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### Authors

Meyers, S.  
Sathaye, Jayant A.  
Masera, O.  
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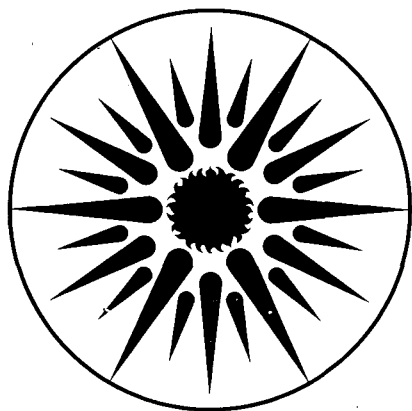
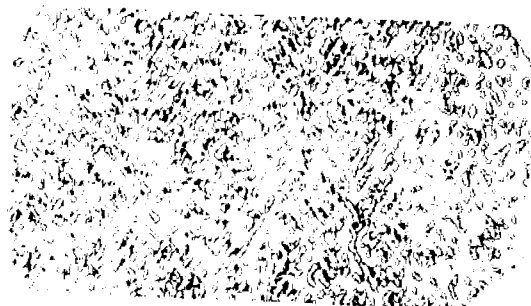
UNIVERSITY OF CALIFORNIA

## APPLIED SCIENCE DIVISION

### Plans for the Power Sector in Thirteen Major Developing Countries

S. Meyers, J. Sathaye, O. Masera, and A. Ketoff

October 1989



APPLIED SCIENCE  
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**PLANS FOR THE POWER SECTOR  
IN 13 MAJOR DEVELOPING COUNTRIES**

*Stephen Meyers (Project Leader)*

*Jayant Sathaye*

*Omar Masera*

*Andrea Ketoff*

International Energy Studies Group  
Energy Analysis Program  
Applied Science Division  
Lawrence Berkeley Laboratory  
1 Cyclotron Road  
Berkeley, CA 94720

October 1989

## ABSTRACT

This report presents an overview of plans for the power sector in the 1990s in 13 major developing countries. Together, these 13 countries account for about 72% of total developing country electricity production. For each country, we present (1) background information on the power sector, (2) estimates of resources available for electricity generation, (3) official forecasts of electricity demand, (4) current or recent plans for expansion of generating capacity through the year 2000; (5) discussion of financial and environmental issues and supply and end-use efficiency, and (6) a brief analysis of the stated plans for the power sector.

The planned or estimated future rates of growth in installed electric power capacity in the 1987-2000 period vary considerably among the 13 countries from a high of 9.8% per year in Pakistan to a low of 2.8% per year in Argentina and Venezuela. The planned future growth is markedly lower than that recorded in the 1979-1987 period in most of the countries, and in most of the rest the planned growth is about the same as that in the 1979-1987 period. For the 13 countries as a group, the future average growth of 6.3% per year is below the rate of 7.5% recorded in 1979-1987. Reasons for lower growth in the future include slower expected economic growth, rapid past expansion in capacity, and difficulties in expanding power capacity.

Compared to 1987, the share of total capacity that is coal-fired is to increase substantially in Indonesia, Malaysia, Pakistan, the Philippines, South Korea, Taiwan, Thailand, and Mexico. The role of hydropower will decrease in many of the 13 countries, while natural gas will become more important in India, Indonesia, Malaysia, Taiwan, and Argentina. For the 13 countries as a group, the share of coal-fired plants is to increase from 35% of total installed capacity to 41% in 2000, while the share of hydropower declines slightly from 39% to 38%. The share of natural gas increases only from 6% to 7%, as growth in some countries is partly balanced by decline in others. The oil-fired share declines from 16% to 9%, while the share of nuclear power grows from 4% to 5%.

The move toward coal may turn out to be even stronger than the plans indicate due to difficulties in constructing planned nuclear and hydro power plants, though environmental problems associated with coal could limit its role as well. Financial, institutional, and environmental challenges to conventional expansion of electricity supply are provoking increasing interest in improving the efficiency of generation and transmission and distribution, cogeneration and other private power generation options, and programs to increase end-use efficiency.

## ACKNOWLEDGEMENTS

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## NOTES AND COMMON ABBREVIATIONS

### Notes

- (1) Numbers for installed capacity often overstate the actual capacity that is available on a regular basis. The extent to which this is true varies among countries depending on the state of repair of their power plants and the nature of their hydroelectric facilities. In general, the share of electricity generation that comes from hydropower is quite a bit less than the share of hydro in total installed capacity. For example, in China hydropower accounts for 29% of total installed capacity, but for only 20% of total generation. Hydro generation also varies seasonally and annually depending on rainfall patterns and reservoir storage capacity. Some hydro capacity is pumped storage and is used mainly to meet peak loads.
- (2) The discussion in this report refers to provision of electricity for public use. With the exception of China (for which separate data were not available), we do not include self-producers of electricity. In many developing countries, production by enterprises for their own use amounts to over 10% of public generation. In Indonesia, self-production amounts to around 85% of public generation. Self-production typically relies on diesel generators, though there is also use of biomass residues in forestry and agro-processing industries.
- (3) The average annual growth rates presented for a particular period in the text and tables in this report reflect the difference between the base and end years. In some cases, the actual historic trend had considerable fluctuation. Choice of a different base year produces a quite different average rate in some cases. For a better portrait of historical trends in electricity generation and consumption from 1970 through 1986 for the 13 countries in this report, we refer the reader to: S. Meyers and J. Sathaye, "Electricity in the Developing Countries: Trends in Supply and Use since 1970," Lawrence Berkeley Laboratory Report LBL-26166, Dec. 1988.

### Common Abbreviations

MW = Megawatt (10E6 W)

GW = Gigawatt (10E9 W)

kWh = kilowatt-hour

TWh = Terawatt-hour (10E9 kWh)

BOE = barrel of oil-equivalent (5.5 million Btu)

AAGR = average annual growth rate

n.a. = not available

FY = Fiscal Year

## 1. INTRODUCTION

This report presents an overview of plans for the power sector in the 1990s in 13 major developing countries. The countries covered include nine in Asia (China, India, Indonesia, Malaysia, Pakistan, the Philippines, South Korea, Taiwan, and Thailand) and four in Latin America (Argentina, Brazil, Mexico, Venezuela). Together, these 13 countries account for about 72% of total developing country electricity production.<sup>1</sup>

For each country, we present (1) background information on the power sector and natural resources; (2) official forecasts of electricity demand; (3) current or recent plans for expansion of generating capacity in the 1990s; (5) brief discussion of financial and environmental issues, and electricity supply and end-use efficiency; and (6) an assessment of the stated plans for the power sector. The amount of information presented varies among countries depending on what was available in the course of this study. The historical data presented as background were compiled from a variety of utility and government sources.<sup>2</sup> For the most part, the plans that we present and discuss are official utility or government documents dating from 1988 or 1989. In some cases, we have extrapolated from the information available to us to estimate the capacity and mix of power plants for the year 2000.

In considering the information presented herein, it is important to bear in mind that the plans of developing countries for the power sector (as in other areas) are often somewhat unrealistic, as evidenced by comparing the historic experience with official plans. Plans for the power sector may represent what the utility or government would like to achieve; what can actually be accomplished may be much less. This feature varies among countries. For some countries, the plans as presented in this report have a good likelihood of being realized; for others, the reality may fall far short of the plans. Of course, events unforeseen at the present will shape the evolution of the power sector in terms of total capacity and the mix of power sources. Plans for the first half of the 1990s are obviously more firm than those for later years. While it is beyond the scope of this report to assess in depth the realizability of the plans presented herein, we have tried to give a sense for this based on our and other observers' perception and understanding of the situation in each country.

Many factors will shape the actual evolution of the power sector in the 13 study countries (as well as in other countries not covered here). The most obvious is the rate of growth in electricity demand, especially peak demand, since this is the demand that the power system seeks to be able to meet with a reasonable degree of reliability. There are some cases where (as occurred in the U.S.) utilities have added too much capacity due to overly optimistic projections of demand. In many developing countries, however, including many of the smaller countries not included in

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<sup>1</sup> In the category "developing countries" we include all non-OECD countries except South Africa, the USSR, and the Warsaw Pact countries of Europe. Some of the included countries are at relatively advanced levels of economic development or have relatively high per capita GDP. Apart from the 13 countries covered in this report, other developing countries that have annual electricity production greater than 20 TWh are Saudi Arabia, Egypt, Iran, Iraq, Colombia, North Korea, and Hong Kong.

<sup>2</sup> For further information on the historical evolution of the power sector in the 13 countries covered in this report, see S. Meyers and J. Sathaye, "Electricity in the Developing Countries: Trends in Supply and Use Since 1970," Lawrence Berkeley Laboratory Report LBL-26166, Dec. 1988.

this report, electricity supply has not been able to keep up with demand, and power shortages of over 10% of the generation capability create problems and increase operating costs for consumers (through the need for backup equipment or shutdown of operations during outages).<sup>3</sup> This problem is due to both rapid growth in demand and operational shortcomings on the part of utilities, and in many cases appears to be growing worse rather than improving. Some countries that have been able to keep comfortably ahead of demand are now facing a situation of impending shortage (e.g., Thailand and perhaps Taiwan). Where a shortage of electricity prevails, the near-term and perhaps longer-term reality is that electricity users will consume whatever the utilities are able to supply. Many industries that now generate a substantial amount of their own power with diesel generators due to lack of reliable public supply would use grid electricity if it were available, since the latter is much cheaper.

In those countries where a condition of electricity shortage appears likely to exist for a good while, the key variable is the capacity of suppliers to expand operations. This capacity has institutional as well as financial aspects. Many utilities in developing countries have difficulties in properly operating their current systems, which often have frequent outages, high technical and non-technical losses, low equipment availability, and fluctuating voltages. There is often poor management and staff morale and a high degree of political interference in operations.

On the financial side, the presence of electricity prices that do not reflect marginal (or sometimes average) costs of supply encourages growth in demand and also prevents utilities from raising sufficient revenues to provide the needed supply. Increase in tariffs in recent years, often under pressure from multilateral lending institutions, have brought prices closer to costs in some countries, but subsidies still exist in many cases. Meanwhile, capital costs of new supply are rising in many cases, while the amount of financing available is recognized as being insufficient to meet the need. Delays in completion of power projects are often significant and add to capital requirements (due to interest during construction).

