PN-ABA-933

ORNL-643

OAK RIDGE
NATIONAL
LABORATORY

MARTIN MARIETTA

The Impacts of Inadequate Electricity Supply in Developing Countries

Donald W. Jones
Arun P. [illegible]dhvi
Edward [illegible]man

OPERATED BY
MARTIN MARIETTA ENERGY SYSTEMS INC.
FOR THE UNITED STATES
DEPARTMENT OF ENERGY

Printed in the United States of America. Available from
National Technical Information Service
U.S. Department of Commerce
5285 Port Royal Road, Springfield, Virginia 22161
NTIS price codes—Printed Copy: A04, Microfiche A01

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

ORNL-6436

THE IMPACTS OF INADEQUATE ELECTRICITY SUPPLY IN DEVELOPING COUNTRIES

Donald W. Jones
Energy Division
Oak Ridge National Laboratory
Oak Ridge, Tennessee

Arun P. Sanghvi
Hagler, Bailly & Company
Washington, D. C.

Edward L. Hillsman
Energy Division
Oak Ridge National Laboratory
Oak Ridge, Tennessee

Date Published - August 1988

Prepared for the
Office of Energy, Bureau for Science and Technology,
U.S.A.I.D.,
under contract no. BST-5728-P-ER-4257-01,
under Interagency Agreement DOE No. 1637-1637-A1,
as part of the Energy Policy Development and Conservation
Project

Prepared by the
Oak Ridge National Laboratory
Oak Ridge, Tennessee 37831
Operated by
MARTIN MARIETTA ENERGY SYSTEMS, INC.,
FOR THE
U. S. DEPARTMENT OF ENERGY
under Contract No. DE-AC05-84OR21400

TABLE OF CONTENTS

EXECUTIVE SUMMARY v

ABSTRACT ix

1. INTRODUCTION 1

2. ELECTRIC POWER AND ECONOMIC DEVELOPMENT 3
   2.1 ENERGY AND ECONOMIC DEVELOPMENT 3
   2.2 ELECTRICITY AND DEVELOPMENT 3
      2.2.1 Electricity Uses in Developing Countries 4
      2.2.2 Characteristics of Electricity Supply 7
   2.3 ENVIRONMENTAL IMPACTS OF ELECTRICITY GENERATION 7

3. ELECTRICITY RELIABILITY AND QUALITY AS A DEVELOPMENT ISSUES . . . 13
   3.1 MEASURING THE IMPACTS OF POWER SHORTAGES 14
   3.2 DOLLAR MAGNITUDE OF ECONOMIC IMPACTS: SOME SPECIFIC COUNTRY EXAMPLES 16
      3.2.1 India 16
      3.2.2 Pakistan 21
      3.2.3 Other Countries 27
   3.3 AN OVERALL ASSESSMENT OF RELIABILITY COSTS 27

4. IMPACTS OF ELECTRICITY SHORTAGES 33
   4.1 DEFINING SHORTAGE 33
   4.2 SOCIOECONOMIC IMPACTS 34
      4.2.1 General Findings 34
      4.2.2 Some Specific Examples 35
      4.2.3 Relevance of the Evidence to Capital Shortages for Power. 38

5. COSTS OF IMPROVING ELECTRICITY SERVICES IN DEVELOPING COUNTRIES . 39
   5.1 THE SIZE OF THE INVESTMENTS 40
   5.2 SECTORAL INVESTMENT TRADE-OFFS 42
   5.3 BORROWING FOR MAJOR POWER SECTOR INVESTMENT 47

6. CONCLUSIONS 49

REFERENCES 51

LIST OF TABLES

Table

1 Effects of electricity generation on SO_x emissions 11

2 Order-of magnitude estimates of power shortages on Indian industry 17

3 Production losses due to power shortages in India (1983-84) 18

4 Use of captive power sets in industry, India 1983-84. 20

5 Impact of outages on key national economic parameters by type of industry, Pakistan 1983-4 22

6 Components of loadshedding cost per kilowatt hour by type of industry and process (Rs./kWh) Pakistan 1983-4 24

7 Components of unplanned outages cost per kilowatt hour by type of industry and process, Pakistan, 1983-4 25

8 Extent of self-generation of power during outages and generator costs per kilowatt hour by type of industry and process, Pakistan, 1983-4 26

9 Costs of power shortages in selected developing countries (1978 $). 28

10 Power sector investment plans (in U.S. $) 41

11 Prominence of the power sector in national public investment . 45

12 Government capital expenditure patterns on power 46

13 Official loans, grants and credits to the power sector 47

EXECUTIVE SUMMARY

Electricity systems throughout the Third World are facing operational crises. Demand growth has been outstripping capacity growth for several years, and systems have deteriorated under the increased stresses. Utilities have been unable, financially and managerially, to expand generating capacity and maintain current equipment. Problems with electricity reliability and quality have imposed real costs on Third World economies. In the early 1980s, India and Pakistan were losing 1.5% to 1.8% of their gross national products (GNP), just in their industrial sectors (including the agricultural sector in India) from electricity reliability and quality problems. Among the losses in Pakistan was 4.2% of the nation's foreign exchange earnings. These estimates exclude losses in the residential, commercial, and government sectors. How representative India's and Pakistan's economic losses from unreliable power are of all developing countries is simply unknown. The fact that Indian and Pakistani authorities consider these losses to be serious, as do authorities in a number of other developing countries regarding their own losses, suggests that, proportionally, the Indian and Pakistani problems are not totally anomalous.

This trend is widely projected to continue over the next decade, with potentially disastrous consequences for electricity supply and to the detriment of income growth and economic development. This paper examines the costs on both sides: the income and development losses that could be expected to accompany unreliable, or unavailable, electricity supply, and the effects on national employment, interest rates, and investment of attempting to make the capital expenditures to upgrade utility systems so they can satisfy the demands made of them.

The economic costs of unreliable power must be distinguished from the costs of failing to meet future power demands under current conditions. The latter type of cost is quite problematic because the projections of unserved demand are based on consumption at highly subsidized prices. If prices were raised to reflect true costs, demand growth could be cut in half. As for evaluating the cost of not serving the remainder of the projected unserved demand, the real cost of capital must be considered. The unavailability of foreign exchange at interest rates that potential borrowers are willing to pay may simply represent the existence of substantial risk premia in developing country power sector lending. Consequently, the assessment of costs to consumers of their unserved power demands that are based on excessively low electricity and capital prices would be overstated.

Much more real are the economic costs imposed by unreliability of actual electricity supply. Planned load shedding, unplanned electricity

electricity has been found to impose economic losses on national economies in the range of 1.5% to 1.8% of Gross Domestic Product (GDP) in the two countries for which dates are available. Included in these costs, it has been found that Pakistan in recent years has lost as much as 4.2%, and possibly more, of its foreign exchange earnings from exports because of reliability problems. These static costs understate the dynamic costs that may be imposed. The affected industrial sectors are often the greatest savers in the country, and the reductions in profits would reduce the rate of capital accumulation for the future as well as depress current income.

Although we are skeptical of assigning costs to the projections of so-called unserved demand for electricity, there are costs to the development process of not having electricity in particular activities. Child health programs that rely on refrigerated vaccines are set back when electricity is unavailable, and education has been found to suffer from absence of lighting for reading. Both can have farreaching effects on the development of human capital. Livestock health programs reliant on vaccines have suffered similarly.

The aggregate cost of expanding generation and transmission capacity sufficiently to alleviate the problem, just during the period 1985-1994, has been estimated to be as high as $520 billion in 1985 prices, at a time when the world capital market is tight. Expansion of coal-fired capacity could cause major increases in atmospheric emissions unless cleaner technology is used. Cleaner generation technologies would raise capital costs further.

Examination of the power sector expansion plans of a number of prominent developing countries indicates that, while quantification is difficult, the investments are large enough to pose macroeconomic problems. There is not enough slack in budgets for governments and multilateral and bilateral lenders to try to avoid large additional borrowings by shifting funds from other development sectors such as agriculture and transportation. Those other programs would be gutted, and the funds obtained that way would in a number of instances be insufficient to meet the power investments anyway. Additional borrowings of $1 billion to $11 billion per year for five years for power sector investments, based on existing development plans, would pose repayment problems for the foreign exchange components, and depending on domestic macroeconomic policies pursued, could precipitate domestic real interest rate increases to the range of 50% per year. If policies stimulated inflation as well, the nominal interest rates could rise even further. Attendant currency overvaluation could hurt exporting and the ability to meet debt payments on power sector borrowing. It was noted above that price reform could cut the projected demand growth by half. Even cutting the projected investments by half leaves serious capital problems for the macroeconomies.

Many of the countries whose electricity systems are in trouble are far from blameless. They have used electricity systems as instruments of other development and/or welfare policies, nearly universally have sold electricity at prices below generation costs, have tolerated governmental interference in system organization and operation, and have fostered haphazard management of government-owned utilities. Nonetheless, there is now a clear and pressing problem, and most of the countries are attempting to remedy some, if not all, of their deficiencies.

ABSTRACT

Many developing countries are experiencing growth in demand for electricity that exceeds their ability to increase generation capacity. Unreliable electricity supplies and unserved demands are consequences. Costs of low quality electricity supply, or unreliable supplies, in manufacturing sectors alone, have been estimated to be as high of 1.8% of gross national product in Pakistan and India in the early 1980s. Losses in the commercial sector, agriculture, and consumer surplus losses in households would raise the loss estimates. Continued expansion of generation capacity is unlikely to be a viable option. Expansion costs during the 1985-1994 period have been estimated at $520 billion in 1985 prices. This amount does not appear to be available in world capital markets, and rearrangement of national development expenditures to accommodate further power sector spending is constrained by the fact that the power sector typically claims 25% to 40% of government capital expenditures already.

1. INTRODUCTION

Electricity supply in developing countries has encountered difficulties in the past few years, and recently reports of crisis-level problems have surfaced. Demand for electricity has been growing by 6% to 12% per year in some countries while supply capabilities have been lagging behind by a percentage point or two per year as the international capital market has tightened. The reliability of existing power systems has deteriorated as they have been overstretched, and power outages and other reliability problems, such as voltage stability and frequency, have caused economic losses.

This paper assesses the character and magnitude of the impacts of electricity system unreliability and of unfilled demand for electricity on income and development in developing countries. Strictly speaking, power system reliability refers to percent of the time electricity consumers can get power when they want it. Closely related to that strict definition of reliability are questions of the quality of the electricity supplied: the stability of voltage and frequency, which, if not maintained within fairly tight tolerances, can burn out electric motors and damage the performance of precision equipment. Throughout the paper, we often refer to both the availability and quality problems under the name of unreliability problems. Poor reliability and outright shortages exact their costs in terms of foregone current income and foregone long-term development. Curing or reducing the problem has its costs as well, in terms of the capital required for system expansions, improvements, and/or rehabilitations.

The following section discusses the role energy in general and electricity in particular play in economic development. In the third section, the costs of poor reliability of a power system are examined, both conceptually and empirically. The impacts of electricity shortages are examined in the fourth section. This is a more elusive issue because of the part that improper electricity pricing has played in exacerbating the power problem by encouraging demand while reducing utilities' financial ability to expand services. These sections address the costs of inadequate electricity supply in developing countries. The fifth section studies the costs and impacts of making the investments currently planned or recommended to meet the growing power demands. This issue itself has two sides. There may be large, additional foreign borrowing costs to the countries unless other development investments are foregone. We explore the costs of additional borrowing of the magnitude entailed, as well as the costs of reducing investment in other development sectors that might be required to reduce the impacts of increased borrowing.

Despite the widespread incidence of the developing country electricity supply problem, detailed information on the subject is available only for a few countries. Consequently, it is not possible to determine a single, total estimate for the value of losses from unreliable electricity for all developing countries. Associated foreign

exchange losses, opportunity costs of not meeting future power demands, the investment required to fulfill those demands also cannot be determined directly. As an alternative, we present the available evidence on economic losses from unreliable electricity supply and review the investment forecasts of a number of prominent countries. From that information, we offer ranges of the magnitudes of the various costs.

2. ELECTRIC POWER AND ECONOMIC DEVELOPMENT

2.1 ENERGY AND ECONOMIC DEVELOPMENT

Economic development is a multifaceted process, but one way it can be thought of is as the substitution of more mechanized, energy-intensive production processes for less routinized, less mechanized, less energized production processes. Metal and plastics replace wood and ropes in machines, and modern energy forms--fossil fuels and electricity--displace traditional energy forms--animate power and biomass fuels. Not only does the structure of production alter energy use, but changing consumption patterns do as well. A larger number of the products made in the new production structures require energy for their operation, either directly or indirectly. Urbanization, which accompanies the evolution of production structure but is distinct from it, fosters additional energy use as well as substitutions of modern energy for traditional energy. Overall, during the long term of economic development, a 1% increase in per capita income is associated with a 1% to 1.3% increase in energy use per capita, but with as much as a 2% increase in modern energy use per capita (Jones, 1987b).

