>11.1 %</td>
</tr>
<tr>
<td>1982</td>
<td>19.9 %</td>
</tr>
<tr>
<td>1983</td>
<td>18.3 %</td>
</tr>
<tr>
<td>1984</td>
<td>21.3 %</td>
</tr>
<tr>
<td>1985</td>
<td>21.7 %</td>
</tr>
<tr>
<td>1986</td>
<td>27.3 %</td>
</tr>
<tr>
<td>1987</td>
<td>27.2 %</td>
</tr>
<tr>
<td>1988</td>
<td>33.9 %</td>
</tr>
</tbody>
</table>

Unavailability of the installed capacity in the National Interconnected System reached a maximum level of 47 percent during April 1988. The monthly unavailability in particular plants reached levels of 70 percent and higher during 1987 and 1988. Table 6 presents the unavailability of the generation plants for the total interconnected system.

The transmission system consists of 7,563 km of 500 kV lines, 2,206 km of 220 kV lines and 11,643 km of 132 kV lines. No noticeable deficiencies have been registered in the operation of the transmission system. Construction delays and financial restrictions on maintenance of stocks of parts in the transmission system have been compensated by the slower growth in electricity demand. As a result, no problems have been registered in the operation of the transmission system.

Table 7: Electricity Losses

<table>
<thead>
<tr>
<th>Year</th>
<th>Losses</th>
</tr>
</thead>
<tbody>
<tr>
<td>1970</td>
<td>13.35 %</td>
</tr>
<tr>
<td>1975</td>
<td>13.72 %</td>
</tr>
<tr>
<td>1980</td>
<td>13.84 %</td>
</tr>
<tr>
<td>1985</td>
<td>21.09 %</td>
</tr>
<tr>
<td>1989</td>
<td>22.89 %</td>
</tr>
</tbody>
</table>

The subtransmission and distribution systems show serious deficiencies. Distribution services are provided by (a) four large companies: SEGBA (3.9 million users), Agua y Energía, EPEC (in Cordoba), and ESEBA (in Buenos Aires Province); (b) nineteen minor provincial utilities, and (c) a large number of mostly small regional cooperatives. Table 7 presents the evolution of losses in the largest distribution company of Argentina, SEGBA, serving
Buenos Aires. Losses have shown an upward trend over the last 20 years. An increasing portion of these losses are "nontechnical," especially from theft. The proportion of technical losses in the SEGBA system can be estimated between 9.5 and 13.5 percent. The loss ratio above 15 percent coincides with the initiation of the economic recession of 1982.

| Hydraulc | 11.8 | years |
| Steam | 17.1 | years |
| Gas turbines | 16.3 | years |
| Nuclear | 9.6 | years |

**Table 8: Average Ages of Generating Plant**

The high levels of unavailability of the thermal generation units are directly related to their old age—steam plants and gas turbines are more than 17 and 16 years of age, respectively—and lack of adequate preventive maintenance. Since 1983, budgetary restrictions caused a drop in maintenance expenditures for the electricity generation equipment in Argentina.

Maintenance of the generation infrastructure is planned and coordinated at the national level. The implementation is then left to the responsibility of the public utilities; they do not necessarily implement it. They face bureaucratic difficulties in a complex process of purchase requests. In addition, labor unions restrict the utilization of overtime work, and private firms can not be contracted for equipment maintenance. The result has been a drop in maintenance expenditures that can be observed in the yearly figures for SEGBA, which is the largest thermal generator.

Planned maintenance is coordinated for two-year periods with the participation of all companies in the National Interconnected System (NIS). Unfortunately, these plans are seldom executed. The main restrictions to timely and adequate maintenance have been (a) insufficient internal generation of funds to cover maintenance expenditures; (b) scarcity of organizational and technical skills because of low salary levels in the power sector; (c) labor union intervention to restrict outside contracting.