Environmental factors are also beginning to have a greater influence in shaping options for the power sector. While for the most part countries have placed little if any emphasis on evaluating the environmental impacts of energy supply options, this situation is changing in response to domestic and international pressures. As such impacts are taken into account more seriously, plans for the power sector may be affected accordingly.

The severity of the problems facing the power sector varies among countries. Where they are significant, one can expect that the rate of expansion that countries would like to achieve — as reflected in the plans discussed in this report — will be difficult to realize. The actual rate of evolution may be slower than hoped for, and the mix of fuels may shift as relative economics, resource availability, and government policy change, but the plans are indicative of the direction in which countries are seeking to move.<sup>4</sup>

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<sup>3</sup> U.S. Agency for International Development, *Power Shortages in Developing Countries: Magnitude, Impacts, Solutions, and the Role of the Private Sector*, March 1988.

<sup>4</sup> It is the fate of a report of this nature that some of the information presented will be superseded by new information not long after the publishing of this report. This point should particularly be borne in mind by those who are reading this report after mid-1990.

## 2. CHINA

### 2.1. Background

The Ministry of Energy (MOE) is responsible for overseeing electric power development in China. There are six regional power administrations which coordinate operations for the regional grids and formulate long-term development plans for approval by the MOE and the State Planning Commission. Below the regional administrations are 22 provincial and municipal power bureaus operating as parts of the regional grids, and eight other power bureaus that still operate in isolation.

China's electricity generating capacity has grown from 63.0 GW in 1979 to 102.9 GW in 1987, by far the highest among developing countries. (Power sector statistics for China include large self-producers.) This total consists of 72.7 GW in thermal power stations and 30.2 GW in hydro power stations. Most of the thermal capacity is coal-fired, and much of the oil-fired capacity is being or has been converted to coal. There are no nuclear power plants in operation, though two (a small domestically-designed plant and a large imported one) are under construction.

In the past few years China has accelerated the rate of growth in generating capacity: 21 GW were added in the 1985-87 period, nearly as much as were built in the 1979-84 period. The addition of 8.1 GW in 1987 was the highest ever, and more power stations of over 1000 MW are being built.

Electricity generation grew at an average annual rate of 7.4% in the 1979-1987 period. Generation in 1987 grew by 10.3% over 1986, reflecting strong demand growth in industry and households. Thermal power plants accounted for 80% of total generation in 1987, about the same share as in 1980. The role of coal has increased, however, as oil has been gradually backed out (Figure 2-1).

Industry dominates electricity consumption, accounting for nearly 80% of total consumption. Residential and commercial consumption is relatively undeveloped, but is growing at a faster rate than industrial demand. About 65% of the population has access to electricity.

Despite the considerable growth in capacity in recent years, shortage of electricity remains a major problem. In many areas the pace of growth in electricity demand has outstripped the ability of power authorities to build additional capacity. Another factor is lack of fuel for the coal-fired power plants upon which China relies, a situation due mainly to the inadequate transport capacity between coal-producing areas and the major demand centers. The inefficiency of Chinese industrial production also contributes to the electricity shortage, as has the rapid growth in residential and commercial electricity demand. The estimated shortage in 1987 was 50-70 TWh, equal to 10-15% of total generation.<sup>1</sup> Electricity is allocated through quotas based on priorities set by central, provincial, and country authorities, but at least 20% of industrial capacity is reportedly idled at any given time due to lack of power.

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<sup>1</sup> Hu Zhaoyi, "Electrical Energy Sources and Consumption in China," Beijing: Electric Power Research Institute, 1988.

Table 2-1  
**Power Sector Statistics for China**  
(Including large self-producers)

	1987	1987 (%)	AAGR 1970-79	AAGR 1979-87
<b>Installed Capacity (GW)</b>				
Hydro	30.2	29	11.1 <sup>a</sup>	5.9%
Thermal	72.7	71	11.1 <sup>a</sup>	6.5%
Coal-fired	64.7	63	n.a.	n.a.
Oil-fired	8.0	8	n.a.	n.a.
Total	102.9	100	11.1	6.3%
<b>Generation (TWh)</b>				
Hydro	100.2	20	10.4%	9.1%
Thermal	397.1	80	10.4%	7.0%
Coal-fired	350.2	70	n.a.	10.1% <sup>b</sup>
Oil-fired	46.9	10	n.a.	-4.3% <sup>b</sup>
Total	497.3	100	10.4%	7.4%
<b>Consumption (TWh)<sup>c</sup></b>				
Industry	305.5	79	n.a.	5.7% <sup>d</sup>
Residential	24.8	6	n.a.	15.3% <sup>b</sup>
Commercial	16.8	4	n.a.	11.9% <sup>b</sup>
Agriculture	32.2	8	n.a.	4.7% <sup>d</sup>
Total	386.0	100	n.a.	7.1% <sup>b</sup>

Sources: China State Statistical Bureau, Energy Research Institute,  
Asian Development Bank

Installed capacity refers to year-end.

(a) Refers to 1973-1979.

(b) Refers to 1980-1987.

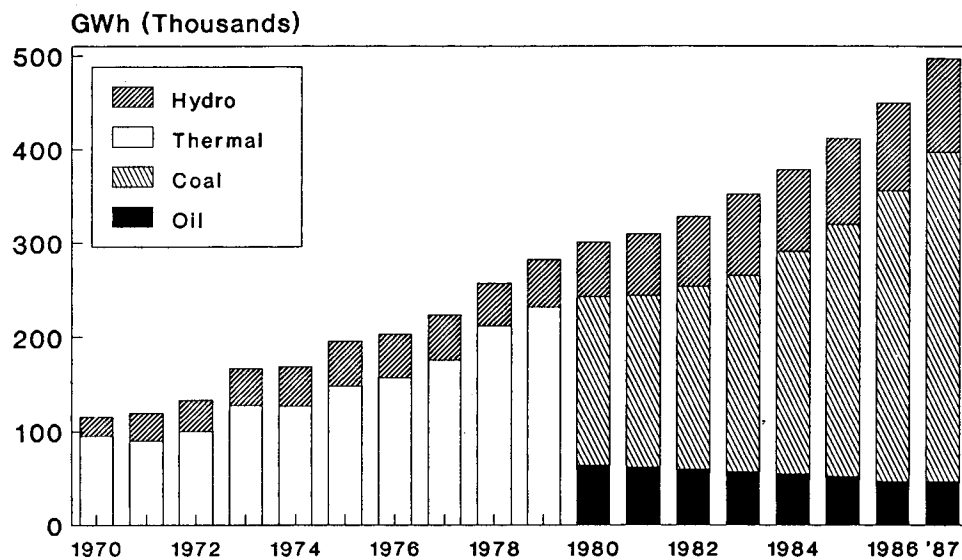
(c) Consumption is for 1986.

(d) The growth rate is for 1980-85, as there was a change in category definition that affects industry and agriculture.

**Electricity consumption per capita in 1986 (including self-production)**  
was 365 kWh.



# ELECTRICITY GENERATION BY SOURCE China



Notes: Includes self-production; Thermal disaggregation unavailable before 1980.

Figure 2-1

## 2.2. Resources For Electricity Generation

China has abundant coal and hydropower resources, but in both cases they are concentrated in regions far from the main demand centers. "Explored reserves" of coal have been placed at 770 billion tons (3000 billion BOE).<sup>2</sup> (Coal production in 1987 was 928 million tons.) The estimated resource in place (within 1500 m depth) is 3200 billion tons. A major difficulty is that most of the coal is in North and Northwest China, far from main demand centers in the south and southeast.

China's exploitable hydro potential amounts to 380 GW, the highest in the world. (This corresponds to 1900 TWh of annual electricity production.) Most of the resource (61%) is in Southwest China, however, thus requiring long transmission (2,000-3,000 km) over very rugged terrain to the main demand centers. Approximately one-fifth of the exploitable hydro capacity is in sites suitable for small-scale (up to 12 MW) projects, where traditional Chinese skills in hydraulic engineering are helpful.

Proved reserves of oil and natural gas have been placed at 2.5 billion tons (18 billion BOE) and 1 trillion cu. m. (6.7 billion BOE), respectively.<sup>3</sup> A 1987 resource assessment placed total oil and natural gas resources at 79 billion tons and 33 trillion cu.m., respectively,<sup>4</sup> but exploration sufficient to realistically determine the status of China's oil and gas resources has not yet occurred.

Verified reserves of fissionable uranium are sufficient to support an installed capacity of 15 GW for 30 years of operation.

## 2.3. Forecast of Electricity Demand

Projections developed in 1987 by China's Electric Power Research Institute (EPRI) showed electricity demand growing from 348 TWh in 1985 to 1020-1180 TWh in the year 2000. This corresponds to an average growth rate of 7.4-8.5% per year. The forecast growth by sector is shown below. The rural and municipal sectors are expected to grow faster than industry, though the latter will still dominate total consumption in 2000. Electricity use will also increase rapidly in transportation, reflecting the growing use of electric locomotives.

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<sup>2</sup> Ma Xuechang, "The Exploitation and Development of China's Energy Resources," in *Energy Future and New Energy Conservation Technologies*, Academic Journal Press, Beijing, Sept. 1988 (in Chinese).

<sup>3</sup> J.P. Dorian and A.L. Clark, "China's Energy Resources," *Energy Policy*, Feb. 1987.

<sup>4</sup> Wang Qinyi, "China confronted with long-term problem of energy resources," *Science and Technology Review*, 1988.

Table 2-2  
Forecast of Electricity Consumption in China  
1987

	1985		2000		AAGR (%) <sup>a</sup>
	TWh	%	TWh	%	
Industry	257	74	700-800	69-68	7.4
Rural <sup>b</sup>	57	16	180-200	18-17	8.4
Municipal <sup>c</sup>	31	9	120-150	12-13	10.3
Transport	3	1	20-30	2	15.2
Total	348	100	1020-1180	100	8.0

(a) Uses midpoint of forecast for 2000.

(b) Includes agriculture and rural small industry.

(c) Includes households and commercial.

#### 2.4. Plans for Power Sector Development

China's national energy policy places the power industry at the center of energy industry development. The official goal set several years ago was to quadruple electricity generation during the 1980-2000 period, which corresponds to an average growth of 7% per year. China's strategy to achieve this goal rests on two fundamental approaches: (1) Accelerated development of large, mid-sized, and small hydroelectric stations, and (2) Construction of numerous coal-fired power plants at mine-mouths in all major coal-mining areas, and at railway junctions, harbours, and near metropolitan areas.<sup>5</sup> Nuclear power is to play a secondary but not unimportant role in those parts of the country that lack both hydro potential and major coal resources.