2.2 ELECTRICITY AND DEVELOPMENT

The residential and commercial sectors consume relatively more electricity in most developing countries than those sectors do in the industrialized countries presently, and more than was the case in the industrialized countries during the early phases of the development of the electric power industry (Jones, 1987a). Electricity provides a relatively small share of the modern energy supply in most developing countries. Electric power provides less energy to industrial uses than do fossil fuels--coal and petroleum products. Electric power is well-tailored to meet certain classes of industrial energy requirements, and when its supply is erratic, industrial users lose or fail to make money.

It is legitimate to ask whether electricity-using development uses the resources that are abundant in developing countries, or whether electrification of production will contribute materially to employment. Direct and reliable evidence from developing countries is scarce, but a detailed study of thirty-five manufacturing sectors in the United States, for the years 1958-1974, has estimated the patterns of technical change as they use or save electricity and labor, among other inputs. Technical change in eighteen sectors was both electricity-using and labor-using; only five sectors with electricity-using technical change experienced labor-saving technical change (Jorgenson and Fraumeni, 1981). This suggests that in a majority of industries, particularly in manufacturing, electrical innovations have not been simply substituting for labor. It would not be surprising if this pattern of innovation carried over to the developing countries, where labor is abundant and there are strong, economic incentives to use it. In fact, with relatively cheaper labor and relatively more expensive electricity, the employment-enhancing

effect of the American pattern of technical change should be even stronger in developing countries.

Developmentally, electricity's importance also lies in its ability to supply the quality of life goods that people have come to expect that development will bring them -- the comfort of air conditioned office buildings and residences, the convenience of electric lighting, the assistance of household appliances. The remainder of this section describes the uses to which electricity is put in developing countries and the characteristics of electricity that make it a special energy form.

2.2.1 Electricity Uses in Developing Countries

It is useful to consider the use of electricity both from the perspective of the development planner, and from that of the end-user. We have noted that electricity supplies a relatively small share of industrial energy in developing countries. It is also true that in the manufacture of many products, combustion of fuels can be substituted for electricity in many processes. However, it is equally true that in most products for which electricity is used, there remain some processes in which electricity has no substitute. In some instances where there are substitute processes for the ones that use electricity, the resulting product is different and no longer of high enough quality to compete in international markets, i.e., is no longer of export quality.

Development involves improvements in working and living conditions and in the quality of life, as well as increased production of goods and services. These uses of electricity tend to be concentrated in commercial, government, and residential activity, where many of the productivity improvements are indirect. The mass technologies for these improvements require electricity to substitute for human labor, to provide comfort or convenience, or to perform new functions that people desire. People want these services, and most governments have goals and programs to increase the number of their citizens who have access to electricity. As a result, the use of electricity to improve the quality of life is increasing relative to industrial, agricultural, or direct productive uses in most if not all countries. These trends will make the performance of electric power systems and the pricing of electricity services increasingly important to the political and economic stability of governments in developing countries.

From the perspective of the end user, electricity can be used to provide five generic classes of service: shaft power, light, heat, electronics, and electrochemical. Each of these classes encompasses a myriad of actual uses. Other energy sources, usually requiring petroleum products, can substitute for electricity in the first three of these classes; services in the remaining two classes are inherently electrical. Substitutes, when technically feasible, usually require some change in the end-use equipment as well as in the form of energy.

Although other forms of end-use energy are thermodynamically more efficient, users generally find that substitutes for electricity in the first three classes provide service of lower quality (convenience, maintenance requirements). The user of the service may find this lower quality acceptable if the cost of substitutes is sufficiently low, or may accept the lower quality if electricity is not available. However, there is evidence that users in developing countries value electricity very highly when it is available to provide these services, and that they will make substantial sacrifices to avail themselves of some of these.

The following paragraphs examine the five major classes of service in greater detail, noting both productive and quality-of-life uses.

Shaft power. This class includes all services that use a rotating shaft to drive equipment--pumps (irrigation, municipal water supply, cooling many industrial processes, powering flows of liquids and gases in many industrial processes), compressors (refrigeration and air-conditioning technologies are almost entirely shaft driven), grinding and crushing (ore, refining, cement production, agricultural processing), and machines in general (rollers, industrial tools, hand tools, residential labor-saving devices, fans, copying machines and other office equipment). Electric motors are the technology for converting electricity to shaft power. In 1980, industrial electric motors consumed 43% of all electricity in Brazil, and electric motors in other sectors consumed another 7%; in 1977, electric motors in the industrial and commercial sectors consumed 61% of total U.S. electricity, and residential motors would add to the total motor share (Geller, 1984, p. 14 and p. 25; U.S. Energy Information Administration, 1986, p. 193).

The ability to substitute other forms of energy for electricity depends on the specific end-use. Diesel engines are a proven technology for providing shaft power, and they power irrigation pumps and machinery in many small industries where electricity service is unavailable. Diesel engines generally require greater maintenance by the user than does grid-supplied electricity, and they are less convenient to control; they also require a fuel source, which in many developing countries means importing petroleum or its products, and transporting fuel to remote locations for use. Otherwise, diesel engines are a suitable substitute in many applications. Cooling can be accomplished without shaft power by burning fuel to drive absorption chillers, but the equipment is less reliable and is economically competitive only when electricity is not available from a grid. Falling water can power equipment when sufficient head exists and equipment can be used at the site; if the hydraulic resource is remote, it is usually more attractive to use the falling water to generate electricity and transmit it to where shaft power is needed.

In general, as the number of machines in an area increases, it becomes more attractive from the point of convenience, environmental quality, and often cost, to begin to substitute electricity for other energy forms.

Services provided by very small electric motors--such as those in office machines, labor-saving devices, hand tools, and fans--are difficult to provide by other forms of commercial energy, and generally require human labor as a substitute.

Electric motors are sensitive to power quality and can be damaged if voltage varies beyond the equipment design tolerances. Recent developments in power electronics may reduce this vulnerability as manufacturers incorporate them into new generations of motors.

Light. This includes lights for residential, commercial, industrial, office and public (street lighting) uses, and the full range of human activities which require light. Lighting contributed disproportionately to residential and commercial consumption, which is growing more rapidly than industrial consumption in many countries.

The hallmarks of electric lighting are its cleanliness, convenience, and quality, and the substitutes for electricity in this application are generally inferior. Substitutes include daylight, which is not always available; kerosene lamps, which produce poorer quality light with less convenience, and often require imported fuel; firewood, as a byproduct of cooking or heating, which is unevenly distributed and of limited quality and convenience; and natural gas in some public and other large applications. However, natural gas may require a large investment in gas supply and distribution equipment, comparable in size to that for electricity services.

The quality of light delivered can be degraded by power quality, with the effects seen in the amount, stability, and color of light. Lighting services are often time-dependent; a power failure can deny customers not only the lighting service but also the applications that light permits.

Heat. This includes cooking, water heating, space heating, clothes ironing, and industrial heating of material (welding, drying, setting of plastics or chemicals, electric furnaces for primary metals). Cooling, which is generally more important than heating in the commercial and residential sectors of developing countries, is generally provided by shaft power or, less often, by non-electric technologies.

In almost every case, other forms of energy may be substituted to provide heating services. The cleanliness of electricity can be an important consideration in industrial applications, where contamination of materials or product must be avoided. Cleanliness and convenience are important to the quality of life and working conditions, and the combustion of fuel provides poorer service on these measures in applications such as ironing and water heating. With the exception of some welding equipment, these applications are less sensitive to power quality than other classes of service. Outages have a more serious effect than power quality on the quality of the final service.

Electronics. This includes telecommunications, microprocessors, process controls, computers, much instrumentation, and the uses of this equipment. Precision tools incorporate this technology to ensure precision of operation or results. An increasing fraction of modern medical services depends upon electronic technology. Many technologies for improving the efficiency of fuel combustion and the efficiency of energy end use require microprocessors. The "modern" sector modernizes largely by using these technologies to improve productivity or provide additional types of service. Precision control of production processes, necessary to produce exports competitive in the world market, requires the use of electronic controls to match the precision of competitors who use them. For the middle and upper classes, improvement in the quality of life is increasingly defined in terms of access to consumer electronic equipment.

There is no substitute for electricity in these applications. Although many of these services require only small amounts of electricity, they generally require that it be of high quality. A large proportion of these services is time-dependent, especially among residential and commercial uses, so that a power failure causes a loss of service which cannot be recovered when power is restored. In developed countries, many users of these services provide back-up sources of power from batteries or generators.

Electrochemical. This includes electroplating, aluminum refining, some photocopying, and some chemical processing. These are very specialized end uses, almost entirely industrial. There is no substitute for electricity in these applications.

2.2.2 Characteristics of Electricity Supply

Electricity delivered to the end user is energy supplied with some degree of reliability (continuity of service, and ability to supply larger or smaller amounts of energy as equipment is switched on or off), and some degree of quality or uniformity over time and space (voltage, current, frequency). Production of electric energy is straightforward, but reliable delivery of electric energy, of expected quality, to the point of use requires a high degree of planning, maintenance, and quality control.

2.3 ENVIRONMENTAL IMPACTS OF ELECTRICITY GENERATION

One of the lessons of the past thirty years in the United States and developing countries alike is that electric power production has a dark side. Electricity generation is a source of various negative environmental effects, most of which can be controlled, but at a cost (OECD, 1985). The environmental costs begin with the fuel production and continue through generation, transmission and distribution, and end use. For thermal generation, coal mining has important environmental impacts, including acid mine drainage, ecosystem damage, mine waste disposal issues, deforestation, and land reclamation issues. Oil and gas

production involve problems of blowouts and spills, hydrocarbon emissions, hydrogen sulfide production and trace metal emissions.

Major environmental problems with electricity generation from fossil fuels are air emissions of sulfur and nitrogen oxides, carbon monoxide and dioxide, hydrocarbons, trace elements, particulates, and radionucleides. The carbon dioxide emissions are central to important questions about induced global climatic change. Generation with coal releases about 25% more CO_2 than oil and about twice as much as natural gas, and techniques for controlling CO_2 emissions are not yet economic. Many of these emittants pose human health hazards as well, although knowledge of physiological and pathological reactions is still limited. Unlike oil- or gas-fired generation, coal-fired generation produces considerable ash wastes that must be disposed of.

Transportation and storage of coal entail risks from accidents, dust emissions, water pollution from storage piles. Coal slurry pipelines require water which must be treated subsequently. Oil transportation entails risks of spills from accidental and operational discharges and from pipeline leaks and explosions. Movement of the generated electricity also has environmental impacts. High voltage transmission lines pose land requirements and impose visual and noise impacts as well as air traffic hazards, communications interference, ozone generation, and fire risks.

Generation of electricity from renewables is not without substantial environmental impacts. Dams and lakes associated with hydroelectric generation can bring tourism and recreational activities, but can have adverse impacts on the hydrological cycle, water quality, riverine ecology, and fish migration. They also can impose losses of potentially productive land and displacement of populations. Use of low-head hydro may reduce land losses as well as obviate the need for high voltage transmission lines.

Geothermal generation can involve steam releases, noises up to 120 decibels in the vicinity of unsilenced wells, and airborne releases of hydrogen sulfide and trace amounts of Radon-222. Most geothermal hot waters contain large amounts of dissolved salts and other solids, including heavy metals. Land subsidence can be a problem in liquid-dominated geothermal fields. Geothermal generation is very inefficient in the sense that 90% of the total heat energy is discharged to the environment and may affect local hydrological cycles.

Biomass generation produces high particulate levels and requires substantial amounts of land if centered around large-scale energy plantations. Solar generation also has large land requirements, and its rotating mirrors pose the risk of affecting the local ecology and microclimate.

A simple example using emissions of oxides of sulfur (SO_x) will illustrate some environmental implications of developing country power production by 2008. In 1984, the total electricity supplied by all

developing countries is estimated to have been 1,700 TWh (Hagler-Bailly, 1987, Exhibit 2.5). Roughly one-third of that was generated from coal. Three capacity expansion scenarios for all developing countries between 1984 and 2008 yield aggregate shares of electricity generated by coal of 33.5% (low growth), 37.6% (medium growth), and 43.2% (high growth) (Hagler-Bailly, 1987, Exhibit 5.1). On the basis of these projections, we can calculate an estimate of SO_x emissions from coal-generated electricity production in 2008. We assume an average calorific content of coal of 11,000 Btu/lb and an average generating efficiency of 10,300 Btu/kWh. We use a current and projected SO_x emission coefficient of .0313: i.e., 3.13% of the weight of coal used in electricity generation finds its way into the atmosphere as SO_x (Darmstadter et al., 1987, Appendix B).