**Box 28: Main Causes of the Infrastructure Deterioration**

The distribution system has suffered from insufficient investment for rehabilitation and expansion of capacity. As a result, voltage reductions and outages are frequent. In addition, maintenance is deficient. Usually there is neither preventive nor predictive maintenance. Most maintenance is

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Year</td>
<td>SEGBA</td>
</tr>
<tr>
<td>1981</td>
<td>10,447</td>
</tr>
<tr>
<td>1982</td>
<td>6,927</td>
</tr>
<tr>
<td>1983</td>
<td>5,288</td>
</tr>
<tr>
<td>1984</td>
<td>5,418</td>
</tr>
<tr>
<td>1985</td>
<td>4,692</td>
</tr>
<tr>
<td>1986</td>
<td>6,321</td>
</tr>
<tr>
<td>1987</td>
<td>9,850</td>
</tr>
<tr>
<td>1988</td>
<td>19,633</td>
</tr>
<tr>
<td>1989</td>
<td>11,485</td>
</tr>
</tbody>
</table>

**Table 9: Maintenance Expenditures in Generation (US $ thousand)**

To summarize, the deterioration of the electricity supply infrastructure in Argentina has been due to:

- Cumbersome bureaucratic procedures;
- political appointment of managers;
- labor turmoil restricting overtime work and contracting of private maintenance services;
- low electricity tariffs;
- shortage of financial sources, and
- a drop in the quality of technical personnel in the 1980's.
No information is available regarding the backlog of maintenance for the transmission system, but it is certainly in better condition than the generation and distribution components. Some delays in the construction of additional capacity have been compensated by the slower growth of electricity demand resulting from the economic recession.

Table 11: Rehabilitation and Maintenance Budget for Generation (1989 US$ million)

<table>
<thead>
<tr>
<th>Year</th>
<th>Maintenance</th>
<th>Rehabilitation</th>
<th>Parts</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1990</td>
<td>31.44</td>
<td>61.57</td>
<td>28.14</td>
<td>141.15</td>
</tr>
<tr>
<td>1991</td>
<td>21.11</td>
<td>77.62</td>
<td>28.14</td>
<td>126.87</td>
</tr>
<tr>
<td>1992</td>
<td>19.95</td>
<td>86.69</td>
<td>28.14</td>
<td>135.78</td>
</tr>
<tr>
<td>1993</td>
<td>26.91</td>
<td>108.17</td>
<td>9.39</td>
<td>144.47</td>
</tr>
<tr>
<td>1994</td>
<td>23.41</td>
<td>69.68</td>
<td>9.39</td>
<td>102.48</td>
</tr>
<tr>
<td>1995</td>
<td>18.21</td>
<td>24.05</td>
<td>9.39</td>
<td>51.63</td>
</tr>
<tr>
<td>1996</td>
<td>22.60</td>
<td>13.32</td>
<td>9.39</td>
<td>33.31</td>
</tr>
<tr>
<td>1997</td>
<td>24.75</td>
<td></td>
<td>9.39</td>
<td>34.14</td>
</tr>
<tr>
<td>1998</td>
<td>24.43</td>
<td>1.37</td>
<td>9.39</td>
<td>35.19</td>
</tr>
<tr>
<td>1999</td>
<td>18.21</td>
<td></td>
<td>9.39</td>
<td>27.60</td>
</tr>
<tr>
<td>2000</td>
<td>22.60</td>
<td></td>
<td>9.39</td>
<td>31.92</td>
</tr>
<tr>
<td>TOTAL</td>
<td></td>
<td></td>
<td></td>
<td>975.70</td>
</tr>
</tbody>
</table>

A budget prepared by SEGBA for the 1990-94 period estimates annual expenditures of about US$125 million in expansion of the grid, rehabilitation, and replacement of the infrastructure in distribution. This budget for the largest distribution company illustrates the conditions and needs of the distribution equipment in the country.
Installed generation capacity in 1988 amounted to 4,015 MW. The hydroelectric component covers 56.2 percent; the remaining 43.8 percent is supplied by thermoelectric plants. This generation equipment is heterogeneous in age, with hydroelectric plants approaching 70 years of existence and thermal plants with more than 50 years together with new plants, all of them in good operating conditions. The availability of thermal plants is estimated at levels above 85 percent; hydraulic plants have availability factors above 97 percent.