A new national energy plan prepared by the Ministry of Energy at the end of 1988<sup>6</sup> envisions growth in electricity generation from 496 TWh in 1987 to 1200 TWh in 2000, which corresponds to an average growth of 7.0% per year. The total projected installed capacity is to grow from 103 GW to 240 GW. The share of hydro in total installed capacity would increase slightly to 30% (though its projected share of total generation is only 20%). The forecast of hydroelectricity production in 2000 is somewhat lower than in previous plans, as is the plan for nuclear energy. The new strategy emphasizes construction of mine-site power plants, but also calls for construction of thermal plants in the coastal area, along the railways from the coal-producing centers to the coast, and along waterways on which coal is transported inland.

<sup>5</sup> Previously, greater use of mine-mouth power plants was envisioned, but awareness of water supply limitations in some regions has caused revision of plans. This will necessitate greater processing and transport of coal.

<sup>6</sup> *The Mid-term Development (1989-2000) of China's Energy Industry*; cited in *People's Daily* (Overseas edition), Jan. 25, 1989.

Table 2-3  
Official Plan for Electricity Supply in China  
Late-1988

	Generation (TWh)		Installed Capacity (GW)	
	1987	2000	1987	2000
Hydro	99.5	225	30	72
Thermal	396.5	(950)	73	163
Nuclear	0	30	0	5
Total	496.0	1200	102.9	240

The figures in the new plan are best understood as targets. Some of the envisioned capacity would be planned and financed by the central government, some by provinces, and some by a combination of the two, as discussed below. Some of the hydro projects require considerable foreign financing and assistance in construction.

## 2.5. Financial Issues

China's goals for expanding power generation require about 10,000 MW of additional generating capacity to be commissioned every year, representing investments of about Y 20 billion (US\$ 5.4 billion) per year. Achieving this level of investment may prove difficult. Since 1980, the financial situation of the power industry has steadily deteriorated.<sup>7</sup> Increase in electricity prices, which are under nationally-unified regulation, has been less than growth in generation costs. Because of the low prices, and the high profits available in other sectors, the power sector suffers from insufficient investment.

Funds for most electricity system expansion are allocated from the central government. With the growth of power shortages in recent years, development of electricity supply with locally-gathered funds has been encouraged. Local authorities and power-consuming entities are being persuaded to pool funds together, and foreign loans are being used to accelerate power industry development. In addition to a number of small thermal and hydro power plants, some large and medium-sized power plants have been constructed through such means. The electricity prices of these local power plants are not restricted by the national electricity price, thus making investment more attractive.

Difficulties with financing and high capital costs may combine to limit growth in nuclear power in China. Although the per kWh cost of nuclear and coal-produced power is about the same (due to the artificially low price of China's coal), the capital cost for nuclear power plants to be built in the near future is about three times more than for similar-sized coal-fired stations. With the problems of coal transport, however, a number of provinces with severe power shortages have made plans to construct nuclear power plants.<sup>8</sup> These are to be financed jointly by

<sup>7</sup> Discussion based on: Zhou Dadi, "Energy Price Management in Economic System Reform," in *Proceedings of the Chinese-American Symposium on Energy Markets and the Future of Energy Demand*, Lawrence Berkeley Laboratory Report LBL-26260, Nov. 1988.

<sup>8</sup> "Power politics," *Far Eastern Economic Review*, April 6, 1989.

provincial and central government authorities.

An important result of the civil unrest and subsequent crackdown in 1989 has been delaying of foreign loans and tightening of credit. This seems likely to slow the growth in the power sector. The decision by several Western governments and aid agencies to freeze low-cost loans, for example, has thrown a hydroelectric power project in southwest China into doubt, and it is considered unlikely that the Chinese could build the project without foreign financing.<sup>9</sup> Other projects may face a similar fate.

The tightening of control by the central government is likely to mean that approval and funding for power projects by Beijing will be more important than previously, though projects planned and financed at the provincial and local level will still be significant. Supply of coal for these projects will need to be coordinated with the central government, however.

## 2.6. Electricity Supply And End-Use Efficiency

The average thermal efficiency of China's coal-fired power plants (31%) is low by international standards. Many of the plants are old and are operated at high capacity with insufficient maintenance. Improving generating efficiency is receiving high priority, however. Transmission and distribution losses are reported to be 8% of net generation,<sup>10</sup> which is low by developing country standards.

In recent years Chinese energy planners have come to place increased emphasis on energy conservation, including electricity conservation. A high price for electricity consumption above a certain quota in most sectors has encouraged efforts to reduce use. There is also a very high price for electricity used for air conditioning, and electric stoves are forbidden. Manufacturers of pumps, fans, compressors and other equipment have been directed to phase out production of inefficient equipment and design and produce more efficient devices. The government is preparing new guidelines for electricity conservation in order to slow growth in demand and help reduce the power shortage.

## 2.7. Environmental Issues

Air pollution and acid rain associated with coal combustion are serious problems that are receiving increased attention within China. Particulate concentrations in Chinese industrial and urban areas are commonly at levels encountered in Europe and North America two generations ago, and acidic precipitation is common in much of southern China. China's coal-fired power plants have around 90% control of particulate emissions, but do not employ flue gas desulfurization.

Much of China's new electricity generation will come from mine-mouth power plants located in the coal-producing provinces of the north. As installation of flue gas desulfurization equipment is unlikely in the near future, the planned expansion will result in rising SO<sub>2</sub> emissions in these areas. Since emissions will come increasingly from tall stacks, the potential for regional acidification will grow. The planned concentration of thermal power plants also raises problems of water availability. In Shanxi, the most important coal-producing province, water

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<sup>9</sup> "Beijing's Economic Ills Pose a New Threat of Social Upheaval," *Wal Street Journal*, Aug. 3, 1989.

<sup>10</sup> Hu, op cit.

shortages are already the norm. Construction of all the envisioned coal-fired power stations would require nearly twice the currently available total water withdrawal.<sup>11</sup> Another problem arising from expanded coal production and associated electricity generation is the substantial amount of land that will be required for mining wastes and fly-ash from electrostatic precipitators in power plants. Increased acid mine drainage is an additional problem.

The main environmental problems associated with the huge increase planned for hydropower are silting of reservoirs and loss of farmland. Recent decades of environmental degradation have increased silt loading of many previously unburdened rivers throughout the southern half of China. Retention of nutrients behind dams and accelerated shoreline erosion are problems that affect farming in the alluvial plains, coastal fishing, and drinking water supply in coastal cities (due to salt water intrusion). Loss of farmland is increased because most Chinese rivers have large seasonal runoff fluctuations and thus require construction of large reservoirs at the upstream sites. Smil estimates that the hydro program (as planned in the mid-1980s) will claim 100-150,000 ha of farmland, most of it high-yielding, by the year 2000, and will also force the resettlement of 1-1.5 million people.<sup>12</sup>

China's nuclear program does not face the kind of public opposition that is growing in Taiwan and South Korea. Since the planned nuclear power plants are to be sited in densely populated areas, however, public concern about the potential for accidents could eventually play a role.

## 2.8. Conclusion

Growth in electricity demand in most of China's key regions is constrained by supply and is likely to be so for the foreseeable future. Despite the acceleration of construction in recent years, China's goals for expanding thermal and hydro generation are very ambitious. This is due to logistics of construction and the problem of chronic underinvestment in the power and coal sectors. Vaclav Smil, a leading expert on China's energy situation, points out that "The challenge is in both the quantity and the quality of the programs: hundreds of new stations that have to be designed and built must have an average size much larger than those put in place before 1980."<sup>13</sup> He points out that the average size of 78 large and medium hydro stations built before 1981 was only about 160 MW whereas the average size of 30 future projects for which design and feasibility studies were completed (as of 1984) is 1000 MW.

A further difficulty is that many of the new coal-fired power plants are to be built in the North and Northeast, where the logistic and infrastructure requirements for this level of construction are enormous. In Shanxi province, the environmental implications of the planned concentration of power plants, particularly in terms of water balances, would be severe. The planned increase in coal use for power generation other than that at mine-mouths will require much improvement in the coal transport system. Coal transport is now a major focus of attention, but addition of the needed infrastructure will take time. Development of the hydropower resources in Southwest China will also be challenging with respect to construction and the need for long transmission lines.

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<sup>11</sup> Smil, V. 1988. *Energy in China's Modernization*. Armonk, NY: M.E. Sharpe, Inc.

<sup>12</sup> Smil, op cit.

<sup>13</sup> Smil, op cit.

Nuclear power will be able to play only a small role in easing the power shortage in the 1990s. The present strategy is to construct nuclear plants with as much local content as possible, but the ability of the recently-created China National Nuclear Corp. to undertake the commercial development of the nuclear power program is uncertain. The high capital cost of nuclear plants relative to coal will also constrain their development, especially in the current environment.

The near-term effect of the political upheaval in 1989 on the development of the economy and the power sector may be severe. An increasing number of economists believe that a significant recession is inevitable.<sup>14</sup> This would obviously slow growth in electricity demand, but the loss of revenues may also constrain expansion of the power system. Those projects that depend on foreign financing, such as some of the large hydro projects, may be most affected, and the dependence on coal may increase as a result.

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<sup>14</sup> *Wall Street Journal*, op cit.

### 3. INDIA

#### 3.1. Background

Electricity generation, transmission and distribution in India is carried out by a number of State Electricity Boards (SEBs). In 1975, the national government established the National Thermal Power Corporation (NTPC) and the National Hydroelectric Power Corporation (NHPC) for the generation of electricity which is then transmitted to the SEBs for distribution to consumers. Electricity for public use is generated by private companies in Bombay, Ahmedabad, and Calcutta.

Total public installed capacity in India grew from 28.7 GW in FY 1979 to 54.2 GW in FY 1987.<sup>1</sup> The total in 1987 consisted of 17.2 GW in hydro power stations, 35.7 GW in thermal power stations (mostly using domestic coal), and 1.3 GW of nuclear power. Despite the growth in capacity, power shortages and unreliability of the supply system have been chronic problems in India. In addition to the public facilities, there is considerable capacity used for industrial self-production, due in part to the unreliability of the public supply.