Table 1 presents the results of these calculations as well as the calculations of Darmstadter et al. (1987) for SO_x emissions for three regions in 1980 and 2030--the Gangetic plain of India, which contained roughly one-third of India's population in 1980, Europe (excluding the Soviet Union but including Turkey), and the United States. Darmstadter et al. derived their projections of coal combustion from the IIASA projections reported in Edmonds and Reilly (1985). Their projections include all coal combustion, but for the United States in 1980, bituminous coal use by electric utilities accounted for 95% of all U. S. bituminous coal use. We have included, in parentheses, linearly interpolated trends for 2008 for the three regions of Darmstadter et al. to facilitate comparison of the two quasi-independent sets of projections. The increase in thermally-fired electricity generation in all developing countries between 1984 and 2008 can be expected to increase SO_x emissions by a factor between 2.6 and 5.5 (3.7 for the medium-growth scenario). Our 2008 interpolation of Darmstadter et al.'s projected SO_x emissions for the Gangetic Plain has a 3.5-fold increase over the 1980 level for that region, which corresponds to the SO_x increase of the medium-growth rate scenario for all developing countries, while Europe's and the United States's emissions are projected to increase 2- and 3-fold. Over the 1980-84 period, coal used in electricity generation in all developing countries accounted for 9% of global SO_x emissions; by 2008, they could account for as little as 8.6% of global emissions or as much as 18%, by the calculations of Table 1.[1]

---

[1]Major coal users omitted from Table 2.1 are the U.S.S.R., Japan, Canada, Australia, and New Zealand. Figures on coal use in these countries are included in the derivation of the percentage figures in the text. Data on Soviet coal production come from Office of Technology Assessment (1981, pp 83-84) and on Soviet coal exports from Russell (1976, pp 77-78) and World Bank (1979, Table 2-6). Data on Japan, Canada, Australia, and New Zealand come from OECD (1984).

Many variant scenarios are possible regarding the growth rates of coal use and possible decreases in SO_x emissions rates by region. However, most of those scenarios would increase, or at the least leave unaffected, the percent of global SO_x emissions attributable to LDC electricity generation by 2008. For example, identical reductions in

The SO_x emissions are characteristic of other pollutants such as NO_x, CO, and hydrocarbons and the growth of thermal electricity generation in the developing countries over the next twenty years threatens to contribute a major increase in global air pollution. Clearly, introduction of more cleanly burning coal-fired electricity generation technology will be a priority for developing countries' power sector expansion, from the perspective of multi-and bilateral lending agencies approving projects if not necessarily from the borrowing countries themselves. This cleaner supply technology will raise the capital cost of meeting expected electricity demand in the next twenty years.

---

emission rates in all regions would leave the percentage unaffected. Greater reductions in emission rates in the currently industrialized countries than in the LDCs would decrease the denominator of the fraction by more than the numerator, increasing the resulting percentage. This is a plausible scenario when operating standards in the LDCs are considered in addition to simple introduction of newer, less polluting equipment based on developed countries designs and emissions standards.

Additionally, the linear interpolation used to derive 2008 projections could equally plausibly be above or below actual coal use reached in that year. A realized, constant percent growth rate for world coal use between 1980 and 2030 would bias the 2008 coal use projection above that attained. On the other hand, efficiency improvements and substitutions away from coal could make the 2008 linear interpolation projection a high estimate. In any event, regional differentials in the growth rate of coal use would be required to affect the percentage figures given in the text, and the most plausible differentials would increase the numerator by more than the denominator, again pushing up the percentage figures for LDC electricity generation SO_x emissions.

Table 1. Effects of electricity generation on SO_x emissions

Year	All Developing Countries: % electricity generation from coal	Actual or projected coal use*	Coal-generated electricity[1] (TWh)	SO_x emissions*
1980	--	--	--	--
1984	33.8	244,731	575	7,342
2008 (low growth)	33.5	607,785	1,441	19,190
2008 (medium growth)	37.6	869,116	2,030	27,049
2008 (high growth)	43.2	1,330,913	3,024	40.285
2030	--	--	--	--

Year	Gangetic Plain of India[2]: Actual or projected coal use*	Gangetic Plain of India[2]: SO_x emissions*	Europe[2]: Actual or projected coal use*	Europe[2]: SO_x emissions*	United States[2]: Actual or projected coal use*	United States[2]: SO_x emissions*
1980	55,517	1,831	732,120	22,910	515,573	16,137
1984	--	--	--	--	--	--
2008 (low growth)	--	--	--	--	--	--
2008 (medium growth)	--	(6,465)**	--	(46,968)**	--	(48,669)**
2008 (high growth)	--	--	--	--	--	--
2030	322,948	10,106	2,104,993	65,870	2,372,000	74,230

*Thousand metric tons.

**Linearly interpolated trend.

[1]Source: Hagler-Bailly (1987), Exhibit 2.5 (A-C).

[2]Source: Darnstadter et al. (1987), Appendix B.

3. ELECTRICITY RELIABILITY AND QUALITY AS A DEVELOPMENT ISSUES

The focus of this chapter is on the short and long-run impacts of power supply inadequacy. Adequacy refers to the power sector's capability -- capacity (kW) and energy (kWh) -- to meet the electricity demand and energy requirements of all its customers. Thus, inadequacy can arise either due to insufficient capacity -- generation or network-- to serve load (kW) at any instant in time; or it can arise due to insufficient energy (kWh) to serve customer requirements over a period of time. In short, adequacy refers to the reliability, i.e., certainty of the availability of power.

In the U.S., which has one of the highest levels of service reliability in the world, power supply interruptions are infrequent. The overall system reliability index expressed as the percentage of energy demand met is of the order of 99.98 percent (DOE, 1981).[2] Service interruptions due to generation capacity deficiency are virtually unheard of. The overwhelming majority of outages (98+ percent) that consumers face are due to faults in the transmission and distribution (T&D) network. Most of these outages are of short duration, typically lasting from a few minutes up to an hour or two.[3] In contrast to such routine and localized interruptions, on rare occasions there is a major network related outage such as the 1965 power failure that blanketed most of the Northeast region of the U.S. in darkness, and the New York City blackout of 1977. Such rare but spectacular events affect large numbers of people and full service restoration may take up to a day or more. These events receive considerable attention from the media, regulators, and politicians.

The reliability picture in many developing countries is substantially different. Most developing economies are capital constrained and therefore unable to provide adequate supplies of power. In many such instances, the cause of low reliability is a deficiency in generating capacity. This situation often is aggravated further by having small power supply systems with small numbers of plants. Reserve capacity is relatively more expensive to build and maintain in very small systems than in very large ones. In addition, the operating availability of the existing power plants in many developing countries is very poor compared to that in developed countries. Whereas the specific factors

---

[2]Marginally lower indices have been reported historically for many European power systems.

[3]Studies of several utilities in the U.S. indicate that most consumers face of the order of 2 to 5 such interruptions annually. Customers in rural areas experience a somewhat higher frequency of outages.

vary by country, the most common reasons for poor plant availability include inadequate preventive maintenance, lack of spares, limited fuel supply or fuel of inferior quality, labor problems, etc.[4]

Another reason for poor power supply reliability in many developing countries, even those that are not faced with a generating capacity deficiency, is the poor state of transmission and distribution systems. These systems often are overloaded and overextended and in many cases may be in advanced stages of disrepair. Power supply authorities already strapped for capital are unable to undertake all the necessary network extension, rehabilitation, and maintenance. Instead, scarce funds tend to be directed to prestige and visible projects like a dam with a power station.

A problem related to power supply inadequacy is that of poor supply quality.[5] Voltage surges and dips, and frequency fluctuations can cause extensive damage to electric motors and other sensitive equipment. This is also a common problem in developing countries that imposes a high economic cost.

The remainder of this section is organized as follows. Section 3.1 begins by identifying and characterizing major dimensions of the impacts of electricity shortfalls and includes an overview of the methodology for assessing the economic costs of such shortages. Section 3.2 presents dollar estimates of some components of these costs for several developing countries.

3.1 MEASURING THE IMPACTS OF POWER SHORTAGES

Short- and long-run costs are distinguished by the adjustments that the firms facing unreliable power make to mitigate their losses. The short-run is the period of time in which the firm can make some changes in operating routines but is constrained to use its currently fixed capital equipment. The long-run is the period in which the firm can also make adjustments to its fixed capital stock, given its expectations of what to expect in the way of continued power unreliability.

These impacts and interactions can be illustrated in the context of a business or manufacturing entity. When faced with a curtailment in electricity supply, the firm must adopt an alternative to the use of grid-supplied electricity. Typically, production must be deferred to a

---

[4]It is not uncommon to find plant availability factors of .35 to .5 (Munasinghe and Gellerson, 1979, p. 353). In contrast, plant availability factors in the U.S. are of the order of .7 to .85.

[5]Whereas reliability refers to service continuity, quality refers to the provision of power within stated voltage and frequency ranges and with the right wave form characteristics.

later time when the supply is resumed. If the plant was already operating at capacity, then overtime production involving additional costs will be necessary. If the enterprise uses a continuous, 3-shift process and is operating at capacity, then this avenue is not available, and the shortage may result in a loss of sales. If the firm owns standby generation, then some of these adverse effects are mitigated, although the decision to acquire stand-by generation capacity would be a long-run adjustment. However, the use of such equipment entails the additional expense of fuel to operate it, and the fuel may entail foreign exchange costs.

In addition, service interruptions may trigger costs related to product spoilage and damage to equipment. Under a situation of controlled load shedding, the firm can reduce such losses as well, as idle factor costs, by re-scheduling activities and by implementing controlled and orderly procedures for shutting down and re-starting the production processes. The extent of these direct economic costs also depends upon a host of factors such as advance notification, duration of the interruption, and timing. The latter refers not only to the time-of-day or season but also to the prevailing market conditions regarding the demand for the firm's output. These direct costs can be very high, particularly under conditions of uncontrolled load shedding and transmission and distribution outages, i.e. sudden interruptions in service without advance notification. In addition to the direct costs noted above, there are indirect costs to the economy because of the secondary effects that arise as a result of the interdependence between one firm's output and another firm's input.

Finally, chronic electricity shortages and poor reliability of supply trigger long-run adjustments. If firms expect that shortages and unreliable service will persist, then they will respond in one or more ways (Sanghvi, 1983, p. 129). The installation of back-up diesel generator sets is the most common long-run adjustment taken by industrial firms. Tables 4 and 9 show the extent of autogeneration capacity by industries in India and Pakistan.

Much other evidence from developing countries on the adjustments and their costs is anecdotal and, where quantitative estimates are available, they are incomplete (Munasinghe & Gellerson, 1979, p. 353). For example, a significant fraction of households in some developing countries have installed one or more voltage regulators to protect appliances such as refrigerators, air conditioners, and television sets against potential damage from voltage fluctuations in grid supplied electricity. It has been reported that in some instances industrial electric motors have to be replaced on average once a year because of poor power quality. In a large number of apartment buildings in the city of Calcutta, and in Kingston, Jamaica, it is reported that emergency backup generators have been installed to run essential equipment such as elevators. In the Punjab region of India, where grid-fed electric pumpsets have played a significant role in the green revolution, a large number of farmers maintain backup capability in a diesel pumpset, to ensure against frequent interruptions in grid supply. A substantial amount of the total

installed generating capacity in many developing countries (of the order of 20-plus percent) is in the form of standby generation on the customer premises.

3.2 DOLLAR MAGNITUDE OF ECONOMIC IMPACTS: SOME SPECIFIC COUNTRY EXAMPLES

This section presents some quantitative estimates of the economic impacts of electricity shortfalls. A detailed analysis of this cost for even one developing country is beyond the scope of this effort, so this section summarizes the results of several country specific studies. The customer class coverage and level of detail in these studies vary considerably, but the dollar estimates they yield underscore the point that the short- and long-run economic costs of power shortfalls can be very high. We are able to offer economy-wide estimates of economic losses for only two countries, India and Pakistan, although we present estimates of costs per kWh of outage for a number of other developing countries. The greater detail presented for India and Pakistan should not be interpreted as implying that costs sustained by those two countries are especially representative of economic costs throughout the developing world. It simply reflects the availability of information, although we believe the Indian and Pakistani costs are not entirely anomalous.

3.2.1 India

Power shortages and unreliability were mostly sporadic in the 1950s and 1960s, and by the 1970s power shortages had become a chronic national problem that now affects most of the states to varying degrees (Jaramillo, et. al., 1973). A recent study by the National Council of Applied Economic Research (NCAER) in India has estimated the impact of power shortages in the agricultural and industrial sectors over the period 1982-1984 (NCAER, 1985).[6]

NCAER's survey of 15,000 bulk electricity-using industrial establishments reported substantial variation in the extent of capacity utilization and its cause, but power shortage was a major culprit in all industries and in all regions. From Table 2, total production losses in 1983-84 are estimated in the study to be approximately $2.7 billion in mid-1987 prices, or about 1.5% of GNP. A comparable estimate for 1982-83 based on the NCAER study is approximately $2.1 billion in mid-1987 prices. Table 3 estimates the production losses to vary considerably by industry and region. For example, the loss in the iron and steel industry was about 43 percent in the Southern Region, but only 3.5 percent in the Western Region. Averaged across all large industries in a

---

[6]In 1986, the industrial sector electricity sales represented 40 percent of national consumption with the agriculture sector consuming 15 percent.

region, production losses range between 1.46 percent in the Western Region to 13.16 percent in the Eastern Region.