The transmission system includes lines in 66, 110, 220, and 500 kV. Its age is also heterogeneous: there are lines in operation that were built in the 1940s. The statistics on losses show practically no variation over the years. That is an indicator of adequate operating conditions and gradual capacity expansion fitted to the demand growth. The figures on electricity not delivered because of transmission faults show an increment during 1985 and 1986 caused by politically motivated sabotage.

The distribution system is in the hands of 23 distribution companies. The percentage of losses, not including Chilectra Metropolitana, was 9.3 percent in 1987. The historical tendency with regard to distribution losses for Chilectra Metropolitana, serving the city of Santiago, show an increment by 1982. The increase was caused by an increment in electricity theft as a result of the economic recession. The actions implemented by the distribution company included consumer campaigns and improvements in the distribution network that allowed a return to the pre-1983 loss levels by 1989.

Table 12 presents the average heat rate registered in Chile for electricity generation. During the 11-year period, the figures show a continuous improvement toward a more efficient utilization of fossil fuels for electricity generation. This reinforces the notion of an efficient electric system in Chile.

The electricity infrastructure in generation, transmission, and distribution is kept in good operating condition. No specific backlog of maintenance and rehabilitation work can be identified.

Planned maintenance is 90 percent implemented. The staff assigned is highly qualified. Given the decentralized structure of the sector with important private participation, the implementation of adequate maintenance is mainly controlled by the desire of each generation and distribution company to maximize profits. Regulations exist regarding the quality and continuity of the service provided by distributing companies and the obligation of compensation payments by the generating companies in the case of rationing.
The expansion and operation of the entire electric system including generation, transmission, and distribution is in charge of a single public utility. The total installed generation capacity in 1990 is 494 MW, 87 percent in hydroelectric plants and the remainder in diesel plants. The installations are relatively young; the oldest hydroelectric plant initiated operations in 1964 and the oldest thermal plant in 1968.

The hydroelectric plants are kept in good operating condition. The thermal plants have been inactive during the last five years, but they have not been well maintained or thoroughly rehabilitated. They show early signs of power deterioration, unavailability, and high incidence of outages during trial runs. The two gas turbines installed in 1970 and 1972 are inoperative since 1984-85 because of damage sustained from their intensive operation preceding the commissioning of El Cajón. All the other thermal plants were mothballed and declared on "cold reserve" in 1985, when the new 300 MW hydroelectric plant El Cajón started operations. Thermal generation has been negligible since then.

The poor operating condition of the thermal plants in Honduras results from neglect caused by the excess capacity that has existed since the inauguration of El Cajón in 1985. Another factor affecting the status of infrastructure in thermal generation as well as transmission is the lack of teamwork at the management level and a communications gap between construction and operation personnel.

The transmission system consists of 1,758 km of lines in 34.5, 69, 138, and 230 kV, with 300 km more under construction. The status of this equipment is considered to be satisfactory, although some older and smaller substations and lines are overloaded.

The distribution system is the weakest component in the Honduran electric system. The characteristics of the distribution equipment are very heterogeneous in terms of age, type, manufacturer, maintenance, and so on. Almost every year more than 55 percent of the undelivered energy from outages can be attributed to the poor performance of the distribution system. Serious maintenance problems have arisen during the last five years from the restrictions on foreign purchases arising from foreign exchange shortages and successive delays in the approval of annual operating budgets by Congress. These factors, especially the latter, have prevented the timely hiring of personnel and acquisition of goods and services to effectively operate and maintain the existing electricity supply infrastructure.

By the end of 1993, the demand will equal the hydroelectric generation capacity, and thermal plants will have to come back on line. Because of this, plans are being made to put the Puerto Cortes (60 MW) and La Ceiba (26.6 MW) thermal plants in perfect operating condition. In addition Cañarveral hydroelectric plant, with 29 MW, will be rehabilitated. The Empresa Nacional de Energía Eléctrica has also requested financing to rehabilitate the distribution network in the seven most important urban centers in the country.