Public electricity generation grew at an average rate of 8.5% per year in the 1979-1987 period. Average GDP growth was 5.2% per year. Generation in 1987 grew by 7.4% over 1986. 74% of total public generation in 1987 came from thermal power plants, while hydropower contributed 24%, and nuclear power 2%.

The mix of fuels used for generation has changed significantly since 1970 (Figure 3-1). The government's decision to push for a strong program of coal mining and coal-based power generation has led to a large increase in coal use. Use of coal increased by two-fold in 1980-1987, while generation from hydro stations increased only modestly. Nuclear power generation has grown somewhat since 1980, but the most rapid increase has been in generation from natural gas. Oil provides a small and declining fraction of generation, although diesel use in the industrial sector for power generation has increased in recent years due to the inability of the utilities to assure a reliable supply of electricity during peak hours. Diesel-based generation by industry for own use has been encouraged, but the policy is controversial since it has led to increased use of imported oil.

Industry accounted for 53% of total sales in 1987, but demand in the residential sector has been growing much faster due to rural electrification and acquisition of modern electric appliances in urban areas. Agricultural electricity use (water pumping for irrigation) has also increased significantly in the 1980s; it accounted for 21% of public consumption in 1987.<sup>2</sup> While consumption has grown at a fast pace in recent years, there is considerable unmet demand due to shortage of power.

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<sup>1</sup> Throughout this chapter, annual periods refer to the fiscal year April-March.

<sup>2</sup> The increase in the agricultural sector is partly caused by inefficient use of electricity. Electricity is available to agricultural users free of charge in several States. In others, the user pays only a flat fee based on pump size and thus has no incentive for conserving electricity.



**Table 3-1**  
**Power Sector Statistics for India**  
(Not including self-producers)

	FY1987	FY1987 (%)	AAGR 1970-79	AAGR 1979-87
<b>Installed Capacity (GW)</b>				
Hydro	17.2	32	6.6%	5.3%
Nuclear	1.3	2	8.3%	5.6%
Thermal	35.7	66	8.5%	10.2%
Total	54.2	100	7.7%	8.3%
<b>Generation (TWh)</b>				
Hydro	47.4	23	6.8%	0.5%
Thermal	149.4	74	8.1%	13.0%
Coal-fired <sup>a</sup>	132.3	66	8.3%	13.4%
Oil-fired <sup>a</sup>	9.7	5	6.4%	4.8%
Gas-fired <sup>a</sup>	7.4	4	7.1%	25%
Nuclear	5.0	2	2.0%	7.2%
Total	202	100	7.2%	8.5%
<b>Consumption (TWh)</b>				
Industry	76.4	53	4.8%	6.8%
Residential	20.6	14	9.1%	11.9%
Commercial	14.7	10	6.7%	7.9%
Agriculture	30.2	21	13.0%	10.6%
Total	145.3	100	6.5%	8.3%

Sources: Department of Power Annual Reports, Tata Energy Research Institute  
Installed capacity refers to year-end.

(a) Estimated based on fuel consumption

**Self-producers' generation** in 1987 was an estimated 15.3 TWh.  
**Electricity consumption per capita** in 1987 (including self-production)  
was around 205 kWh.

# ELECTRICITY GENERATION BY SOURCE India

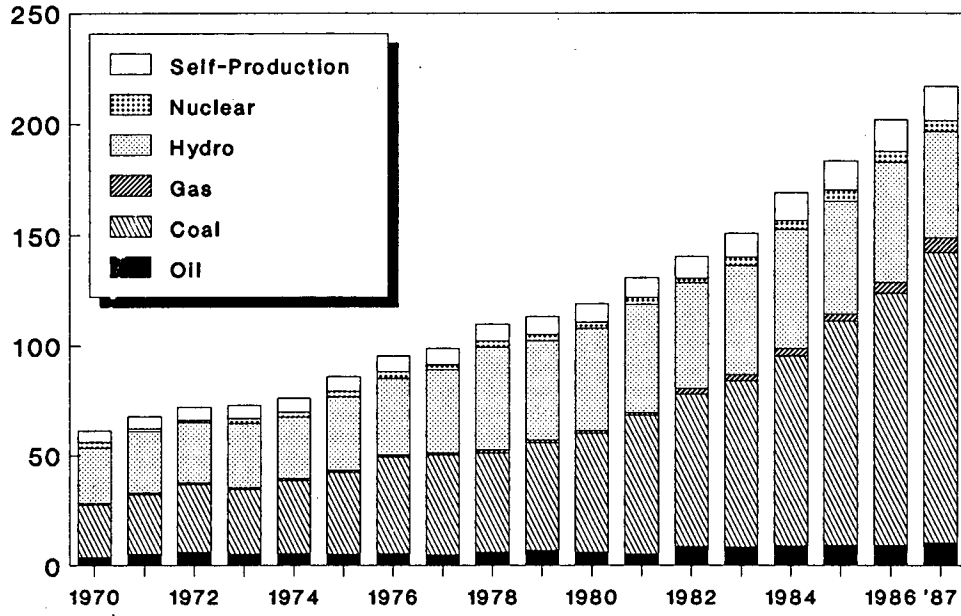


Figure 3-1

### 3.2. Resources for Electricity Generation

India has an exploitable **hydropower** potential estimated at around 90,000 MW.<sup>3</sup> More than 80% of the potential remains untapped because of geological and political problems (related to flooding of land) and the distance of sites from load centers. Proved reserves of **coal** amount to 70 billion tons (246 billion BOE) and total resources are about 255 billion tons. Much of the coal comes from relatively new open-cast mines and is of poor quality, however. Coal seams are also becoming more difficult to mine. Estimated reserves of **natural gas** amount to 478 billion cu. meters (3.2 billion BOE);<sup>4</sup> 1987 production was 11.5 billion cu. meters. **Oil** reserves are also sizable but production of oil is insufficient to meet national demand, and increased use for power generation is not likely.

### 3.3. Forecast of Electricity Demand

The estimates used by the Central Electricity Authority (CEA) in its *National Power Plan 1985-2000* were based on its Twelfth Power Survey, which was completed in March 1985.<sup>5</sup> This Survey forecast a generation requirement of 429 billion kWh in 1994 and of 685 billion kWh in 1999. Projections made slightly later by the Planning Commission as part of the Seventh Plan estimated an average annual increase in total electricity demand of 6.6%-7.6% between 1989 and 1999, amounting to a generation requirement of 496-535 billion kWh (see Table 3-2). The Energy Demand Screening Group, which was set up by the Planning Commission to review assumptions and methodology of demand forecasts, estimated an average growth rate of 7.4% per year through 1999 in their August 1986 report.

Table 3-2  
Projections of Electricity Consumption by Sector  
Seventh Plan (1985)  
(billion kWh)

Sector	1989	1999
Industry	139	240-283
Domestic	27	81-86
Agriculture	32	41-42
Others	28	53-57
Total	223	424-465
Generation	262	496-535

<sup>3</sup> Seventh Five-Year Plan, Chapter 6 on Energy, Govt. of India.

<sup>4</sup> *Economic Survey 1988/89*. Economic Division, Ministry of Finance.

<sup>5</sup> Forecasts are given in *National Power Plan 1985-2000*, Central Electricity Authority, June 1987.

A more recent forecast by the CEA, released in December 1987 in its *Thirteenth Electric Power Survey*, projects a generation requirement of 385 billion kWh in 1994, which is considerably lower than the requirement of 429 billion kWh that had been forecast by CEA in 1985. Peak load is projected at 73 GW. The generation requirement in 1999 is forecast to be 594 billion kWh, and the peak load to be 112 GW.

### 3.4. Plans for Power Sector Development

In the *National Power Plan 1985-2000*, issued in June 1987 by the CEA, it was estimated that additions of 47,000 MW would be needed in the Eighth Plan period (1990-1994) to meet a loss-of-load-probability (LOLP) of 5%. (This assumed CEA's 1985 demand forecast based on its 12th Power Survey, which was much higher than the forecast adopted in the 7th Plan). For a LOLP of 10%, addition of 40,000 MW would be needed. It was estimated that further addition of 59,000 MW would be needed in the 9th Plan period (1995-1999) to meet the 10% LOLP criteria. (A desired LOLP would be in the 1-5% range.)

The actual proposal of the Power Ministry for the Eighth Five-Year Plan<sup>6</sup> called for an addition of around 38,000 MW in the 1990-1994 period (see Table 3-3). This would be equal to 70% of the total installed capacity as of mid-1988. This amount is less than that estimated by the CEA as desirable, but then growth in consumption has been quite a bit lower than that used by the CEA in its analysis (because of inadequate supply).<sup>7</sup> About three-fourths of the additions would be thermal power, with most of the rest hydro. Three additional 235 MW nuclear reactors are also due to be commissioned by 1995. Most of the thermal power plants in the Plan are to use coal, though some 6000-8000 MW may use natural gas instead.

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<sup>6</sup> Presented in "Seeking radical solutions," *India Today*, Jan. 31, 1989.

<sup>7</sup> CEA forecast the generation requirement in 1989 to be 269 billion kWh. Actual generation in 1989 will probably be around 230-235 billion kWh. Of course, there is considerable unmet demand.

Table 3-3  
Proposed Capacity Additions in India's  
Eighth Five-Year Plan  
(thousand MW)

Type	Installed (mid-1988)	Target <sup>a</sup> (mid-1990)	Eighth Plan Additions <sup>b</sup> (1990-94)	Target <sup>c</sup> (mid-1995)
Thermal	35.7	44.9	28.1	72.9
Hydro	172.2	20.0	9.4	29.4
Nuclear	1.3	1.8	0.7	2.5
Total	54.2	66.7	38.2	104.8

(a) National Power Plan 1985-2000 (June 1987)

(b) *India Today*, Jan. 31, 1989, p. 64

(c) Sum of 1990 target and proposed additions

The proposed mix shown above represents a significant shift from that proposed by CEA in the *National Power Plan 1985-2000*. In CEA's 10% LOLP scenario, the required 40,000 MW of new capacity in the 8th Plan period were given as 50% thermal, 42% hydro, and 8% nuclear. The Power Ministry's proposal contains much less hydro and nuclear capacity, which reflects the need to build less capital-intensive power stations.

In addition to public utility power stations, there is likely to be considerable increase in generation by captive power stations of industry. The CEA projects growth from an estimated 11.3 billion kWh in 1987 to 17.7 billion kWh in 1990.<sup>8</sup> This reflects the inability of the public utilities to build capacity fast enough to meet industrial demand and the encouragement of self-generation by the government despite the cost in oil imports.