Table 2. Order-of magnitude estimates of power shortages on Indian industry[1,2]

Year	Estimated shortfall Gwh	Estimated shortfall %	Loss of value added 10^7 Rupees[3]	Loss as a % of GDP
74-75	10,953	14.1	1,630	2.6
75-76	8,599	10.3	1,300	2.0
76-77	5,124	5.8	810	1.1
77-78	15,837	15.5	2,500	3.0
78-79	11,186	10.3	1,750	2.3
79-80	19,068	16.1	2,980	3.6
82-83	--	--	2,199	1.3
83-84	--	--	2,879	1.5

[1] Years 74-80 based upon World Bank, 1979. Years 82-84 based upon NCAER, 1985.

[2] Years 74-80 based upon the following simplifying assumptions:

- o All cuts are allocated to industry;
- o All power shortages are energy shortfalls;
- o A 2% impact on GDP is approximately equal to 1,500 crore 10^7) rupees per year;
- o Does not include damage, spoilage, and process restart costs due to unscheduled load shedding; and
- o Does not include long-term adaptive response costs to economy.

[3] Current exchange rate is approximately Rs. 13.12 to a dollar.

Table 3. Production losses due to power shortages in India (1983-84)

Industrial type	Average loss as a percentage Value of production			
	Northern Region	Southern Region	Eastern Region	Western Region
Textiles	12.35	7.76	NA	2.31
Cement & cement products	NA	2.43	NA	NA
Paper	37.08	9.32	9.25	9.24
Chemicals & fertilizers	1.30	15.71	30.90	0.72
Electrical industry	6.30	5.81	6.48	0.52
Iron & steel	37.07	43.41	12.57	3.45
Non-ferrous metal	15.17	10.40	20.00	Nil
Engineering	23.52	2.33	21.36	2.98
Transport equipment	10.11	0.83	5.00	3.46
Rubber	50.25	14.33	NA	Nil
Coal mining	NA	NA	8.00	Nil
Food products	NA	NA	15.00	12.36
All industries				
1. % of loss	12.06%	8.94%	13.16%	1.46%
2. Total value of production loss (10^7 Rupees)[1]	407	620	729	229

[1] At 1979-80 prices.

Source: NCAER, 1985.

The NCAER report also estimated the impacts of electricity shortages in agriculture, primarily for irrigation on the basis of a survey of 2,000 electric pumpset-owning farmers throughout India. In some states there was substantial standby diesel pumping capacity, which is a direct manifestation of the problem of unreliable grid power supply. The estimates of production loss in agriculture attributable to power shortfall were not based upon a crop-response function which would attempt to relate crop yields to key inputs, including water usage, but largely upon the perceptions of farmers in the sampl· The percent losses were small relative to the losses typical in the industrial survey, from 1.5% to 5.3% across states, with an all-India average of 2.3%. This actually may indicate that agricultural losses from electricity reliability problems were effectively nil. Crop losses depend upon how good the rains are, and the 1983-84 season was considered to be a good year for rain.[7] It also appears that low electricity tariffs and unmetered supply, as well as lack of knowledge about water management, have stimulated over-watering. Consequently, losses of irrigation water caused by electricity unreliability may have reduced irrigation to something closer to an optimum quite fortuitously.

Long-run capital adjustments mitigate the short-run production losses from unreliable electricity, but they entail costs of their own. The electricity reliability problems are evidence of too little capital in the grid, and the evidence on autogeneration says that at least some of the additional capital is being supplied privately. Comparison of industry losses in Table 3 with the extent of autogeneration by industry in Table 4 offers some weak but suggestive evidence that autogeneration capacity is mitigating production losses.

It cannot be said that the full value of autogeneration equipment is an additional cost of unreliable power, because it substitutes for additional capacity that utilities do not have. However, if the grids could expand and if they could upgrade their management to maintain quality service, grid-supplied electricity could be produced with greater economies of scale than autogeneration can offer. These are major qualifications to the present environment, however. The difference in the electricity supply costs of the grid and self generation methods is a long-run cost.

The loss estimates of Tables 2 and 3 fall somewhere below the short-run costs and above the long-run costs, assuming partial adjustment has been made. Also, the difference in electricity supply costs of a reliable grid and autogeneration is excluded from those loss estimates.

---

[7]Even if 1983-84 had been a bad rainfall year it is not apparent that the costs would be higher. This is because of the presence of standby diesel pumping capacity.

Table 4. Use of captive power sets in industry, India 1983-84

Industry type	Percentage of units reporting at least one captive set				Average capital cost of captive plants in the reporting units (10^7 Rupees)			
	Northern region	Southern region	Eastern region	Western region	Northern region	Southern region	Eastern region	Western region
1. Textiles	100.0	76.9	100.0	77.4	9.31	7.37	10.94	13.58
2. Cement & cement products	NA	66.7	NA	NA	NA	50.96	NA	NA
3. Paper	Nil	50.0	83.3	22.2	Nil	466.13	14.25	136.83
4. Chemicals	16.7	53.7	69.2	29.5	380.00	25.65	9.55	47.23
5. Electrical industry	28.6	67.9	76.9	15.0	19.17	5.25	9.14	3.86
6. Iron & steel	14.3	50.0	69.2	26.7	24.35	19.37	641.04	878.60
7. Non-ferrous metal	100.0	60.0	100.0	50.0	2,077.66	3.23	7.78	NA
8. Engineering	33.3	63.6	64.7	30.0	0.25	2.45	10.25	8.91
9. Transport equipment	50.0	64.3	100.0	12.5	66.25	11.92	19.15	10.00
10. Rubber	50.0	50.0	Nil	Nil	2.50	NA	Nil	Nil
11. Coal mining	NA	NA	Nil	25.0	NA	NA	Nil	5.87
12. Food products	25.0	66.7	100.0	Nil	NA	9.85	4.46	Nil

Source: NCAER, 1985.

3.2.2 Pakistan

Table 5 presents estimates of the impacts of power shortfalls to industry. The 8.2 percent reduction in value added is equivalent to a decline in value added of approximately $350 million in 1987 U.S. dollars. The study further estimates that these direct costs to the economy should be escalated by a multiplier of 1.34 to account for the indirect multiplier effects. The resulting total--direct plus indirect--costs of the shortfall, representing a 1.8 percent reduction of GDP, are expected to continue at least for the duration of this decade. Additionally, Table 3.4 estimates the adverse impact on national exports of manufactured goods as a consequence of power shortages to be about 4.2 percent of manufactured exports. This translates into a reduction in exports of about $75 million in hard currency.

Since 1980, electricity consumption has risen at an average annual rate of over 11.2 percent. This relatively high growth rate in electricity demand in recent years is attributable to at least three major factors: (1) maintenance of tariff increases at levels substantially below increases in the prices of other goods and services, which further stimulated demand for electricity;[8] (2) the substantial increase in electricity demand by newly developed, electricity-intensive industries; and (3) increased remittances from Pakistani nationals employed in Gulf countries, triggering demand for electrical appliances.

Increases in residential demand, together with high pumping loads and the rural electrification program, have contributed in large measure to the deterioration of WAPDA's[9] system load factor[10] from approximately

---

[8]Until recently residential electricity tariffs did not have a fuel adjustment clause.

[9]Water and Power Development Authority of Pakistan. WAPDA's service territory includes all of Pakistan except for the major port city of Karachi and its environs, which are served by the Karachi Electric Supply Corporation (KESC).

[10]System load factor is the ratio of actual utilization of all generating plant (hours/year) to the maximum possible utilization level of 8760 hours/year. Higher load factors imply more efficient utilization of generating plant.

Table 5. Impact of outages on key national economic parameters by type of industry,[1] Pakistan, 1983-4

	Decline in value added[2] (%)	Decline in value of production (%)	Decline in exports (%)
A. BY INDUSTRY GROUP			
Food, beverages & tobacco	21.2	2.7	11.2
Textiles	9.4	4.8	4.2
Wearing apparel & footwear	4.4	0.6	0.9
Wood & paper	6	6.3	1.4
Chemicals & petro-chemicals	5.9	3.8	4.5
Non-metallic mineral products	2.1	1.2	0.0
Metal & metal products	7.2	2.4	3.7
Machinery & equipment	7	1.2	6.1
Other industries	8.8	0.9	0.7
B. ALL INDUSTRIES	8.2	2.6	4.2

[1]Derived by eliminating any sample biases by industry or region.
[2]The impact on value added excludes labor-related costs which reduce profits by an identical amount leaving value added unchanged.

Source: AID, 1987b.

66 percent in 1975-76, to 56.5 percent in 1985-86.[11] WAPDA's generation capacity additions have not kept pace with demand, and consequently, the country has had recurrent power shortages since 1982. These shortfalls are expected to continue for at least the duration of this decade.

Load shedding previously was restricted principally to the period December through June, but in recent years it has become a year-round phenomenon. Tables 6 and 7 summarize the cost estimates of a recent study of load shedding in WAPDA's service area study (AID, 1987b). Table 3.5 indicates that the cost of load shedding to industry ranges from a low of $0.29/kWh for textiles to a high of $1.77/kWh for the machinery and equipment industry, with an average of approximately $0.50/kWh. In contrast, uncontrolled load shedding (i.e., outages with no advance notification) cost industry, on average, $0.81/kWh, or is approximately 60 percent more (Table 7). In both instances, spoilage cost -- i.e., damage to machinery and goods -- is a significant component of total cost, accounting for over 60 percent of total direct cost and about 15 percent of total outage cost.

Industrial electricity users have resorted to substantial self-generation to mitigate losses from unreliability, and Table 8 provides insight into long-run costs of that strategy. The total cost per kWh of self-generation ranges from a low of $0.1 /kWh to a high of $0.74/kWh. In contrast, WAPDA's systemwide average, long-run marginal cost of supply is estimated to be approximately $0.076/kWh. Thus, the economic cost of grid supply by WAPDA ($0.076/kWh) is substantially (between 2- and 10-fold) lower than the autogeneration cost incurred by industry. The extent of this divergence provides some indications of the resource costs to the economy because of this inefficiency.

---

[11]Recent shifts in electricity consumption shares are as follows:

Consumer Segment	Percentage Share of Total WAPDA Sales 1970-71	1980-81	1985-86
Residential	9.78	20.49	29.11
Commercial	3.68	4.91	5.65
Industrial	44.28	38.40	38.02
Agricultural	27.03	23.44	18.58
Public Lighting	0.56	0.63	0.58
Bulk Supply	14.67	11.04	7.83
Traction	---	0.48	0.23
TOTAL	100.00	100.00	100.00
Total Consumption (GWH)			

Table 6. Components of loadshedding cost per kilowatt hour by type of industry and process (Rs./kWh) Pakistan, 1983-4

	Spoilage cost	Net idle factor cost	Total direct cost	Adjustment costs: Labor related cost[1]	Capital related cost[2]	Timing related cost[3]	Total adjustment costs	Total loadshedding cost: Rs./kWh	$/kWh
A. BY INDUSTRY GROUP									
Food, beverages & tobacco	8.25	0.89	9.14	0.20	0.50	0.10	0.80	9.94	0.68
Textiles	1.33	2.70	4.03	0.09	0.13	0.04	0.26	4.29	0.29
Wearing apparel & footwear	2.40	0.68	3.08	1.97	6.38	0.00	8.35	11.43	0.79
Wood & paper	7.64	3.31	10.95	0.14	0.24	1.40	1.78	12.73	0.87
Chemicals & petro-chemicals	7.83	2.12	9.95	0.32	0.31	0.00	0.63	10.58	0.73
Non-metallic mineral products	0.04	0.51	0.55	0.30	3.40	0.00	3.70	4.25	0.29
Metal & metal products	3.71	2.45	6.16	0.20	0.20	0.06	0.46	6.62	0.45
Machinery & equipment	15.94	3.34	19.28	0.77	5.47	0.19	6.43	25.71	1.77
Other industries	4.14	0.65	4.79	0.23	0.25	0.00	0.48	5.44	0.37
B. BY PROCESS									
Batchmaking	2.51	0.71	3.22	0.12	0.36	0.08	0.56	3.78	0.26
Continuous	9.90	9.89	19.79	0.56	1.68	0.00	2.24	22.03	1.51
C. TOTAL SAMPLE	3.64	2.19	5.83	0.21	0.56	0.07	0.84	6.67	0.46

[1]Cost of additional overtime and/or shifts.
[2]Cost of generators and/or more intensive operations of machinery.
[3]Cost of changes in shift timings or in working days.

Source: AID, 1987b.