Maintenance is coordinated by the public utility responsible for providing electric service at the national level. Each generation plant has its own maintenance personnel and stock of spare parts. Maintenance problems have been caused by delays in the approval of the annual budget by Congress that prevented timely purchases of services and goods.
Table 13: Outage Frequency and Unserved Energy

<table>
<thead>
<tr>
<th>Year</th>
<th>Gen.</th>
<th>Tran.</th>
<th>Dist.</th>
<th>Total</th>
<th>Gen.</th>
<th>Tran.</th>
<th>Dist.</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1985</td>
<td>404</td>
<td>543</td>
<td>887</td>
<td>1834</td>
<td>621897</td>
<td>619245</td>
<td>773839</td>
<td>2014981</td>
</tr>
<tr>
<td>1986</td>
<td>171</td>
<td>460</td>
<td>941</td>
<td>1572</td>
<td>287023</td>
<td>554209</td>
<td>1044016</td>
<td>1818248</td>
</tr>
<tr>
<td>1987</td>
<td>178</td>
<td>446</td>
<td>702</td>
<td>1326</td>
<td>110271</td>
<td>251224</td>
<td>880684</td>
<td>1242179</td>
</tr>
<tr>
<td>1988</td>
<td>81</td>
<td>471</td>
<td>1019</td>
<td>1571</td>
<td>1405</td>
<td>527717</td>
<td>1002170</td>
<td>1531292</td>
</tr>
<tr>
<td>1989</td>
<td>98</td>
<td>352</td>
<td>1332</td>
<td>1782</td>
<td>175140</td>
<td>1103746</td>
<td>1450994</td>
<td>2729880</td>
</tr>
<tr>
<td>1990</td>
<td>44</td>
<td>358</td>
<td>844</td>
<td>1246</td>
<td>524</td>
<td>256537</td>
<td>878230</td>
<td>1135291</td>
</tr>
</tbody>
</table>

NOTE: Due to the flood of 1988, available records on outage data before 1985 were lost. The data for 1990 is up to August.
JAMAICA

The Jamaica Public Service Company Limited (JPSCo) is the only public utility in the country. Its power infrastructure in generation had a total capacity of 522 MW in 1990. Only 24 MW came from eight small hydroelectric plants; the remainder was from thermal plants, mainly steam units.

Table 14: Unavailability Rates

<table>
<thead>
<tr>
<th>Year</th>
<th>Unavailability</th>
</tr>
</thead>
<tbody>
<tr>
<td>1973</td>
<td>18.0 %</td>
</tr>
<tr>
<td>1974</td>
<td>16.5 %</td>
</tr>
<tr>
<td>1975</td>
<td>16.5 %</td>
</tr>
<tr>
<td>1976</td>
<td>2.3 %</td>
</tr>
<tr>
<td>1977</td>
<td>5.2 %</td>
</tr>
<tr>
<td>1978</td>
<td>10.8 %</td>
</tr>
<tr>
<td>1979</td>
<td>7.9 %</td>
</tr>
<tr>
<td>1980</td>
<td>20.6 %</td>
</tr>
<tr>
<td>1981</td>
<td>5.4 %</td>
</tr>
<tr>
<td>1982</td>
<td>30.7 %</td>
</tr>
<tr>
<td>1983</td>
<td>6.1 %</td>
</tr>
<tr>
<td>1984</td>
<td>6.1 %</td>
</tr>
<tr>
<td>1985</td>
<td>8.2 %</td>
</tr>
<tr>
<td>1986</td>
<td>6.7 %</td>
</tr>
<tr>
<td>1987</td>
<td>6.1 %</td>
</tr>
<tr>
<td>1988</td>
<td>7.5 %</td>
</tr>
<tr>
<td>1989</td>
<td>8.0 %</td>
</tr>
</tbody>
</table>

Note: % of installed capacity.