### 3.5. Financial Issues

The power sector additions proposed by the Power Ministry for 1990-94 (including transmission and distribution) would require an estimated investment of Rs. 80,000 crore (\$53 billion at Rs.15/\$), which is more than was needed for all the earlier plans put together. Given the tight funds squeeze in India, it is considered unlikely that the Planning Commission will clear all of the Power Ministry's proposals for the Eighth Plan. Projects with lower capital cost may have an advantage over those with high front-end costs.

### 3.6. Electricity Supply and End-Use Efficiency

Transmission and distribution losses in India were around 20% of gross generation in 1986. The thermal efficiency of typical steam power plants is relatively low.

The importance of improving supply efficiency and moderating growth in electricity demand through energy conservation is recognized by the CEA. The National Power Plan states

<sup>8</sup> Central Electricity Authority, *Thirteenth Electric Power Survey of India*, Dec. 1987.

that if the projected peak load and energy demand in 1999 could be reduced by 10%, the capacity requirements would be reduced by 16 GW, resulting in savings in the overall investment requirements by about Rs. 28,000 crore (\$19 billion).

While the Plan does not describe any direct measures to reduce demand by 10%, such a decrease seems quite feasible. A recent analysis for the southern State of Karnataka estimates that capacity requirements in 1999 could be reduced from the officially-projected 9400 MW to 4375 MW through a combination of efficiency improvement measures, decentralized electricity generation for villages based on biomass, cogeneration in sugar factories, substitution of electricity with other energy carriers, load management, and a structural shift toward less power-intensive industry.<sup>9</sup> The efficiency measures considered include "friction-less" foot valves and PVC pipes for agricultural water pump sets; compact fluorescents to replace incandescent bulbs; and a variety of measures in industry. While there are many barriers to a reduction in demand requirements of this magnitude, efforts to tap the electricity conservation potential in the industrial sector are beginning to receive more attention.

### 3.7. Environmental Issues

There are several environmental concerns associated with the operation of power plants and with coal mining. Most power plants in the country have only about 85% removal of particulates and no control of sulfur oxides (though Indian coals are relatively sulfur-free). Ash disposal is also a major problem, since the ash content of the coal has been increasing steadily. Land subsidence from mining of underground coal and land use conflicts arising from expansion or opening of coal mines are also problems.

Opposition to several proposed hydroelectric projects has been increasing. Proposed dams on the Narmada river in West-Central India and the Tehri Dam in the Himalayan foothills have encountered stiff opposition from environmentalists and the local population that will be displaced by the construction and consequent flooding.

### 3.8. Conclusion

A persistent problem in the past has been the power sector's inability to meet targets by the end of each five-year plan. In the Seventh Plan period, however, the targeted addition of 22.4 GW is likely to be reached. But since the States put most of their allocated money into completing existing projects (in order to meet the Plan targets), few projects for the 1990-95 period have come very far along.<sup>10</sup> Thus, the targets set for 1995 are unlikely to be met, which will result in insufficient capacity. Indeed, the situation is such that even if the targets were met, consumption of electricity would continue to be constrained by lack of supply.

An additional problem is that the quality of coal is deteriorating, and environmental problems associated with coal mining are mounting. To diversify the generation mix, and bring capacity on line relatively quickly, the government is considering adding 6000-8000 MW of plants fueled by indigenous and imported natural gas. These plants have the advantage of short lead time for installation and lower capital cost than coal-fired units. Other measures being

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<sup>9</sup> A.K.N. Reddy, et al., A Development-Focused End-Use-Oriented Energy Plan for Karnataka, draft manuscript, Indian Institute of Science, Bangalore, India, 1989.

<sup>10</sup> *India Today*, op cit.

considered to improve the power situation are private sector investment in power, rationalization of power sector rates, reduction of the significant T&D losses, renovation and rehabilitation of thermal and hydro stations, and in the longer run, cooperating with Nepal to develop its substantial hydro resources. The government has been hopeful about private sector generation projects, but problems have arisen with respect to financing and purchase guarantees. The other measures are not new, and if past experience is a guide, may not meet with great success.

In the previous five-year plans, the delays in power plant construction were mostly because of lack of financing or poor management of construction projects. But given the stiff environmental challenges being mounted, it is conceivable that the planned construction of power plants (especially hydro) will be delayed or changed. In this context, greater use of natural gas is an attractive option. A recent report from the Ministry of Industry<sup>11</sup> calls for substitution of domestic coal with domestic and imported natural gas at power plants located several hundred miles from coal mines, but closer to natural gas fields. It shows that the natural gas option would be less expensive than burning coal in such cases, as well as more favorable environmentally. The difficulties in expanding conventional supplies could also lead to greater interest in end-use efficiency and options for decentralized electricity generation, though there does not yet exist a strategy for implementing such schemes at the national level.

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<sup>11</sup> "Towards a New Energy Policy." Ministry of Industry, Bureau of Industrial Costs and Prices, Govt. of India.

## 4. INDONESIA

### 4.1. Background

The State Electric Power Corporation (PLN) is responsible for electricity generation and transmission on the various islands of Indonesia, though much of the country's industrial sector generates its own electricity. PLN's installed capacity grew rapidly from 2.5 GW in FY 1979 to 7.1 GW in FY 1987.<sup>1</sup> The growth has been supported by introduction of new coal-fired plants and expansion of hydro power. As of March 1989, PLN's installed capacity came to 8.4 GW: 1.9 GW in hydro power stations, 1.7 GW in steam/fuel oil power stations, 1.7 GW in steam/coal power stations, 1.7 GW in diesel units, 1.2 MW in gas turbines, and a small amount of geothermal power.<sup>2</sup>

Electricity generation by PLN grew at a very rapid rate of 15.6% per year in the 1979-1987 period. This was much faster than the average growth in GDP of 4.7% per year. Generation in 1988 grew by 14% over the previous year. The high growth reflects the relatively underdeveloped state of the public system in 1980. Shortage of power has been an historic problem that has caused many industries to meet their needs through self-generation. Since the oil boom, the government has invested heavily in expansion of generating capacity, but previously suppressed demand has emerged, and shortage of power remains a problem.

About 40% of PLN's total generation in 1988 came from oil, 23% came from hydro, and 21% came from coal. The importance of oil has declined considerably since 1982, as coal has taken on an increasingly larger role (Figure 4-1). Self-producers generated nearly 80% as much electricity as PLN, mostly from oil.

Industry accounted for 42% of public electricity consumption in 1987, which is comparatively low due to the prevalence of industrial self-production. In contrast to the pattern in most other Asian developing countries, its demand has been growing even more rapidly than that of other sectors. One reason for this is growing use of the PLN system by factories that previously relied on self-production. The residential sector, whose consumption has been growing rapidly, accounted for 40% of public consumption in 1987.

### 4.2. Resources for Electricity Generation

Indonesia has considerable reserves of oil, natural gas, coal, hydro and geothermal power, as well as biomass resources. A difficulty is that 75% of the electricity demand is on Java, but Java has only 6% of the potential hydro resource, 4% of the proven natural gas reserves, and none of the known coal reserves.

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<sup>1</sup> Throughout this chapter, the annual periods refer to the fiscal year, which runs from April 1 through March 31.

<sup>2</sup> National Energy Coordinating Board, "1989 National Energy Policy."



Table 4-1  
**Power Sector Statistics for Indonesia**  
 (Not including self-producers)

	1987	1987 (%)	AAGR 1970-79	AAGR 1979-87
<b>Installed Capacity (GW)</b>				
Hydro	1.5	21	8.0%	18.7%
Thermal	5.5	77	22.9%	12.4%
Total	7.1	100	19.1%	13.8%
<b>Generation (TWh)</b>				
Hydro	5.2	23	6.8%	11.1%
Thermal	16.4	73	21.3%	16.7%
Coal-fired	4.4	20	-	-
Oil-fired	11.3	51	21.3%	11.4%
Gas-fired	0.7	3	-	-
Geothermal	0.7	3	-	-
Total	22.3	100	14.5%	15.6%
<b>Consumption (TWh)</b>				
Industry	7.2	42	23.0%	20.5%
Residential	6.8	40	11.8%	13.8%
Commercial	3.1	18	10.8%	11.3%
Total	17.1	100	14.5%	15.6%

Sources: PLN and Central Bureau of Statistics  
 Installed capacity refers to year-end.

**Self-producers' generation** in 1987 was an estimated 18 TWh.  
**Electricity consumption per capita** in 1987 (including self-production) was around 205 kWh.

# ELECTRICITY GENERATION BY SOURCE Indonesia

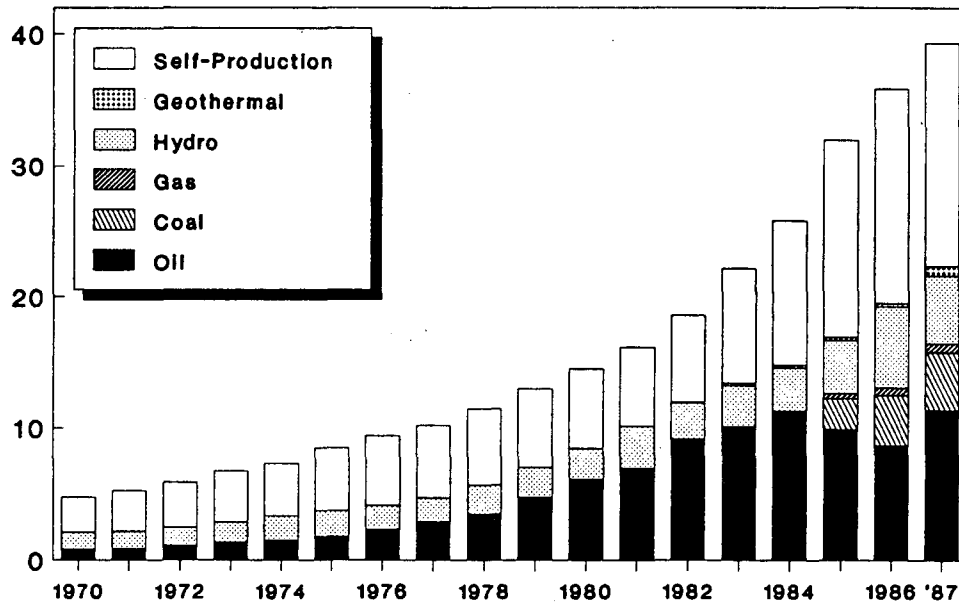


Figure 4-1

The ultimately recoverable oil resource has been estimated at 50 billion barrels. Proved reserves of natural gas have been placed at 69 trillion cu.ft. (TCF) (13 billion BOE), with additional 29 TCF of potential reserves. The estimate of proved reserves of coal has recently been revised upward to 23 billion tons (105 billion BOE).<sup>3</sup> The coal reserves are in Sumatra and Kalimantan.