Table 7. Components of unplanned outages cost per kilowatt hour by type of industry and process, Pakistan, 1983-4 (Rupees)

	Spoilage Cost	Direct cost: Net idle factor cost	Direct cost: Total direct cost	Adjustment costs: Labor related cost[1]	Adjustment costs: Capital related cost[2]	Adjustment costs: Total adjustment costs[3]	Total unplanned breakdowns cost per: Rs./kWh	Total unplanned breakdowns cost per: $/kWh
A. BY INDUSTRY GROUP								
Food, beverages & tobacco	26.94	1.88	28.82	1.01	0.44	1.45	30.27	2.08
Textiles	1.90	3.06	4.96	0.23	0.09	0.32	5.28	0.36
Wearing apparel & footwear	8.01	1.81	9.82	1.88	1.26	3.14	12.96	0.89
Wood & paper	26.95	3.94	30.89	0.69	1.42	2.11	33.00	2.27
Chemicals & petro-chemicals	6.23	10.75	16.98	0.59	1.32	1.91	18.89	1.30
Non-metallic mineral products	0.23	1.96	2.19	0.43	1.80	2.23	4.42	0.30
Metal & metal products	7.85	4.66	12.51	0.35	0.55	0.90	13.41	0.92
Machinery & equipment	13.79	8.40	22.19	6.35	5.74	12.09	34.28	2.35
Other industries	6.19	1.11	7.30	2.20	0.50	2.70	10.00	0.69
B. BY PROCESS								
Batch-making	2.69	3.67	6.36	0.42	0.28	0.70	7.06	0.48
Continuous	23.66	9.60	33.26	1.22	2.48	3.70	36.96	2.54
C. TOTAL SAMPLE	6.40	4.03	10.43	0.62	0.68	1.30	11.73	0.81

[1]Cost of additional overtime and/or shifts.
[2]Cost of generators and/or more intensive operations of machinery.
[3]Cost of changes in shift timings or in working days.

Source: AID, 1987b.

Table 8. Extent of self-generation of power during outages and generator costs per kilowatt hour by type of industry and process, Pakistan, 1983-4

	Percentage of Sample firms using generators (%)	Average extent of substitution of WAPDA by generators (%)	Total Cost per KWH of self generation (Rs/kWh)	Total Cost per KWH of self generation ($/kWh)	Percentage of sample firms planning to invest in generators (%)
A. By industry group					
Food, beverages & tobacco	9	83	3.13	0.21	17
Textiles	8	82	2.68	0.18	11
Wearing apparel & footwear	19	84	7.30	0.50	11
Wood & paper	6	93	10.76	0.74	16
Chemicals & petro-chemicals	17	81	5.32	0.37	12
Non-metallic mineral products	8	98	2.92	0.20	6
Metal & metal products	9	88	1.97	0.14	19
Machinery & equipment	19	85	6.63	0.46	23
Other industries	22	75	9.85	0.68	11
B. By process					
Batch-making	10	81	2.80	0.19	14
Continuous	16	86	5.76	0.40	21
C. Total sample	12	83	3.42	0.23	16

Source: AID, 1987b.

3.2.3 Other Countries

This section summarizes several other developing country studies which have attempted to develop estimates of the costs of electricity shortfalls. However, estimates in the following studies are generally not based on as detailed and complete an analysis as in the India and Pakistan case studies discussed in the preceding section.

Table 9 summarizes estimates of the costs of power supply inadequacy reported in other studies. With the exception of the two cases discussed at length earlier, other studies have focused on estimating the cost per unit (kWh) of shortfall. This occurs because, with the exceptions of India, Pakistan, Egypt, and Bangladesh, the countries listed in Table 9 have not been subject to shortfalls in generation capacity.[12] Thus, the majority of study estimates in Table 9 were developed for the purpose of evaluating projects that improve local area reliability as a result of reinforcing or rehabilitating the sub-transmission and distribution network. As a consequence, most of these estimates relate to unplanned outages.

Electricity interruption costs in Table 9 are typically in the $0.50/kWh to $5.00/kWh range. This range gives commonly experienced costs. However, certain individual customers will have costs substantially higher than the $5.00 number. With average electricity tariffs in the range of $0.08/kWh to $0.12/kWh, these data indicate that in the short run, customers would be willing to pay from 5 to 50 times the average tariff to avoid the adverse effects of power supply interruptions.

3.3 AN OVERALL ASSESSMENT OF RELIABILITY COSTS

For India, the cost of unreliability in electricity supply in the industrial and agricultural sectors has been around 1.5% of GDP, while in Pakistan, the costs of only industrial sector reliability problems has been around 1.8% of GDP. This includes some 4.2% of foreign exchange earnings from manufactured exports, but excludes any agricultural sector losses. Neither estimate includes the value of foregone services associated with residential and commercial outages. To put these percentage figures in a more familiar perspective, they may be compared with the magnitude of the 1982 recession in the United States: between December 31, 1981 and December 31, 1982, real GNP in the United States fell by 1.8%.

---

[12]Because of foreign exchange restrictions during the period 1978-82, the Jamaica Public Service Company suffered from a shortage of spare parts for its large thermal generating stations. As a result, the system was frequently unable to satisfy demand, resulting in widespread outages over that four-year period. However, this situation has been rectified, and most service interruptions that Jamaican customers now face are related to network disturbances.

Table 9. Costs of power shortages in selected developing countries (1978 US$)

Country	Study Reference	Sector(s)	Type of Shortfall	Cost of Shortage	Overall Measurement Approach
Bangladesh	World Bank, 1982	All	Unplanned outages	1.00$/kWh	Based upon estimates reported in other studies.
Brazil	Munasinghe & Gellerson, 1979	Households	Unplanned outages	1.95-3.00$/kWh	Wage rate reflects cost leisure
		Industry	Unplanned	1.77-8.42$/kWh	Survey to assess idle factor costs, and spoilage.
Chile	Jaramillo & Skcknic, 1973	Households	Unplanned outages	0.53$/kWh	Annuitized value of household appliances made idle.
		Industry	Unplanned outages	Range: 0.25-12.00 $/kWh Central Tendency 1.50-6.00 $/kWh	Input-output model.
Costa Rica	Munasinghe, 1980	Households	Unplanned outages	N/A	Wage rate reflects cost leisure.
		Industry		N/A	Survey to determine idle factor costs and damage costs.
Egypt	Bernstein & Hegazy, 1987	Industry	Unplanned	0.40 $/kWh	Input-output model

Table 9. Costs of power shortages in selected developing countries (1978 US$) (continued)

Country	Study Reference	Sector(s)	Type of Shortfall	Cost of Shortage	Overall Measurement Approach
India	World Bank, 1979 and NCAER, 1985	Industry	Controlled load shedding	Annual cost ranges from 1 to 3% of GDP (1.5 to 3 billion dollars annually)	Survey to determine production loss attributable to power shortfall.
		Agriculture	Controlled load shedding	Sector production loss of 2.3% in 1983-84.	Survey to determine production loss attributable to power short-fall.
Jamaica	Sharpe, 1975	Industry	Unplanned outages	1.25 $/kWh	Estimate of fraction of value added cost.
Pakistan	AID, 1987b	Industry	Controlled load shedding	Range:0.26-1.77 Average: 0.46 $/kWh	(1) Survey to determine idle factor costs, spoilage, restart costs
			Unplanned outages	Range 0.36-2.54 Average: 0.81 $/kWh	(2) Survey to determine idle factor costs, spoilage, restart costs
			Controlled and Uncontrolled load shedding	$350 million in 1984-85	(1) + (2)

Table 9. Costs of power shortages in selected developing countries (1978 US$) (continued)

Country	Study Reference	Sector(s)	Type of Shortfall	Cost of Shortage	Overall Measurement Approach
Paraguay	Westley, 1981	Residential		N/A	Consumer surplus loss.
Taiwan	Munasinghe, 1980	Industry		0.06-2.16$/kWh	All value added cost
Tanzania	Tanesco, 1985	Households		0.50 $/kWh	Cost of obtaining substitute services from alternate means.
		Industry		0.70-1.40 $/kWh	Some fraction of value added cost depending upon plant capacity utilization.
		Commercial		1.00 $/kWh	Assumed equal to average cost to industry.
		All sectors		0.70-1.10 $/kWh	

N/A: Not available.

The foreign exchange cost estimate probably understates the total foreign exchange cost of outages by failing to include the hard currency cost of imports purchased to substitute for domestic consumption of affected industries' outputs. Some, but probably not all, of this effect may be captured in the 4.2% figure cited above.

How transferrable are the reliability loss figures of 1.5% to 2% of GDP? First, manufacturing probably is more exposed to electricity reliability losses than is agriculture, and if this is the case, other things being equal, countries with larger manufacturing shares of GDP would suffer larger percent losses from poor reliability. India and Pakistan have relatively high agricultural GDP shares compared to Thailand, Indonesia, the Philippines, and Egypt, but low compared to Bangladesh. But other things need not be equal. The larger manufacturing shares may be partly the result of more reliable electricity supplies, and reliability losses would not be larger shares of GDP. How large could reliability losses conceivably get as a percent of GDP? News from Sudan reported that nearly 60% of the industry in Khartoum was idled throughout the summer of 1986 because of electricity unreliability, but only around 6% of Sudan's GDP comes from manufacturing, and spare parts problems may have accounted for some of the idle capacity reported. As a judgement estimate, we suggest an upper bound for reliability losses of around 4% of GDP, and that rate of losses would be sustainable for only short periods of time. At that point, it would pay to begin using liquid fuels and self-generation, although those power production methods are costly themselves, as noted above.

Inclusion of commercial and government sector losses might raise this figure by one half to one percentage point, although commercial sector electricity unreliability affects comfort as well as output. While the Indian study suggested that Indian agriculture was not particularly hurt by reliability problems, agriculture in dryer countries like Sudan and Egypt might be more susceptible to poor electricity reliability. However, the agricultural output in Sudan that relies on electricity for irrigation pumping accounts for only around 3% of GDP (Jones et al., 1987). Unreliability of liquid fuel supply is as big a concern for Sudanese irrigation as electricity reliability is. Pakistani irrigation, however, relies much more heavily on electric pumping, but tariffs for agriculture are well-subsidized.

Figures in the range of 1.5% to 2% of GDP or GNP are large enough to cause concern, but as static, single-period estimates they may understate the long-term costs. Dynamic costs include not only the current period's income losses but the income that is lost in future periods as a result of the current losses. They may be far higher than the static, single-period costs. If the affected sectors have higher than average savings rates, investment may be seriously disrupted by the reduction in profits, and the rates of growth of the capital stock and of income, will be retarded. The rate of entry of new technology in the form of new equipment would be slowed down. To the extent that these investment/capital accumulation forces are prime movers of development, as well as of simple income growth, the forces that produce the strongest

demands for improvement in human capital, the entire development process could be impeded well beyond what the current shares of GDP loss superficially would suggest.

4. IMPACTS OF ELECTRICITY SHORTAGES

4.1 DEFINING SHORTAGE

Shortage is a very elusive concept. The question of how much of an item a potential consumer wants must be linked to the question of how much he or she is willing to pay for that amount of the item. Economists combine those two sets of questions to produce the concept of demand, which refers to how much a consumer would be willing to pay for so many units of an item, when the consumer has so much income and other closely related items, both substitutes and complements, cost so much. Using the concepts of demand and supply, it is difficult for an unfilled demand, or a shortage, to be sustained. At a given price, demand may exceed supply, but in that case, supply would increase, at an increased cost. The increased cost would cause some consumers to decide they did not want the item, and the shortage would be eliminated. A demand-supply equilibrium does not imply that no consumer would not want to have more than he gets, but that no consumer is willing to pay what would be required to obtain more.

Given the pricing policies and financial management of many developing country utilities, this discussion of shortage versus demand-supply equilibrium is especially relevant. Many more industrial electricity customers might step forward if more electricity could be generated, and many villages would indeed be better off if they were electrified, but the question is how many consumers can pay the cost of that additional electricity and still be better off. The issue is substantially different from that of outage costs, which involve the cost of variable quality of electricity supplies. The cost of so-called shortages is more ill-defined because it runs very close to being the cost of foregoing what one was unwilling to pay for in the first place. Conventionally speaking, it would be improper to project the amount of electricity that consumers would be willing to use under an uneconomic price regime, subtract from that the amount they will not be supplied at that set of prices, and call the difference any kind of welfare loss.

There is an income issue here as well, however. The demand for electricity is a function of consumer income as well as the electricity price, and the consumers' incomes in many developing countries simply may be too low to sustain any more than a minimal amount of electricity consumption, and many low-income individuals might be unable to pay even for a hook-up. Ideas of a desirable distribution of consumer welfare may suggest that the distribution of electricity consumption be something other than what a full-cost pricing system would generate. In that case, some portion of unfulfilled wants for electricity could be identified as a welfare loss, but its valuation would involve some arbitrariness.

Nonetheless, the availability of electricity makes some developments possible that otherwise would be impossible or far less conveniently accomplished. At this point, the issue shifts from the quantity of

electricity regularly provided, to whether electricity is available at all at certain locations for certain purposes, and from the value of well-defined welfare losses to less precisely valued identification of contributions that electrification can make to development.