Table 14 presents the unavailability rates of the generation equipment of JPSCo. Unavailability was excessively high from 1973 to 1982, with a noticeable improvement for the 1983-89 period, when unavailability varied within a range of 6 to 8.2 percent.

The transmission system includes a total of 310 km in 138 kV and 738 km in 69 kV. The equipment has an average age above 20 years, with some of the lines in operation since 1951.

Table 15 shows JPSCo's statistics on average minutes lost per customer as a result of outages in the last nine years. The quality of the service provided by JPSCo improved over the above period in terms of energy not delivered per customer because of outages. The data also show that since 1985, about 60 percent of the electricity not supplied is caused by failures in the distribution system.

The oldest thermal units have been in operation since 1959. The most recent additions are two 18.5 MW gas turbines installed in 1990. The average age of the thermal units is about 20 years. But about 70 percent of the thermal generation is provided by units with more than 16 years of operation—that is, units nearing the end of their useful life. The age of the hydroelectric plants also varies widely. It includes one plant built in 1945 and three new ones installed in 1988. In addition, some industries have their own generation; their total installed capacity is 106 MW.
Total electric losses have been practically constant at about 20 percent since 1980. Low voltage conditions are frequent, evidence that the transmission and distribution equipment is overloaded.

The reason for the deterioration of the electric services and that of the power infrastructure experienced in the last decade is the inadequate timely maintenance of the generation equipment and the lack of capacity expansion of the entire generation, transmission, and distribution facilities.

Table 15: JPCo's Outages Times per Customer

<table>
<thead>
<tr>
<th>Year</th>
<th>Generation</th>
<th>Transmission</th>
<th>Distribution</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Minutes</td>
<td>Percent</td>
<td>Minutes</td>
<td>Percent</td>
</tr>
<tr>
<td>1982</td>
<td>610.8</td>
<td>86.8%</td>
<td>120.0</td>
<td>6.1%</td>
</tr>
<tr>
<td>1983</td>
<td>692.8</td>
<td>86.0%</td>
<td>145.1</td>
<td>6.1%</td>
</tr>
<tr>
<td>1984</td>
<td>1727.6</td>
<td>31.3%</td>
<td>1811.4</td>
<td>32.8%</td>
</tr>
<tr>
<td>1985</td>
<td>256.4</td>
<td>10.4%</td>
<td>787.1</td>
<td>31.9%</td>
</tr>
<tr>
<td>1986</td>
<td>165.1</td>
<td>9.4%</td>
<td>554.8</td>
<td>31.7%</td>
</tr>
<tr>
<td>1987</td>
<td>116.5</td>
<td>6.6%</td>
<td>583.9</td>
<td>33.2%</td>
</tr>
<tr>
<td>1988</td>
<td>151.3</td>
<td>10.3%</td>
<td>314.8</td>
<td>21.4%</td>
</tr>
<tr>
<td>1989</td>
<td>72.9</td>
<td>7.2%</td>
<td>353.7</td>
<td>34.6%</td>
</tr>
<tr>
<td>1990</td>
<td>148.8</td>
<td>11.4%</td>
<td>292.5</td>
<td>23.2%</td>
</tr>
</tbody>
</table>

Table 16: JPCo's Expenditures in Generation, Transmission & and Distribution (J$ thousand)

<table>
<thead>
<tr>
<th>Year</th>
<th>Gen.</th>
<th>Trans.</th>
<th>Dist.</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1981</td>
<td>10134</td>
<td>285</td>
<td>1739</td>
<td>12161</td>
</tr>
<tr>
<td>1982</td>
<td>8350</td>
<td>276</td>
<td>1338</td>
<td>10164</td>
</tr>
<tr>
<td>1983</td>
<td>11751</td>
<td>347</td>
<td>2035</td>
<td>14133</td>
</tr>
<tr>
<td>1984</td>
<td>13722</td>
<td>410</td>
<td>2409</td>
<td>16547</td>
</tr>
<tr>
<td>1985</td>
<td>26125</td>
<td>703</td>
<td>2682</td>
<td>29510</td>
</tr>
<tr>
<td>1986</td>
<td>19403</td>
<td>575</td>
<td>3294</td>
<td>23272</td>
</tr>
<tr>
<td>1987</td>
<td>27808</td>
<td>1224</td>
<td>3430</td>
<td>23763</td>
</tr>
<tr>
<td>1988</td>
<td>32432</td>
<td>6181</td>
<td>19342</td>
<td>57955</td>
</tr>
<tr>
<td>1989</td>
<td>34779</td>
<td>6469</td>
<td>13241</td>
<td>56489</td>
</tr>
<tr>
<td>1990</td>
<td>54279</td>
<td>5481</td>
<td>23169</td>
<td>85929</td>
</tr>
</tbody>
</table>