The overall hydropower potential throughout Indonesia has been placed at 75,000 MW, but only 4,200 MW are located in Java, the major demand center. A geothermal potential estimated to be in excess of 10,000 MW is scattered throughout the archipelago, and in contrast to natural gas deposits, geothermal potential exists in regions where there is substantial demand for electricity (e.g., Java).<sup>4</sup>

#### 4.3. Forecast of Electricity Demand

PLN's official forecast of May 1988 shows electricity sales increasing very rapidly from 17.0 TWh in 1987 to 84.0 TWh in the year 2000, which amounts to an average growth rate of 13.1% per year. Growth in sales was projected to gradually slow from 14-15% per year in the early 1990s to 10-11% per year by the end of the century. Peak demand was forecast to grow from 3.8 GW in 1987 to 17.2 GW in the year 2000.

PLN forecast the highest growth to be in the industrial sector, partly due to the expected connection of many industries that currently generate their own power. Residential demand was also forecast to grow rapidly, in part due to the current low level of electrification in rural areas. The May 1988 forecast projects substantially less growth than the forecast that was prepared in July 1987, which had projected total sales of 92.8 TWh in the year 2000.

#### 4.4. Plans for Power Sector Development

Government policy calls for a reduction in use of oil for power generation, thus freeing up oil for export, and greater use of indigenous non-oil resources. Domestic coal and natural gas figure most prominently in the plans. Projections made in 1988 showed around 75% of the total net growth in installed capacity through the year 2000 coming from coal-fired power plants (Table 4-2).<sup>5</sup> Coal-fired capacity is to grow from 1.7 GW in mid-1989 to 9.7 GW in 2000. The plans will require considerable increase in the provision of land and sea transport infrastructure, since coal must be transported from other islands to Java.

The role of natural gas in both steam and combined-cycle power plants is also due to increase substantially. Capacity of hydropower is to grow, but its share in total capacity will decline slightly.

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<sup>3</sup> Resource estimates are from "1989 National Energy Policy" report.

<sup>4</sup> Resource estimates are from draft of Repelita V Plan chapter on Mining and Energy.

<sup>5</sup> Based on PLN information of May 1988 prepared for the Government of Indonesia's Repelita V Plan.

Table 4-2  
 PLN Projection for Electricity Supply  
 May 1988  
 (Installed capacity in MW)

	Actual Mid-1989		Planned Mid-2000	
	MW	%	MW	%
Hydro	1930	23	3716	20
Coal	1730	21	9740	51
Oil	3357	40	2207	12
(Steam	1686		1330)	
(Diesel	1671		1439)	
(Gas turbine	823 <sup>a</sup>		768)	
Natural gas	405	5	2972	16
(Steam	0		1430)	
(Combined cycle	0		1500)	
(Gas turbine	405 <sup>a</sup>		42)	
Geothermal	140	2	395	2
Total	8385	100	19030	100

(a) Split between oil and natural gas was estimated by authors.

Debate is ongoing regarding the future development of nuclear power. PLN and the Ministry of Mines and Energy contend that it would not be economically competitive with power plants using domestic coal, but there is support for nuclear development in some influential government circles.<sup>6</sup> The high capital cost of nuclear power is a problem, however.

#### 4.5. Financial Issues

Indonesia's ambitious power development plans carry a high capital cost. For the 1989-1993 period, the capital requirements of the power sector total 13,405 billion Rp. (US\$ 7.9 billion). About two-thirds of this is expected to come from multi-lateral and bi-lateral assistance, with the remainder to come mainly from resources generated by PLN. Electricity prices were raised an average of 25% in early 1989 in order to increase PLN's revenues.

The U.S. Embassy reported in 1988 that hydropower projects were increasingly difficult for the government to fund.<sup>7</sup> Their large "up-front" cost is at odds with the government's current bias to defer costs as much as possible. Many power projects are under consideration for World Bank financing. For other future projects, the Minister for Research and Technology, who chairs a government team that oversees the development of electric power generation projects, has

<sup>6</sup> "Energy-rich Indonesia debates the merits of tapping nuclear power," *Asian Wall Street Journal Weekly*, Feb. 8, 1988.

<sup>7</sup> Embassy of the U.S.A., "The Petroleum Report, Indonesia," Sept. 1988.

proposed that the government work with foreign contractors on a "build, operate, and transfer" basis. At the end of a specified time period, the contractor would transfer the plant to either the government or another private (national) company. The Minister suggested that consortia of energy companies, equipment companies, and banks could be formed to make such investments.

#### 4.6. Electricity Supply and End-Use Efficiency

Transmission and distribution losses have grown faster than generation in the 1980s, partly due to theft. They amounted to 18.0% in 1987. PLN has been implementing an action plan (with World Bank financing) to improve power sector efficiency, including rehabilitation of steam and hydro power plants and the distribution system. PLN's goal is to reduce losses to 12.4% in 2000.

In 1987, the government established an Energy Conservation Corporation (KONEBA). It is an autonomous enterprise with a commercial orientation, and is providing audits and training to energy users, with technical assistance through a World Bank-supported program.<sup>8</sup>

#### 4.7. Environmental Issues

The island of Java is the main center of electricity demand and is also densely populated. Thus, environmental considerations may eventually limit the burning of coal. As available hydro and geothermal resources on Java will probably be exhausted by 2010, it may be necessary to consider other options. These include nuclear power and laying of a submarine cable to transmit electricity from Sumatra to Java.

#### 4.8. Conclusion

Electricity consumption in most of Indonesia is constrained by lack of reliable supply. The average growth in sales of 13% per year forecast by PLN for the 1987-2000 period is nearly as high as the average for the 1980-1987 period, but GDP growth in the latter was comparatively low. Such high growth in electricity demand sustained over such a long period would be unusual among developing countries, but is not implausible if Indonesia is successful in diversifying its economy. Whether industrial self-production gives way to the public system, as called for in PLN's plans, will depend on the ability of PLN to deliver reliable power. While there is considerable potential for improving electricity end-use efficiency, there are also strong barriers to significant improvement.

It may prove difficult to add generating capacity at a pace sufficient to meet the forecast level of growth. Further, PLN's forecast includes considerable reduction in transmission and distribution losses. Given the dispersed nature of electricity demand in Indonesia, and the continuation of rural electrification, the goals for loss reduction may be difficult to achieve. If this is the case, generation would have to be greater than planned to allow sufficient reserve margin. There is also some question as to whether domestic coal production and the required transport infrastructure can be expanded quickly enough to meet the plans for the power sector.

Some government officials have said that with crude oil below \$18 per barrel, coal utilization becomes uneconomical.<sup>9</sup> Given the uncertainty regarding future oil prices, however, the

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<sup>8</sup> RCG/Hagler, Bailly, Inc., *Energy Inefficiency in the Asia/Near East Region and its Environmental Implications*, U.S. Agency for International Development, June 1989.

<sup>9</sup> U.S.A. Embassy, *op cit*.

government remains committed to increasing use of domestic coal for power. If coal production should fall short of requirements, the government could opt to use fuel oil or natural gas, or to import coal, depending on the relative economics.

## 5. MALAYSIA

### 5.1. Background

Electricity in Peninsular Malaysia, where more than 90% of Malaysia's electricity is consumed, is supplied by the National Electricity Board (NEB), a state-owned company. The Sarawak Electricity Supply Corporation (SESCO) and the Sabah Electricity Board (SEB) perform a similar function in the states of Sarawak and Sabah, which are separated from Peninsular Malaysia by several hundred kilometers of ocean. In addition to the state companies, other licensees operate generation plant for supply to isolated areas.

Total installed capacity of all of the above more than doubled from 2.1 GW in 1979 to 5.3 GW in 1987. 4.7 GW of this was in Peninsular Malaysia. The national total consists of 3.9 GW in thermal power stations and 1.4 GW in hydro power stations. The NEB system in 1989 has considerable surplus capacity. There is also industrial self-production of electricity, some of it based on biomass wastes.

Public electricity generation grew at an average rate of 8.1% per year in the 1979-1987 period. (Average GDP growth was 4.9% per year.) Generation in 1987 grew by 5.9% over 1986. Around half of total public generation in 1987 came from oil, 29% came from hydropower, and around 19% came from natural gas. Malaysia has substantially reduced the dependence of the power sector on oil (Figure 5-1). Generation from hydro more than tripled in 1980-1987, and use of natural gas increased considerably beginning in 1985.

Industry accounted for 40% of public consumption in 1987, while the residential and commercial sectors accounted for 24% and 36%, respectively. Demand in the residential sector has been growing faster (13% per year in 1979-1987) than that of other sectors. Overall consumption has increased at a slower rate in the 1980s than in the 1970s, mostly due to lower economic growth.

### 5.2. Resources for Electricity Generation

Malaysia is well-endowed with oil, natural gas, and hydropower resources. Remaining oil reserves are estimated to be around 2.9 billion barrels (production in 1987 was around 180 million barrels). **Natural gas** is more plentiful: recoverable reserves have been estimated at about 53 trillion cu. ft. (10 billion BOE). Half of these are located off the east coast of Peninsular Malaysia while the remaining half are located off Sarawak. There are no indications of coal in exploitable quantity or quality in Peninsular Malaysia, although reserves of lignite in Sarawak have been estimated to total 400-500 million tons (0.7 billion BOE). **Hydropower** resources are assessed at about 27,000 MW, but only 13% of this exists in Peninsular Malaysia. Most of the resource is in Sarawak.