4.2 SOCIOECONOMIC IMPACTS

Development planners have argued that electricity has numerous socioeconomic benefits, ranging from improved literacy to improved general quality of life to improved economic productivity to reduced incentives for rural-to-urban migration (Cecelski and Glatt, 1982). Anecdotal evidence supports many of these claims, but little rigorous research has been done to verify them and measure the benefits. A recent review of evaluations of rural electrification (RE) programs in developing countries concludes that most of the claims that RE has significantly higher social than private benefits are either unfounded or unsubstantiated; the only claim that appears to stand scrutiny with some consistency is that RE has backward and forward linkages with agriculture, but even that claim is qualified by crop choices (Pearce and Webb, 1987).

Most studies focus on the effects of rural electrification, and describe what is occurring in existing electrified areas without attempting to define what would have happened without electricity; many note changes in the way people live and attribute them to electricity when other energy forms could have permitted these changes. The most effective way to estimate these benefits would be to compare conditions in electrified regions with those that would have existed without electric power or with some alternative energy form such as diesel (Barnes, 1987). The comparison would need to control for ex ante social and economic differences between the electrified and unelectrified areas and the investments made in non-electric services.

4.2.1 General Findings

Two general observations reflect compelling anecdotal information. First, the use of electricity, even at subsidized prices, is expensive for very poor people, yet they are willing to make sacrifices when electricity is available to purchase and operate appliances such as electric lights, televisions, and fans. The people clearly perceive benefits to electricity use. What is uncertain is whether the benefits are large enough for a nation to continue to subsidize electricity prices or the expansion of rural electrification or bear the environmental costs of power production, and how much the benefits are reduced when electricity supplies are unreliable or the power is of poor quality.

The second observation is that electrification alone is unlikely to have much benefit; people may use electricity but not in the quantities expected or for the uses and benefits hoped for by the planners (Barnes, 1987). Since people generally can be relied to act in their own best interests, this points to difficulties in constructing and/or implementing adequate plans. On the other hand, an integrated

development project that improves the access of households and small firms to capital, and that makes public investments in agriculture, education, health services, water supplies sanitation, and housing, as well as making electricity available, can greatly improve the economic productivity and quality of life of the targeted areas. It is not possible from available evidence to isolate the contribution that electricity makes to such an integrated project other than to say that electricity becomes an integral part of the project once the project has made investments in electric end-use equipment for irrigation, public lighting, or health-care. Again, the amount by which benefits of such projects are reduced when power is unreliable or of poor quality is unknown.

4.2.2 Some Specific Examples

With this in mind, the following examples illustrate some of the postulated socioeconomic benefits of electricity.

4.2.2.1 Vaccination

Vaccines for many human and livestock diseases require refrigeration. Lack of access to reliable refrigeration is cited as one of three obstacles to the eradication of rinderpest from African livestock. Even with a partial control program, the disease is estimated to have caused direct losses of $400 million from 1980-1984, and indirect losses of $1 billion (Walsh, 1987). The total worldwide losses from diseases which could be prevented by vaccination if refrigeration were more widespread would be much greater. As in integrated development projects refrigeration alone, which can be provided through non-electric technologies, would not substantially reduce these costs, but the expansion of electric refrigeration would simplify the effort.

4.2.2.2 Education

Electricity without schools is unlikely to improve education; electricity without television signals limits the use of this medium for instruction or information dissemination. On the other hand, the effect of electricity on the use of education and information exchange services when they are available is unclear. Some studies have found that households with electric lights are no more likely to send children to school than comparable households without, but that children who can read by electric lights spend more time reading at home than those who lack electric lights; in households with access to both television reception and lights, children spend more time reading, but adults may watch television instead and thus spend less time reading than adults do in nonelectrified households (Barnes, 1987). Adult evening classes require light, but they also require funding, and they must meet people's needs before adults will enroll.

4.2.2.3 Income and Employment

It appears possible for electricity use to have a full range of outcomes on employment and income, depending upon local cultural, social, and economic circumstances which remain poorly understood. Poorly controlled studies have found village electrification associated with increases in small-scale industrial activity, household manufacturing, and the share of the labor force employed in industry, relative to villages without electricity. This may increase productivity or income but not employment. Rural households in some cases improve their income by undertaking cottage industrial activity using electric lights in the evening. In at least some circumstances, rural electrification has no effect on income distribution and land distribution (Barnes, 1987), but in others it clearly could increase inequality, and in others it could decrease it.

4.2.2.4 Quality of Life

Electrification probably widens the gap in the quality of life between the rich and middle classes and the very poor, because the very poor often cannot afford the electricity or end-use equipment and associated benefits. This is evident from data on appliance ownership, where for households of comparable income and education, electrified households are more likely to have appliances of any type than are non-electrified households. On the other hand, as the income of electrified households rises, these appliances are more likely to be electric than nonelectric. Rural electrification probably improves the quality of life of women and children more than it does that of men, because the former spend more time in the home (Barnes, 1987). On the other hand, electrification in urban areas may be as important for improving the lighting, ventilation, and comfort of the workplace environment for men.

4.2.2.5 Environmental Quality

Electrification can reduce fuelwood consumption if (1) it is part of a strong, well-designed and implemented development program which includes substitution of electricity for fuelwood in cooking as one of its objectives or (2) it permits households to substitute electricity for kerosene in lighting and thereby allows substitution of kerosene for fuelwood in cooking. The first of these appears to have been successful only in Costa Rica, where its success has created difficulty for the power system (Trocki et al., 1987). The second has been documented in some cases in India (Barnes, 1987) and probably is dependent on income, local energy markets, and cultural preferences for cooking methods; it is therefore probably not a reliable outcome of electrification. Substitution of electric lights for kerosene lights, even without a reduction in fuelwood, and the adoption of electric fans, both improve the indoor air quality of residences.

It should be pointed out, however, that the heavy subsidization of electricity prices in developing countries generally benefits the middle and upper income groups in those countries, and the subsidization

generally is paid for by the lower income groups, at least in terms of what could have been subsidized that would have benefited the poor had not the upper-income subsidy been provided. Jones (1985) notes that in Egypt in 1979, the wealthiest 21% of urban households received 30% of energy subsidies (including, but not restricted to, electricity) while the poorest 26% received 15% of the subsidies. With regard to the political sensitivity of electricity price increases, he also observes that "the leaders of such protests are typically upper middle class and many of the followers are urban workers in the top half of the income distribution. It was certainly not the rural poor who went to the streets in Cairo and Bangkok to protest rises in the prices of such services as electricity and kerosene" (Jones 1985, p. 345). The populist, income-distribution, political arguments in favor of heavy subsidization of electricity prices, as well as supporting employment padding in parastatal utilities, should be viewed with suspicion. The poor in developing countries generally would benefit more from full-priced electricity than the current, subsidized arrangements.

4.2.2.6 Migration

Cities and the larger towns and villages are more likely to have electricity than small villages and rural areas, and it has been suggested that rural electrification, by reducing this disparity and improving the quality of rural life, might reduce the rate of rural-to-urban migration. There is no hard evidence on either side of this question. Survey evidence from India suggests that rural electrification may increase migration from electrified villages for jobs, but may be accompanied by enough improvement in the availability and quality of education that it reduces migration to larger settlements for education (Barnes, 1987); the net effect may be close to zero in this case. Barnes suggests that the increase in emigration reflects rising expectations, perhaps from higher agricultural incomes and greater information flows associated with electrification. He also observes from the Indian survey that, although permanent emigration from electrified villages increases slightly, seasonal migration seeking employment decreases.

4.2.2.7 Political Stability

Poor areas which have received little public investment of any kind are probably more likely to be disaffected with the authorities than are those which have benefitted from such investment. Development, rather than electrification, is probably more important in building support for an existing government or political system. It is unclear how much electrification alone could build support, or how much other forms of investment could make up for its absence; a poorly designed electrification project by itself could reduce political support rather than improve it. It is clear from anecdotal evidence that the maintenance of electricity services and the price of electricity for existing users does affect general satisfaction for these users. Deterioration of service quality can become one more thing over which people become dissatisfied or angry, as can price increases, especially

when they are unaccompanied by visible improvements in the quality or availability of service.

4.2.3 Relevance of the Evidence to Capital Shortages for Power.

The need to coordinate electrification with other services in development takes on a special importance when development funds are short. Many cultures, including the western cultures in which the leaders of many developing countries were trained, tend to value visible, concentrated, physical results over the intangible. In power systems development, this leads planners to prefer large investments to small, and investments in power plants to those in transmission, distribution, or end-use efficiency (Tendler, 1971; Collier, 1984, pp 14-17; Sathaye, 1987). In integrated development which includes electricity, this may lead developers to favor power investments to those in the services which enable effective use of power. When development funds are scarce, the preferred tangible parts of the program may receive funding preference over the intangible, and thereby reduce the chances for successful application of those investments that are made. A reduction in the demands for capital to expand electric power services would, paradoxically, improve the chances for these investments to be productive.

5. COSTS OF IMPROVING ELECTRICITY SERVICES IN DEVELOPING COUNTRIES

We have explored the foregone income and developmental activities that would be sacrificed by unavailable and/or unreliable power supplies in developing countries. However, providing the power is by no means costless either. In this chapter the consequences of making the investments in the power sector that would be required to meet demands by 1995. A number of financing options are at least theoretically possible for meeting utility expansion demands. Governments could divert their own tax-derived resources from other programs to utilities. Financing could come from domestic capital markets. Governments could engage in deficit financing to fund power sector development, although this might amount to no more than government borrowing from domestic capital markets. Foreign borrowing could be used. As a final alternative, by raising electricity prices, utilities could finance the expansion from internal funds. These options are not mutually exclusive and, in fact, ordinarily would be undertaken in some combination with one another. Rather than simply discuss the advantages and disadvantages of each of these options individually, this chapter considers several financing strategies that are packages of these individual options. This offers the advantage of identifying the financing problems that still remain even when the array of individual financing options has been tailored to best meet some development goals that a country might have.

Two polar financing strategies are considered. First, a country might attempt to make the additional power sector investments without reducing development spending in other sectors such as agriculture and transportation. Additional capital would have to be raised domestically and/or externally, both of which actions would have farreaching effects. Alternatively, if capital availability is highly constrained, expansion of capital spending in the power sector would require curtailments in other development areas. It is possible, perhaps even likely, that some combination of these unattractive situations might be forced upon a country: it might increase its overall level of capital expenditure and have to contract some of its nonpower investments.

This chapter begins with a consideration of the potential crowding out of nonpower development investments by a big push in power investments. We begin by examining the recent sectoral distribution of capital expenditures in some high-priority AID-supported countries to assess the size of potential impacts on other development efforts. Next we consider the possibility of the increased power sector investments coming from increased, rather than redirected, investment. Such a policy could have significant macroeconomic impacts, and we study those possibilities. In the last section we consider the problems associated with borrowing.

5.1 THE SIZE OF THE INVESTMENTS

The actual magnitudes of the investments required to "solve" the power crises in individual countries are subject to considerable debate. For example, one aggregate estimate of $522 billion between 1985 and 1994 has appeared in the literature. Of that, $172 billion was projected to be in foreign exchange requirements, the remainder in local currencies (Heron, 1985). That is a disturbingly large number, and there are reasons to suspect that it is far too high. The study simply extrapolated a 6% annual growth rate of aggregate electricity demand in the developing countries and ignored actions other than capacity expansion that could bring supply growth into line with demand growth, as well as feedback effects that would tend to damp electricity demand growth independently of deliberate policy actions. First, electricity price reform could go a long way to containing demand growth. At least two AID Missions claim that electricity price reform could go a long way toward solving the respective countries' electricity problems. From Egypt: "The potential for rationalized rates to resolve the energy [electricity] problem is high" (AID, 1987a, p. 22). From Pakistan: "Our analyses indicate that were energy [electricity] prices raised to their economic value, demand [for electricity] would fall substantially" (AID, 1987c, p. 32). However, most developing countries have resisted rapid electricity price reform because of its political sensitivity. Second, lower-priced rehabilitation of equipment and judicious installation of capacitors in transmission systems would increase the effective supply of electricity often more cheaply than direct installation of more generating capacity would.

In the way of feedbacks, while not a solution itself, the continuation of reliability problems would lead industrial electricity consumers to substitute alternative power sources for grid-supplied electricity even if governments did not let market forces determine electricity prices. The Heron paper considered the feasibility of a $522 billion power sector investment bill only from the perspective of multilateral loan availability, ignoring the borrowing countries' repayment capacities and the potential consequences for their national financial systems of investments and foreign and domestic debts of that magnitude. On the positive side, the Heron projection incidentally directs attention to the feasibility of continuing to address the developing country electricity sector's problems principally by capacity expansion programs.

Rather than make independent projections of electricity demands, this section presents some information on planned power sector investments in several countries that are reported to be facing major power shortages over the next decade. Table 10 presents this information, as well as load growth forecasts and information on electricity prices. The figures are incomplete, and some are suspect as will be noted. The developmental and national financial implications of actually making power sector investments of the announced, planned magnitudes are considered from several perspectives.