Between 1981 and 1988, electricity consumption increased by 36 percent, an annual rate of 3.9 percent. During this period available generation capacity slightly decreased. Reserve margins appear sufficient, but they are insufficient, considering the age of the generation units. These conditions have led to frequent postponing of necessary maintenance of the thermal generating units, rather than implementing a load shedding policy.

The overall picture is one of increasing total maintenance expenditures in the generation, transmission, and distribution infrastructure, as illustrated in the following table.

This apparent increment in maintenance expenditures might not be real. It is not clear from the data source whether the figures are expressed in constant or nominal terms.

Another data source indicates that total expenditures of the power sector in personnel and materials in Jamaica, expressed in constant 1989 US dollars, were $37 million in 1977. Ten years later, in 1987, they remain the same.

The above information reinforces the initial assertion that the deterioration of the quality of the electric services and of the power infrastructure in Jamaica in the last decade has resulted from failing and insufficient capacity at the generation level and insufficient capacity of the transmission and distribution network.
Data is not available on the average heat rate of thermal generators in Jamaica. About 70 percent of the thermal generation is provided by units with more than 16 years old. As a reference, it can be mentioned here that plans to overhaul four steam units at Old Harbour Power Station estimate heat rate improvement as follows.

There is a well-organized maintenance management structure in the power sector. Nevertheless, the desire to avoid load shedding or to avoid approaching critical reserve margin levels has led to postponing planned maintenance.

Countermeasures intended are to improve expansion planning of the power sector to identify the necessary investment and to standardize distribution equipment.

The Jamaica Public Service Company Limited has been granted total funds of US$83.6 million by the Interamerican Development Bank for rehabilitation and expansion of the generation, transmission, and distribution infrastructure in the electric sector. About US$43 million of the fund are earmarked for rehabilitation of thermal generating units, and approximately US$5 million for rehabilitation of hydroelectric generation. This program also includes rehabilitation of the transmission and distribution equipment.
The electric system is operated by the Guyana Electricity Corporation (GEC), a public utility. In addition, there are two industries supplying their own electricity—the Guymine system, serving the bauxite industry, interconnected to the GEC system, and Guysuco, a sugar company with its own isolated system. The GEC system consists of 10 thermal generation plants in two separate 69 kV grids, with generation at 50 and 60 Hz, interconnected through a frequency converter station. The total installed capacity at GEC was 84.8 MW in 1990. The largest plant includes 30 MW of installed capacity, supplied by three steam units. The rest of the plants have smaller diesel generators that add up to 55 percent of the total installed capacity.

The average age of the diesel generators is about 15 years; the steam units are about 25 years old. The generation equipment in general is in very poor condition. The available capacity in 1990 was only 32.8 MW, corresponding to 39 percent availability. Table 18 presents the unavailability rates of generation equipment.