**Table 5-1**  
**Power Sector Statistics for Malaysia**  
 (Not including self-producers)

	1987	1987 (%)	AAGR 1970-79	AAGR 1979-87
<b>Installed Capacity (GW)</b>				
Hydro	1.4	26	8.5%	10.7%
Thermal	3.9	74	16.6% <sup>a</sup>	13.3%
Total	5.3	100	16.1% <sup>a</sup>	12.6%
<b>Generation (TWh)</b>				
Hydro	4.6	29	-1.1%	19.8%
Thermal	11.5	71	13.9%	5.3%
Oil-fired <sup>b</sup>	8.4	52	13.8%	1.4%
Gas-fired <sup>b</sup>	3.0	19	-	-
Total	16.1	100	10.5%	8.1%
<b>Consumption (TWh)</b>				
Industry	5.4	40	7.7%	5.2%
Residential	3.2	24	13.6%	12.8%
Commercial	4.9	36	13.3%	8.1%
Total	13.5	100	10.3%	7.7%

Sources: National Electricity Board, Ministry of Energy, Asian Development Bank  
 Installed capacity refers to year-end.

(a) 1973-79

(b) Estimated by LBL based on fuel consumption.

**Self-producers' generation in 1987 was an estimated 1.1 TWh.**

**Electricity consumption per capita in 1987 (including self-production) was around 1040 kWh.**



# ELECTRICITY GENERATION BY SOURCE Malaysia

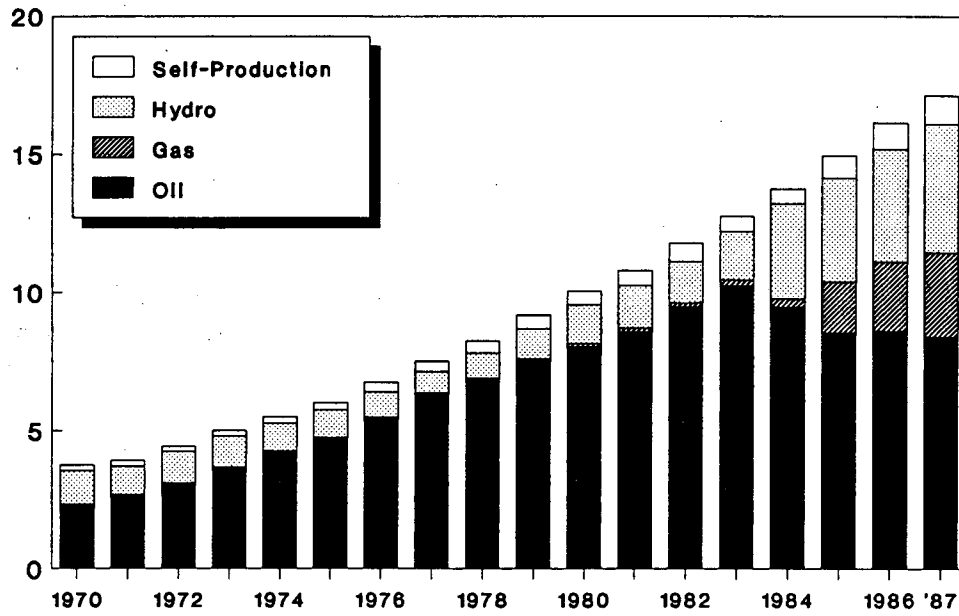


Figure 5-1

### 5.3. Forecast of Electricity Demand

The forecast developed in late-1988 by NEB<sup>1</sup> shows total electricity sales in Peninsular Malaysia growing from 14.2 TWh in 1988 to 36.6 TWh in 2000 in the "Normal" scenario. This corresponds to an average annual growth of 8.2% per year. Peak load on the NEB integrated system is projected to grow from 2720 MW in 1988 to 7042 MW in 2000. Sales in 2000 are forecast to be 30.0 TWh in the "Low" scenario, and 44.5 TWh in the "High" scenario.

### 5.4. Plans for Power Sector Development<sup>2</sup>

Electricity supply for Peninsular Malaysia will rely increasingly on indigenous natural gas. This will involve conversion of 1355 MW of existing oil-fired capacity to gas and construction of numerous combined-cycle power plants. In addition, NEB is adding 600 MW of coal-fired units also capable of burning gas and oil in 1989, and plans to have an additional 576 MW of hydro capacity on line by 1995. Total installed capacity of NEB is projected to grow from 4.5 GW in 1987 to 6.9 GW in 1995 and to 8.6 GW in 2000, as shown below.

Table 5-2  
Peninsular Malaysia Power Development Plans<sup>a</sup>  
Sept. 1988  
(Installed capacity in MW)

	1987 Actual	1995	2000
Oil	2379	~1000	~800
Gas	900	3505	5355
Hydro	1250	1826	1826
Coal	0	600	600
Total	4529	6931	8581

(a) Estimated by authors based on material provided by NEB.

After the year 2000, plans call for further additions of gas-fired combined-cycle power plants and development of some 1000 MW of hydropower in Peninsular Malaysia. The Bakun hydroelectric project in Sarawak, which has a potential capacity of 2400 MW, is under consideration. As the available power would be far in excess of the future needs of Sarawak, the Malaysian government is studying the possibility of constructing a submarine transmission link to Peninsular Malaysia. The World Bank concluded that the Bakun project is economically viable, and that the submarine link would be challenging but possible technically.<sup>3</sup> However, the high cost of the project (estimated at US\$ 6.8 billion in 1986), poses a barrier to its realization. Nuclear

<sup>1</sup> LLN (NEB), Load Forecast 1988/89.

<sup>2</sup> The plans refer to Peninsular Malaysia, which accounts for over 90% of total electricity consumption. We were not able to get current power development plans for Sabah and Sarawak.

<sup>3</sup> World Bank, *Malaysia Power Sector Issues and Options*, Washington, April 1987.

power is under consideration as a long-term option.

### **5.5. Financial Issues**

We were not able to get current financial information regarding Malaysia's planned power system expansion. In the wake of the buildup of external debt in the early 1980s and period of economic stagnation in 1985-86, the government has been seeking to cut back on capital-intensive projects and to promote the use of non-oil resources, thereby releasing as much petroleum as possible for export.

NEB has had strong financial performance in recent years. It has financed more than 50% of its investment program in recent years from cash either generated internally or raised through activities related to operations. The World Bank mission in 1986 concluded that barring an unexpected erosion in the Malaysian currency, NEB should be able to maintain its sound capital structure.<sup>4</sup> The situation is helped by the fact that NEB's expansion in the coming years, which is focused on increasing transmission capacity and installing combined-cycle power plants, is not highly capital-intensive relative to programs of other utilities in Asia.

### **5.6. Electricity Supply and End-Use Efficiency**

The thermal efficiency of most major power plants in Malaysia is relatively good. Transmission and distribution losses were about 11.8% of net generation in 1987; modest improvements can be achieved, according to the World Bank's 1986 mission.

Efforts to save electricity in Malaysia's commercial sector are growing. The government is in the process of implementing energy standards for new commercial buildings. Many companies offering energy management services for existing buildings have cropped up recently, and the availability of devices for energy management has increased as well.<sup>5</sup> As a result, energy management services have become much more affordable.

### **5.7. Conclusion**

Electricity demand in the residential and commercial sectors will be a key factor in shaping future generation requirements. Increase in air conditioning in particular could add significantly to demand growth, and change the shape of the load.

Malaysia has natural gas resources sufficient to fuel much of the required power system expansion. The timing of conversion of currently oil-fired power plants to natural gas and construction of combined-cycle power plants on the west coast of Peninsular Malaysia, where most of the demand is located, will depend on the completion of pipelines from the east coast where the gas is produced. Gas resources are sufficient to supply the likely needs of the power sector into the next century. Given its high cost, the Bakun hydroelectric project seems unlikely to be developed in the foreseeable future, though it remains an option.

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<sup>4</sup> World Bank, *op cit*.

<sup>5</sup> K.S. Kannan, "Status of Building Energy Conservation in Malaysia," Faculty of Mechanical Engineering, Universiti Teknologi Malaysia, 1989.

## 6. PAKISTAN

### 6.1. Background

Pakistan has two public electricity supply companies: the Water and Power Development Authority (WAPDA), and Karachi Electric Supply Corp. (KESC), which serves Karachi. Total installed capacity nearly doubled from 3.5 GW in mid-1980 to 6.7 GW in mid-1988. The total consists of 2.9 GW in hydro power stations, 2.0 GW in oil/gas thermal power stations, 1.5 GW of gas turbines, and small combined-cycle and nuclear power plants. In addition to the public facilities, there is considerable capacity used for industrial self-production; this is due in part to the unreliability of the public systems.

Public electricity generation grew at an average rate of 9.7% per year in the FY 1979-1986 period.<sup>1</sup> Average GDP growth was 6.9% per year. Generation in 1986 grew by 12.2% over 1985. Fifty-three percent of total public generation in 1986 came from hydro, around 30% came from gas, and around 14% came from oil (imported). Use of oil has increased sharply in the 1980s due to lack of indigenous natural gas (Figure 6-1).

Industry accounted for 37% of public consumption in 1986, less than in many countries (in part because of considerable self-generation). Demand in the residential sector has been growing extremely rapidly (16% per year in 1980-1987); it accounted for 31% of public consumption in 1986. Agriculture is also an important consumer, accounting for 16% of consumption. Around 35% of Pakistan's population is served by electricity, and the government has ambitious plans for rural electrification.

Despite the growth in generation capacity, Pakistan suffers from considerable load-shedding and power interruption due to lack of reliable capacity. There has been gradual deterioration in WAPDA's system load factor largely due to increases in residential demand, as well as high water pumping loads and substantial rural electrification.

### 6.2. Resources for Electricity Generation<sup>2</sup>

Pakistan has an exploitable **hydropower** potential variously estimated between 25 and 36 GW of capacity. Most of the potential is in the upper reaches of the Indus and its tributaries in the North West Frontier Province and Northern Punjab. **Natural gas** reserves have been estimated at about 4 trillion cubic meters (27 billion BOE), though they are in general poorly characterized. (The *Oil and Gas Journal* placed proved reserves at end-1987 at only 0.6 trillion cubic meters.) Estimates of **oil** reserves are also rather speculative; recoverable reserves in known deposits amount to 140 million barrels. **Coal** deposits are known in the Punjab, Baluchistan, and Sind. Total reserves have been put at 763 million tons (2.7 billion BOE). Deposits range in quality from lignite to sub-bituminous coals.

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<sup>1</sup> Throughout this chapter, annual periods refer to Pakistan's fiscal year, which runs from July 1 through June 30. 1979 refers to FY 1979-80.

<sup>2</sup> Source: Pakistan country paper, prepared for Asian Forum on Energy Policy, UN Economic and Social Commission for Asia and the Pacific, Bangkok, Oct. 1986.