Table 10. Power sector investment plans (in U. S. $)

	Planned investments or reported requirements	Investment plan period	Forecast annual load growth	Forecast period	Electricity tariff as % of LRMC
Bangladesh	$ 2.95 billion[1]	1985-92	16.6%	1985+	
Egypt	$ 4.41 billion	1986/7-92/3	7%	1986-2000	4.6-70%
India	$55.3 billion	1984/5-89/90	10-11%	1984/5-94/5	60-70%
Indonesia	$11.44 billion[2] $42.2 billion[3]	1987/8-93/4 1985-2000	10%	1987+	
Jamaica	$417 million	1987/8-93/4			
Pakistan	$11.31 billion[4]	1985/6-92/3	10.6% 8.3%	1983-88 1989-93	66%
Philippines	$ 2.67 billion	1986-96	5.7%	1986-96	
Senegal	$265 million	1985-90			
Sudan	$683 million	1986-95			
Thailand	$ 6.7 billion	1986-95	7.7% 5.3%	FY1986-FY92 FY1993+	

[1]In 1985 prices.
[2]In 1987 prices.
[3]In 1980 prices.
[4]Does not include investment plans of Karachi Electricity Supply Company which could amount to an additional 20%.

Sources: World Bank, Asian Development Bank, African Development Bank, Inter-American Development Bank.

The power sector investments planned or otherwise reported as desirable are impressive, even when divided by the number of years in the investment plan period. Indonesia's recommended power sector investments average between $2.3 billion and $5.6 billion per year, depending on the expansion plan, for a six-year total of $11.4 billion or a 15-year total of $42 billion. The Indian power sector expansion plans are even more impressive, at just over $11 billion per year during the 1984/85-1989/90 Plan period. Pakistan's plans call for just under $1.9 billion per year for six years. For a small country, the Jamaican investment plans are substantial at $70 million a year for six years. The cost of the Egyptian expansion plan is relatively low at only $882 million per year over a five-year period to install 7190 MW of additional generating capacity. Philippine plans call for a 11-year total of $2.6 billion, while Thailand's call for $6.7 billion in ten years. These power sector investment plans are especially impressive when compared with several of the countries' total external debts as of the end of 1982: Indonesia, $21.9 billion; the Philippines, $20.7 billion; and Thailand, $11.1 billion (Schuh, 1986, p. 49).

Clearly, the planned expenditures are large enough to cause concern about where the money is going to come from. To temper this picture somewhat, the last column in Table 10 offers some numbers on electricity tariffs as percentages of the long-run marginal cost of producing the electricity. Indian and Pakistani tariffs are reported to run as high as two-thirds of cost, while Egyptian rates are reported to range from 7 to 70 miliemes per kilowatt hour (U.S. $0.01 to $0.10), with generation costs ranging between 100 and 150 millemes per kilowatt hour (U.S. $0.143 to $0.214). A doubling of rates, on average, with a price elasticity of -0.5 and ignoring secondary income effects, could cut growth rates in half, but half of the projected growth rates shown in Table 10 are still in the respectable 4.1% to 8.3% per year range. Reducing the investment requirements by half still would leave most of the countries reported in Table 10 with serious fiscal requirements for their power sectors. At the same time, a doubling of real electricity tariffs in a short time would face major political difficulties.

5.2 SECTORAL INVESTMENT TRADE-OFFS

Suppose developing countries undertook these major power sector investments but determined not to expand their total levels of foreign borrowing beyond what they would have been without this major investment push in one sector. This is an unlikely scenario, but it is one end of the spectrum of choices between simply adding the additional power sector bill to the rest of the development investment list on the one hand, and on the other hand, towing the line on foreign borrowing and taking the power sector investment out of other expenditure items. Additionally, it highlights the potential costs of the power sector spending in terms of other foregone development investments. However, getting an empirical handle on this scenario is complicated by the dispersed and inconsistent character of data on public investment in developing countries. These problems and some approaches to reducing or solving them are discussed below.

The major sectoral claimants on public capital development expenditures are energy, agriculture and rural development, transportation, and industry. Education, urban development, and population, health, and nutrition are comparatively minor claimants. Consolidated information on government capital expenditures in developing countries is difficult to obtain because IMF data do not include expenditures of public enterprises which sell goods and/or services to the public (IMF, 1986, p. 6). However, some alternative sources may be a rough guide to overall capital expenditure patterns inclusive of parastatals. The following discussion describes utility funding sources and the portions of those sources for which at least partial data exist. With that information, we can interpret the existing data, with care, to roughly estimate shares of capital development spending going to different sectors. From those estimates and additional information on levels of power sector capital spending, we can assess the potential impacts of redirecting investment to the power sector.

The typical government enterprise may cover its production costs but generally is not profitable enough to generate its investment capital internally, particularly in the power sector. Investment comes predominantly from borrowing, occasionally from grants, usually foreign borrowing since 50% to 80% of investment requirements are in foreign exchange. The public corporations undertake some of the borrowing in their own names, and the government often borrows some on behalf of the utility, sometimes having to relend the money at a slightly higher interest rate. The corporations' shares of the borrowings appear to be larger than the governments' shares, at least for the power sector.

Preferred borrowing has been from official lending agencies such as the World Bank, the various regional development banks such as the Asian Development Bank, and the development agencies of the industrialized countries, but borrowing, sometimes extensive, also has been conducted from commercial banks. Funds borrowed by the government from both official and commercial sources would show up in the IMF statistics on government finances as government borrowing, and the expenditure of these funds would appear as government capital expenditures. Grants to the government, but not to the parastatals, would appear in the capital expenditure data if they are used for investment purposes rather than current expense items such as training. Funds borrowed by both the public corporations and the government from official lending agencies would appear in the figures for those agencies' loans to the country in question.

Direct parastatal borrowings from commercial banks and internally generated capital funds would be the only figures not to appear in either of these two sources--the government borrowing and capital expenditure figures on the one hand, and the development bank lending figures on the other. For most of the countries specifically considered in this section, these missing investments could account for relatively small shares of total power sector investment. Both Pakistani and Jamaican power corporations are forecast to be able to generate some 40% of their next decade's investment from internal sources, but at least in

Pakistan's case, the forecast is dependent upon substantial electricity tariff reform. Of other sectors, the most likely to be able to attract commercial loans are the industry and mining and possibly the roads categories. Agricultural and rural development projects are less likely destinations of commercial loans, as are education and urban infrastructure projects. Population, health and nutrition projects are almost certain to be officially funded through loans and/or grants. In any case, any commercial loans to those sectors would likely be to the government rather than to a publicly owned corporation and thus would appear in the IMF statistics.

Table 11 offers some figures on the pattern of official multilateral loans and credits as well as numbers on power sector investment as a percent of total public investment, including government investment in parastatals. Table 12 reports the 1980s pattern of government capital expenditures going to the category "electricity, gas, steam and water" and, for one country, the percent of net lending to the government going to that category of activities. The figures of Table 11 are higher-end estimates of the sectoral distribution of public investment to the power sector, and those of Figure 12 are lower-end estimates, although they are not really upper or lower bounds. Actual numbers can be attached easily to the lower-end distribution estimates, but not so readily to the upper-end estimates because the loan data do not always include all sources of loans, particularly commercial loans, and they exclude equity capital investments. Consequently, neither sectoral distribution nor total level of investment figures are as firm for the upper-end estimates. However, Table 13 offers some partial numbers on assistance levels in the power sector in several developing countries. These amounts are restricted to official loans, grants, and credits, and exclude commercial loans, utilities' equity investments, and government contributions to power sector investment that do not originate in official borrowing, but they do generally include government-signed official borrowings to re-lend to the power sector.

Finally, we offer some evidence which probably is less direct than it appears on sources and uses of funds in the power sector, actual and/or projected, for three countries, in Table 14. The funds reported may include current as well as capital expenditures, and the projected funding pattern in Indonesia is contingent upon substantial tariff increases, as is the optimistic forecast for internal cash generation in Pakistan noted above. What is particularly important is the share of funds devoted to debt service compared to what can be devoted to capital expenditure.

Now we are prepared to put together the information from these tables. Consider the case of Thailand. From Table 13, it received $2.19 billion (in current dollars) of power sector loans in the thirteen years from 1973 through 1985. We could double that figure, for a rough price level adjustment, to $4.4 billion in thirteen years; the exact adjustment would depend upon the timing of the loans, and doubling probably exaggerates the price level change. From Tables 11 and 12, the power sector has claimed between 3% and 26% of national public

Table 11. Prominence of the power sector in national public investment

	Power sector investment as % of public investment	Power sector loans and credits as % of		
		World Bank loans/ IDA credit	AfDB/ AfDF	ADB loans
Bangladesh		13%		
Egypt		12%	32%, 14%[3]	
India	25%	20%		
Indonesia		18%		17%[5]
Pakistan	29%			37%[6]
Philippines		26%[1]		
Thailand	26%	30%[2]		43%
Sudan			10%-30%[4]	

[1]From Asian Development Bank.

[2]All energy loans from IBRD: 19.3% of all external loans go to power.

[3]32% of AfDB lending and 19% of AfDF lending.

[4]Higher figure contingent upon current loan approval.

[5]All energy projects.

[6]All energy assistance; lending has been primarily for hydropower and thermal power development.

Sources: World Bank, Asian Development Bank, African Development Bank.

Table 12. Government capital expenditure patterns on power

A. Percent of government capital expenditures going to electricity, gas, steam and water

	1980	1981	1982	1983	1984	1985
Egypt	-	1.9	2.4	5.6	7.1	5.3
Indonesia	9.9	11.2	11.5	8.3	12.4	-
Pakistan	14.5	13.1	12.5	-	-	-
Thailand	2.5	4.8	5.2	3.0	4.1	1.5

B. Percent of lending minus repayments going to electricity, gas steam and water

	1980	1981	1982	1983	1984	1985
Thailand	13.5	-24.8*	60.3	53.0	-	29.2

*Net repayment of loans

Sources: International Monetary Fund, Government Financial Statistics Yearbook, 10 (1986).

investment, probably much closer to the higher figure, say 25% to be conservative. From Table 10, its current plans call for $6.7 billion dollars in power sector investment in the ten years from 1986 through 1995, which on a yearly basis is double the real rate of investment of the previous thirteen years. Thailand's real GNP grew at an annual rate of 5.1% from 1980 to 1985 which were relatively sluggish years for the world economy. Extending that growth rate through 1995 would give a 73% increase in GNP by 1995, so even by the end of the investment plan period, a 100% increase in annual power sector investment would not be fully covered by GNP growth, and in the years between 1986 and 1995, the shortfall would be even greater. To keep from expanding aggregate borrowing more than proportionally to the growth of the economy, the share of national public investment going to the power sector might have to rise to as much as 50% in the late 1980s, gradually falling to 32% by

Table 13. Official loans, grants and credits to the power sector

	Assistance level (Current US$)	Period covered	Agencies Included among lenders/donors
Bangladesh	$295 million	1979-86	IDA
	$347 million	1973-85	ADB
Egypt	$325 million	1979-86	IBRD, IDA
India	$4.9 billion	1979-86	IBRD, IDA
Indonesia	$1.89 billion	1979-85	IBRD
	$3.19 billion	FY1982/3-FY86/7	All official & commercial sources
Jamaica	$68.5 million	1978-87	IBRD
	$42.7 million	-85	IDB
Pakistan	$2.35 billion	1975/6-85/6	Multilateral & bilateral sources
	$290 million	1985-86	IBRD
Philippines	$2.3 billion	1968-86	All official development assistance to National Power Corporation
Thailand	$2.19 billion	FY1973-FY85	All sources except AID & technical assistance.

Sources: World Bank, Asian Development Bank, African Development Bank, Inter-American Development Bank.

1995, still above the current share. Development funds going to other sectors such as agriculture, transport and communications, industry, etc. correspondingly would be squeezed. The prospects for most of the other countries in Tables 10 through 13 entail equivalent or harder squeezes on competing sectors.

5.3 BORROWING FOR MAJOR POWER SECTOR INVESTMENT

The alternative end of the spectrum of choices to finance the power sector expansions of the coming decade is to borrow. Currently, that may be a very restricted option, particularly internationally, but it is useful to explore the impacts that such borrowing could have on the

aggregate economy of a developing country, particularly in light of the recent developing country debt crisis

Foreign borrowing and public sector deficits to the extent potentially involved in power sector investments of the magnitudes of those desired in India, Indonesia, Pakistan, and the Philippines could precipitate some undesirable consequences which, once underway, could be difficult to control. The borrowing and the deficits could fuel spending on nontraded goods and services such as housing, causing the exchange rate to become overvalued and the trade balance to deteriorate. In anticipation of devaluations, domestic interest rates could shoot up to the range of 40% to 50%, effectively choking off domestic investment demand. Most of the official loans have four- to five-year grace periods, but that length of time can permit a country to compound its domestic macroeconomic problems as well as to resolve them. If exchange rate overvaluation and consequent weakening of the traded goods sectors lasted throughout the grace period, the country could have serious problems in making its debt service payments. If a large number of developing countries began to export more heavily to repay foreign debts, pressure on the current accounts of the industrialized countries could lead to populist political pressures for higher tariffs in those countries, further aggravating the debt repayment problem. The exporting required to service the debt on an aggregate of $200 to $300 billion of additional debt for power sector loans could be large enough to initiate such counterpressures.