**Table 18: Unavailability Rates**

<table>
<thead>
<tr>
<th>Year</th>
<th>Unavailability</th>
</tr>
</thead>
<tbody>
<tr>
<td>1980</td>
<td>24.7 %</td>
</tr>
<tr>
<td>1981</td>
<td>43.9 %</td>
</tr>
<tr>
<td>1982</td>
<td>61.4 %</td>
</tr>
<tr>
<td>1983</td>
<td>57.0 %</td>
</tr>
<tr>
<td>1984</td>
<td>50.0 %</td>
</tr>
<tr>
<td>1985</td>
<td>45.5 %</td>
</tr>
<tr>
<td>1986</td>
<td>46.0 %</td>
</tr>
<tr>
<td>1987</td>
<td>55.9 %</td>
</tr>
<tr>
<td>1988</td>
<td>59.6 %</td>
</tr>
<tr>
<td>1989</td>
<td>69.1 %</td>
</tr>
<tr>
<td>1990</td>
<td>67.2 %</td>
</tr>
</tbody>
</table>

Note: % of Installed Capacity.

There are 208 km of transmission lines in 69 kV in the two isolated systems. The subtransmission system or rural grid includes a total of 444 km of lines in 13.8, 11.0, and 4.0 kV. The average age of the 69 kV lines is 10 years; that of the rural grid is 22 years.

Technical losses are estimated at about 15 percent for the last ten years. "Nontechnical" losses vary between 10 and 20 percent. These are indicators of poor conditions in the transmission and distribution system, as well as of inefficient commercial practices.

The situation of the electric sector in Guyana is typical of an underdeveloped national economy in crisis: generation equipment shows high unavailability levels, technical and "nontechnical" losses are about 35 percent, and outage rates of the transmission and distribution components are above 50 percent.

The immediate reason for the deficiencies is the lack of proper maintenance practices, particularly important given the age of the units. National economic difficulties have created scarcities of foreign exchange and low electric tariffs. The scarcity of funds for the electric sector, with no investment to increase capacity, has brought conditions of a chronic deficit in generation capacity. The insufficient or nonexistent reserve margin led to postponement of maintenance, utilization of reconditioned spares, and cannibalization of other units.

Because high management has feared aggravating the deficit in generating capacity by taking facilities off line for maintenance, it took decisions to withdraw a unit for
maintenance away from plant personnel. Low electric tariffs resulted in low wages, high staff turnover, and unavailability of personnel with suitable skills in the electric sector. Financial constraints in the sector and scarce foreign exchange in the economy have meant delays and restrictions in the purchase of spare parts.

Table 19: Thermal Efficiency

<table>
<thead>
<tr>
<th>Year</th>
<th>Efficiency (kWh/gal)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1980</td>
<td>11.93</td>
</tr>
<tr>
<td>1981</td>
<td>12.34</td>
</tr>
<tr>
<td>1982</td>
<td>11.92</td>
</tr>
<tr>
<td>1983</td>
<td>11.99</td>
</tr>
<tr>
<td>1984</td>
<td>12.22</td>
</tr>
<tr>
<td>1985</td>
<td>12.22</td>
</tr>
<tr>
<td>1986</td>
<td>12.19</td>
</tr>
<tr>
<td>1987</td>
<td>11.94</td>
</tr>
<tr>
<td>1988</td>
<td>11.77</td>
</tr>
<tr>
<td>1989</td>
<td>11.44</td>
</tr>
<tr>
<td>1990</td>
<td>13.61</td>
</tr>
</tbody>
</table>

The entire generation equipment in Guyana is thermal. Efficiency figures for the 1980-90 period show a variation between 11.44 kWh per gallon of fuel in 1989 and 13.61 kWh per gallon of fuel in 1990. No historical tendency to either improve or deteriorate the average fuel efficiency in electricity generation can be noticed. Table 19 presents the available annual statistics.

No specific rehabilitation plans have been formulated for the next few years, although clearly the entire power infrastructure is in badly need of such a program. The feasibility of implementing overhaul and rehabilitation of the electricity infrastructure is basically dependent on the availability of external credit sources to finance the necessary expenditures.
Total installed generation capacity in 1991 was 17,416 MW. The hydroelectric plants account to 57 percent; the remainder is distributed among the thermal plants: 27 percent steam generators, 15 percent gas turbines, and 1 percent diesel units.