6. CONCLUSIONS

On the economic costs of power unreliability, this study has devoted possibly excessive attention to the cases of India and Pakistan. Unfortunately, that is simply where the data are, and we can only caution against assuming that these two countries are necessarily representative of electric power problems in all developing countries. Nevertheless, these two examples do permit us to put some quantitative flesh on a theoretical framework. Authorities in both India and Pakistan consider their countries to have serious electricity system problems, and that fact alone suggests that other countries where the power system is considered to have serious trouble could be suffering economic losses of similar proportions.

Current reliability problems in electricity supply have been imposing production losses at least as high as 1.5% to 1.8% of GNP in India and Pakistan, respectively. These estimates include manufacturing and agricultural losses in India but only manufacturing losses in Pakistan. Including losses in the commercial, government, and residential sectors would push these percentage losses higher, although to an unknown extent. These loss estimates are particularly high when it is considered that electricity supplied only around 6% of total energy in India and around 7% in Pakistan during the time period of the loss estimates. These reductions in GNP can be compared to the effects of the 1982 recession in the United States, which reduced GNP by 1.8% between December 31, 1981 and December 31, 1982.

Included in the losses for Pakistan are foreign exchange losses amounting to at least 4.2% of 1983 foreign exchange earnings. This estimate excludes the foreign exchange cost of items imported to substitute for lost domestic production.

The power sector investments planned to meet expected electricity demand growth of the coming decade are large. They are large relative to previous annual rates of investment, and they would substantially increase the share of national public sector investment going to the power sector. Without major additional borrowing, much of it in foreign exchange, development investments in other sectors would have to be sacrificed and redirected to power, and without those other investments, the power sector investments probably would not have their intended effects. Additional foreign and domestic borrowing of the extent envisioned for the power sector investments could crowd out borrowing for other public and private investments or could trigger sizeable national financial problems which could lead to unemployment, inflation, or both. Capacity increases of the magnitudes contemplated for the developing countries could significantly increase global atomospheric carbon emissions. The use of cleaner coal technologies for generating equipment to mitigate this problem could raise capital costs beyond those currently projected.

REFERENCES

Barnes, Douglas F. (1987) Electric Power for Rural Growth: How Electricity Affects Rural Life in Developing Countries. Boulder: Westview.

Bernstein, M., and Y. Hegazy. (1987) "The Economic Costs of Electricity Shortages: A Case Study of Egypt." University of Pennsylvania, March.

Cecelski, E. and S. Glatt. (1982). "The Role of Rural Electrification in Development", Discussion Paper D-73E. Washington: Resources for the Future.

Collier, Hugh. (1984) Developing Electric Power; Thirty Years of World Bank Experience. Baltimore: Johns Hopkins University Press.

Darmstadter, Joel, Leslie W. Ayres, Robert U. Ayres, William C. Clark, Pierre Crosson, Thomas E. Graedel, Robert McGill, John F. Richards, and Joel A. Tarn. (1987) Impacts of World Development on Selected Characteristics of the Atmosphere: An Integrative Approach. Volume 2-Appendices. ORNL/Sub/86-22033/1/V2. Oak Ridge, Tenn.: Oak Ridge National Laboratory, August.

Geller, Howard S. (1984). "The Potential for Electricity Conservation in Brazil." Sao Paulo, Brazil: Companhia Energetica de Sao Paulo.

"Groping in the Dark," India Today, July 15, 1984, pp 40-47.

Hagler-Bailly, Inc. (1987) "Electric Power in Developing Countries; Current Situation and Future Prospects." Draft prepared for Office of Energy, Agency for International Development. Washington, D.C., November.

Heron, A. (1985) "Financing Electric Power in Developing Countries," IAEA Bulletin 27: 44-51.

Hogan, W., and A. Manne. (1977) "Energy Economy Interactions: The Fable of the Elephant and the Rabbit." In C. Hitch (ed.), Modeling Energy-Economy Interactions: Five Approaches. Washington, D.C.: Resources for the Future.

International Monetary Fund (IMF) (1986). Government Finance Statistics Yearbook 10. Washington, D.C.: International Monetary Fund.

Jaramillo, Pablo, and Esteban Skoknic. (1973) "Costo Social de Las Restricciones Energia Electrica." Santiago, Chile: Oficina de Planificacion, August.

Jones, Donald W. (1987a). Energy Use and Fuel Substitution in Economic Development: What Happened in Developed Countries and What Might Be Expected in Developing Countries." Paper presented at the Ninth International Meeting of the International Association of Energy Economists, Calgary, Alberta, July.

_____. (1987b) Urbanization and Energy Use in Economic Development. ORNL-6432. Oak Ridge, Tenn.: Oak Ridge National Laboratory.

Jones, Donald W., John P. Stovall, Judith G. Raby, and Dana R. Younger. (1987) Mid-Term Evaluation of USAID Sudan Energy Planning and Management Project (650-0059). ORNL-6421. Oak Ridge, Tenn.: Oak Ridge National Laboratory.

Jones, Leroy P. (1985) "Public Enterprise for Whom? Perverse Distributional Consequences of Public Operational Decisions," Economic Development and Cultural Change 33: 333-47.

Jorgenson, Dale W., and Barbara M. Fraumeni. (1981) "Relative Prices and Technical Change." In Ernst R. Berndt and Barry C. Field (eds), Modeling and Measuring Natural Resource Substitution. Cambridge: MIT Press, pp 17-47.

Khosla, S., and T. V. Gopalaswami. (1986) "Return on Capital of State Electricity Boards -- An Assessment," Urja.

Munasinghe, Mohan. (1980) The Economics of Power Systems Reliability and Planning. Baltimore: Johns Hopkins University Press.

_____. (1987) Rural Electrification for Development. Boulder, Colo.: Westview Press.

Munasinghe, Mohan, and Mark Gellerson. (1979) "Economic Criteria for Optimizing Power System Reliability Levels," Bell Journal of Economics 10: 353-65.

National Council of Applied Economic Research (NCAER). (1985) "Impact of Power Shortage in Agriculture and Industry." New Delhi: Central Electricity Authority, July.

Office of Technology Assessment, U. S. Congress. (1981) Technology and Soviet Energy Availability. Washington, D.C.: U. S. Government Printing Office.

Organization for Economic Co-Operation and Development (OECD). (1984) Energy Balances of OECD Countries 1970/1982. Paris: OECD.

_____. (1985) Environmental Effects of Electricity Generation. Paris: OECD.

Pearce, David, and Michael Webb. (1987) "Rural Electrification in Developing Countries; A Reappraisal," Energy Policy 15: 329-38.

Russell, Jeremy. (1976) Energy as a Factor in Soviet Foreign Policy. Westmead, Hants., U.K.: Saxon House.

Samanta, B., and A. Sundaram. (1983) "Socioeconomic Impact of Rural Electrification in India." Operations Research Group, Baroda, (Discussion Paper D-730, Resources for the Future, Washington, D.C.)

Sanghvi, A. P. (1982) "Economic Costs of Electricity Supply Interruptions: U.S. and Foreign Experience," Energy Economics 4: 180-98.

_____. (1983) "Optimal Electricity Supply Reliability Using Customer Shortage Costs," Energy Economics 5: 129-36.

_____. (1987) "Optimal Selection of Reliability Standards in Practical and Theory." Draft final report submitted to Electric Power Research Institute (EPRI), January.

Sathaye, Jayant A. (1987) "Rural Electricity in the Philippines; Planning Issues," Energy Policy 15: 339-51.

Sathaye, Jayant A., et. al. (1987) "Value of Service Reliability Study." Final report submitted to Pacific Gas & Electric Company.

Schramm, G. (1985) "The Economic Costs of Unreliable Power Supplies." In Corazon Morales Siddayo (ed.), Criteria For Energy Pricing Policy. Gaithersburg, Md: Graham & Trotman, pp 115-17.

Schuh, G. Edwin. (1986) The United States and the Developing Countries: An Economic Perspective. Washington: National Planning Association.

Schurr, Sam, et. al. (1981) Energy, Productivity and Economic Growth. Oelgeschlager, Gunn & Hain, Cambridge, MA.

Sharpe, H.H. (1975) "Reliability Dollar Value Analysis." Planning Department, Jamaica Public Service Company, Kingston, Jamaica, November.

Tanzania Electricity Supply Company Limited (TANESCO). (1985) "Rehabilitation Study of Existing Generation, Transmission, and Distribution Facilities." Final report prepared by EPDC, Ltd, April.

Tendler, Judith. (1971) Inside Foreign Aid. Baltimore: Johns Hopkins University Press.

Trocki, L., et al. (1987) "The Energy Situation in Five Central American Countries." Report LA-10988-MS, Los Alamos: Los Alamos National Laboratory.

U. S. Agency for International Development (AID). (1987a) Country Development Strategy Statement, FY1988--FY1993, Pakistan. Islamabad: AID/Pakistan, April 11.

_____. (1987b) "The Financial and Economic Impact of Power Interruption and Load shedding in the Industrial Sector in Pakistan." Report prepared for WAPDA and USAID, by EBASCO, AEPES, and ITECO, March.

_____. (1987c) Country Development Strategy Statement, FY 1989, Egypt. Cairo: AID/Egypt, January 29.

U.S. Department of Energy (DOE). (1981) "The National Electric Reliability Study." DOE/EP-0005, April.

U.S. Energy Information Administration. (1986) Annual Energy Review 1985. Report DOE/EIA/A-0384(85). Washington: U.S. Department of Energy.

Walsh, J. (1987). "War on Cattle Disease Divides the Troops," Science 237: 1289-91.

Westley, G.D. (1984) "Electricity Demand in a Developing Country," Review of Economics and Statistics 66: 459-67.

_____. (1981) "The Residential and Commercial Demand for Electricity in Paraguay." Inter-American Development Bank, Paper on Project Analysis # 19, June.

World Bank. (1979a) India: Economic Issues in the Power Sector. Washington: World Bank.

_____. (1979b) Coal Development Potential and Prospects in the Developing Countries. Washington, D.C.: World Bank, November.

_____. (1982) Bangladesh: Issues and Options in the Energy Sector. Washington: World Bank.

INTERNAL DISTRIBUTION

1. M. Brown
2. B. L. Bush
3. C. Chang
4. J. Christian
5. S. J. Dale
6. W. Fulkerson
7. C. B. Grillot
8. J. L. Hardee
9. G. Harrison
10. L. J. Hill
11-15. E. L. Hillsman
16-45. D. W. Jones
46. J. O. Kolb
47. P. N. Leiby
48. W. R. Mixon
49. W. N. Naegeli
50. R. D. Perlack
51. A. M. Perry
52. C. H. Petrich
53. S. Rayner
54. J. H. Reed
55. D. E. Reichle
56. L. W. Rickert
57. T. Rizy
58. E. Rogers
59. R. D. Roop
60. R. B. Shelton
61. G. G. Stevenson
62. E. J. Szarleta
63. T. J. Wilbanks
64. S. B. Wright
65. Central Research Library
66. Document Reference Section
67-69. Laboratory Records
70. Laboratory Records - RC

EXTERNAL DISTRIBUTION

71. J. J. Cuttica, Vice President of Research and Development, Gas Research Institute, 8600 W. Bryn Mawr Avenue, Chicago, IL 60631

72. Mr. David J. Jhirad, Office of Energy, U.S. Agency for International Development, SA-18, Room 509, Washington, DC 20523

73. J. P. Kalt, Professor of Economics, Kennedy School of Government, Harvard University, 79 John F. Kennedy Street, Cambridge, MA 02138

74. D. E. Morrison, Professor of Sociology, Michigan State University, 201 Berkey Hall, East Lansing, MI 48824-1111

75. R. L. Perrine, Professor, Engineering and Applied Sciences, Civil Engineering Department, Engineering I, Room 2066, University of California, Los Angeles, CA 90024

76. Mr. Ross Pumphrey, Office of Energy, U.S. Agency for International Development, SA-18, Room 509, Washington, DC 20523

77. Mr. Alberto Sabadell, Office of Energy, U.S. Agency for International Development, SA-18, Room 509, Washington, DC 20523

78-82. Mr. Arun P. Sanghvi, Hagler, Bailly & Co., 2301 M Street, N.W., Washington, DC 20037

83. Mr. James B. Sullivan, Office of Energy, U.S. Agency for International Development, SA-18, Room 509, Washington, DC 20523

84. Ms. Shirley Toth, Office of Energy, U.S. Agency for International Development, SA-18, Room 509, Washington, DC 20523

85. Office of Assistant Manager for Energy Research and Development, DOE/ORO, P.O. Box 2001, Oak Ridge, TN 37831-8600

86-95. OSTI, U.S. Department of Energy, P.O. Box 62, Oak Ridge, TN 37831