The generation equipment, particularly the hydroelectric plants, is in general relatively new. The average age of the hydraulic plants is 12.5 years and that of the thermal plants 15 years. With the operation of the hydroelectric plant El Guri in 1985, with ten 630 MW units, the available generation capacity more than doubled the total demand. Under these conditions, the availability of the generation units is not critical.

It is observed that the forced outage rates (FOR) registered for the hydroelectric plants are very small, below 2 percent in all cases, reaching minimum levels of 0.05 percent. The record for the thermal plants is very heterogeneous, with plants with a FOR of 74 percent and other plants with FOR levels as low as 10 percent.

The thermal plants, because of the large reserve margin, are not under pressure to reduce maintenance periods and increase availability. This could explain at least partly the relatively high FOR levels recorded.

The transmission system consists of 1,249 km of 765 kV lines, 2,090 km in 400 kV and 3,638 km in 230 kV. The 1989 figures show outage levels of 2.38 percent for the 765 kV lines, 24.81 percent for the 400 kV lines and 28.73 percent for the 230 kV transmission lines (excluding the 1000 km of 230 kV lines operated by CADAFe). Such outage levels may appear outrageously high at first sight, but they include long periods of planned maintenance. Again, this lack of urgency in reducing the maintenance and repair periods stems from the large reserve margin in generation capacity.

Total annual levels electric losses have been at about 15 percent since 1983, although levels as low as 11.4 percent were recorded in the 1970s. The increase in losses may result in part from the increase in load transfers the system experienced during the 1980s. The unusually large reserve margin in generation equipment has caused a lax attitude toward maintenance of the generation equipment. The very low tariff for secondary energy, generated by the hydroelectric plants, results in a lack of financial incentives to control technical and nontechnical losses.

In addition, the power sector in Venezuela shows severe financial constraints. Flow of Funds figures register deficits, that is Decreases in Working Capital, during 1979, 1980, 1981, 1983, 1985, and 1988. The large investments in construction of hydroelectric plants have resulted in a heavy financial load to the sector. In consequence, it is not surprising that the electric sector has sharply curtailed current expenditures on maintenance of the thermal generation, transmission, and distribution infrastructure.

The electric system in Venezuela was equally based on thermal and hydroelectric generation until 1980. Since then it has become more dependent on hydroelectricity. In 1990, thermal generation amounted to
10,535 GWh, whereas hydroelectric generation reached a total of 43,742 GWh.

No coordination of maintenance at the national level has existed since 1984. The unusually large reserve margin has prevented supply problems, but these problems might arise if the lax attitude toward maintenance persists.

Even though the thermal generation covers a smaller proportion of total generation, it still remains an important component in absolute value. The average heat rate registered shows a general tendency to higher efficiency levels.

Plans exist to rehabilitate a total of 274 MW of thermal generating units until 1996. In addition, CADAFE will install gas burners in three 400 MW units presently operating with bunker oil.

Table 2A: Average Heat Rates

<table>
<thead>
<tr>
<th>Year</th>
<th>kcal/kWh</th>
<th>Year</th>
<th>kcal/kWh</th>
</tr>
</thead>
<tbody>
<tr>
<td>1971</td>
<td>3444</td>
<td>1981</td>
<td>2844</td>
</tr>
<tr>
<td>1972</td>
<td>3141</td>
<td>1982</td>
<td>2767</td>
</tr>
<tr>
<td>1973</td>
<td>3150</td>
<td>1983</td>
<td>2847</td>
</tr>
<tr>
<td>1974</td>
<td>3232</td>
<td>1984</td>
<td>2950</td>
</tr>
<tr>
<td>1975</td>
<td>4191</td>
<td>1985</td>
<td>2805</td>
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<td>1976</td>
<td>4266</td>
<td>1986</td>
<td>2751</td>
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<td>1977</td>
<td>3765</td>
<td>1987</td>
<td>2650</td>
</tr>
<tr>
<td>1978</td>
<td>3894</td>
<td>1988</td>
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<td>3332</td>
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</tr>
<tr>
<td>1980</td>
<td>2856</td>
<td>1990</td>
<td>2451</td>
</tr>
</tbody>
</table>