**Table 6-1**  
**Power Sector Statistics for Pakistan**  
(Not including self-producers)

	FY1986	FY1986 (%)	AAGR FY1969-78	AAGR FY1978-86
<b>Installed Capacity (GW)</b>				
Hydro	2.9	44	12.7%	8.0%
Thermal	3.6	54	7.7%	7.5%
Nuclear	0.1	2	-	0
Total	6.7	100	10.7%	7.5%
<b>Generation (TWh)</b>				
Hydro	15.2	53	12.2%	8.0%
Thermal	13.0	45	6.0%	10.5%
Oil-fired <sup>a</sup>	4.1	14	-16.4%	-
Gas-fired <sup>a</sup>	8.8	31	7.4%	5.8%
Nuclear	0.5	2	-	-
Total	28.7	100	9.3%	9.2%
<b>Consumption (TWh)</b>				
Industry	8.0	37	3.6%	10.6%
Residential	6.8	31	15.4%	15.9%
Commercial	3.4	16	7.8%	10.8%
Agriculture	3.5	16	7.9%	8.5%
Total	21.7	100	7.1%	11.7%

Source: Ministry of Natural Resources

Installed capacity refers to year-end.

(a) Estimated by LBL based on fuel consumption

**Self-producers' generation in 1986 was an estimated 3.4 TWh.**

**Electricity consumption per capita in 1986 (including self-production) was around 245 kWh.**

# ELECTRICITY GENERATION BY SOURCE Pakistan

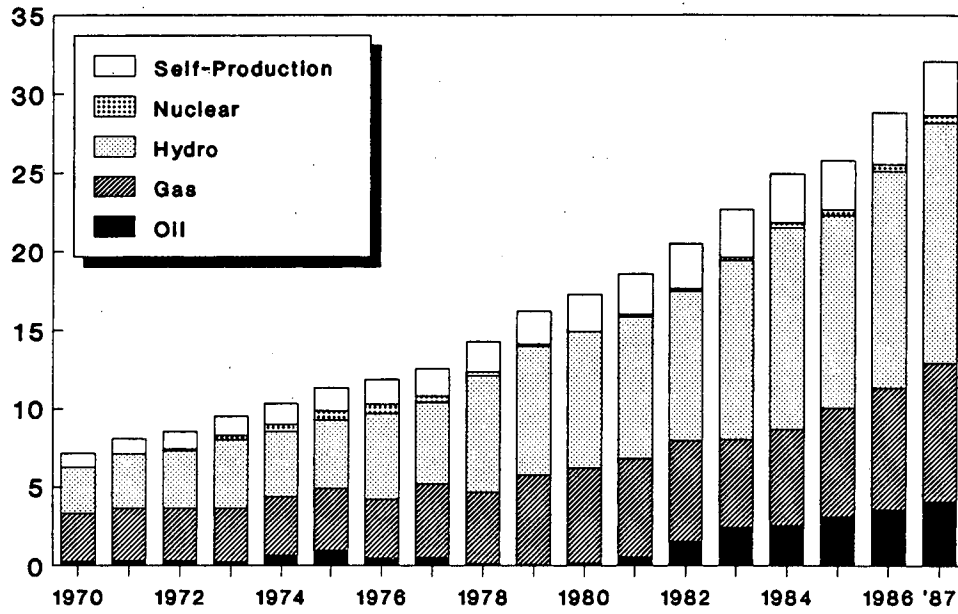


Figure 6-1

### 6.3. Forecast of Electricity Demand

Forecasts developed for the Seventh Five-year Plan (which was released in 1988) show peak demand growing from 5161 MW in mid-1987 to between 8900 and 9570 MW in mid-1993, depending upon the degree of load management and energy conservation implemented (see Table 6-2). Generation requirements are projected to grow from 28.8 TWh in mid-1987 to between 47.7 and 49.0 TWh in mid-1993. Peak demand is projected to grow considerably faster than electricity sales, in part due to the expected growth in residential uses.

Table 6-2  
Pakistan Electricity Demand Projections  
(1988)  
(Peak demand in MW, mid-year)

	1987	1993	AAGR
With LM and EC <sup>a</sup>	5161	8900	9.4%
With LM	5161	8970	9.6%
Without LM and EC	5161	9570	11.0%

(a) LM = Load management; EC = Energy conservation

The Seventh Plan targets an increase in village electrification from around 33% of total villages in mid-1988 to 55% by mid-1993. The actual extent of village electrification in the Sixth Plan period was considerably less than that targeted.

### 6.4. Plans for Power Sector Development

The policy for the power sector is to bring on new capacity as quickly as possible in order to reduce the serious shortage of electricity. The Seventh Plan calls for rapid growth in installed generation capacity from 6716 MW in mid-1988 to 13,112 MW in mid-1993 (see Table 6-3). This is to be based as much as possible on indigenous hydro resources, though the magnitude of new capacity called for also requires considerable growth in thermal capacity. Hydro and thermal plants would each account for close to 40% of installed capacity in 1993. The new thermal capacity will rely on both indigenous gas and imported oil, as gas supplies are insufficient to fuel the planned capacity. The Seventh Plan gives substitution of heavy oil in power generation lowest priority for the allocation of gas supplies.

The Plan calls on the private sector to play a major role in building new power supply. Twenty percent (1330 MW) of the total additional generation capacity is to come from the private sector. In addition, the government hopes to tap the considerable potential for co-generation from industry (estimated to total over 1800 MW by 1993) by introducing appropriate incentives and a regulatory mechanism.

Table 6-3  
Pakistan Power Development Program  
Seventh Five-Year Plan  
(Installed capacity in MW, mid-year)

	1988	%	1993	%	1998 <sup>a</sup>	%
Hydro	2900	43	5068	39	6408	37
Oil/gas thermal	1956	29	4924	38	5344	31
Gas turbine	1508	23	2108	16	2374	14
Gas C.C.	200	3	580	4	580	3
Coal	15	<1	295	2	2415	14
Nuclear	137	2	137	1	137	1
Total	6716	100	13112	100	17258	100

(a) Values for 1998 do not reflect plant retirement. Planned additions for the 1993-1998 period are tentative.

Less firm plans for the 1993-1998 period show the introduction of considerable coal-fired capacity (around 2000 MW). This would be based on imported coal and indigenous coal from a mine being developed at Lakhra. Growth in hydro is called for in the late-1990s. Engineering studies have been carried out for the proposed Kalabagh Dam on the Indus River, which would have an initial capacity of 2400 MW. Whether this project, which will cost around US\$ 3.5 billion, will go ahead is uncertain.

### 6.5. Financial Issues

The Seventh Plan envisions a total public investment in the power sector of 89 Rs. billion (US\$ 5.1 billion) between 1988 and 1993. Most of this is accounted for by WAPDA's hydro development. In addition, the Plan calls for private investment of 20 Rs. billion (US\$ 1.2 billion). To help finance the growth in capacity, WAPDA's electricity tariffs are to be adjusted to cover costs and generate funds to meet 40% of average capital expenditures. Given the magnitude of WAPDA's program, calculations show that the requisite tariff increases will be over 15% per year in the first three years, declining somewhat thereafter.

### 6.6. Electricity Supply and End-Use Efficiency

The thermal efficiency of typical power plants in Pakistan is low by international standards. Transmission and distribution losses are very high (22% of generation in 1986), and this is an area where the government is seeking to make improvements.

Various load management measures have been implemented in the past few years to reduce load shedding. Additional load management measures, possibly including peak period pricing for large industrial customers, are to be implemented in coming years.

Until recently, the level of energy conservation activity in Pakistan was very low. There is now growing awareness in government circles of the potential benefits of electricity conservation. An Energy Conservation Centre (ENERCON) was established in 1986; it serves as the focal



point for all conservation activities. Conservation programs focus primarily on industry and buildings. The initial phase of ENERCON's activities focused on developing capabilities and increasing awareness. The next phase of the program, implementation of conservation measures, is just beginning.<sup>3</sup> An Energy Conservation Loan Fund has been included in the current Five Year Plan, and the World Bank plans to include a \$35 million line of credit in its next energy sector loan to help finance implementation of energy conservation projects.

#### **6.7. Environmental Issues**

The hydro projects planned for the 1990s have not faced opposition on environmental grounds. The Kalabagh Dam would, however, entail major impacts, including substantial displacement of people.

#### **6.8. Conclusion**

Despite the government's efforts, growth in electricity consumption will likely continue to be constrained by lack of supply. There is room for improving the efficiency of electricity generation and reducing line losses. There is also much potential for increasing end-use efficiency, but also significant barriers. Both of these areas are receiving increased attention, however.

The expansion of power supply called for in the Seventh Plan is very ambitious: the average growth in installed capacity is 14% per year. Given the difficulties of financing, it is likely that some of the planned hydro capacity will be delayed. Delay in some of the oil/gas thermal units is also probable. Increase in private participation in power development is an important part of the official strategy. It may be difficult to achieve the magnitude of generation hoped for, however, given the need to develop appropriate institutional arrangements and overcome traditional barriers to private generation.

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<sup>3</sup> RCG/Hagler, Bailly, Inc., *Energy Inefficiency in the Asia/Near East Region and its Environmental Implications*, U.S. Agency for International Development, June 1989.

## 7. PHILIPPINES

### 7.1. Background

The National Power Corporation (NAPOCOR), a state-owned company, is responsible for the planning and operation of seven separate power grids in the Philippines. There are also numerous rural electric cooperatives administered by a separate agency, as well as many industrial self-producers. The Luzon system accounts for three-fourths of NAPOCOR's total electricity generation, the Mindanao grid 16%, and the five grids in the Visayas islands 8%.

Total public installed capacity grew from 4.1 GW in 1979 to 5.8 GW in 1987. At the end of 1987, NAPOCOR's total installed capacity consisted of 2.1 GW in hydro power stations, 2.4 GW in oil-fired power stations, 0.9 GW in geothermal power plants, and 0.4 GW of coal-fired capacity. Growth in capacity since 1980 has come mainly from hydropower and coal-fired power plants. The 620-MW nuclear power plant which was built at Bataan has been mothballed by the government as a result of widespread public opposition to its operation.

Total public electricity generation grew at an average annual rate of 5.0% in the 1979-1987 period, much of which was marked by political turmoil and economic stagnation. Generation in 1987 grew by 9% over 1986, and 1988 saw an increase of 9.3%. This growth reflects the upturn in economic activity that began in 1986. Oil-fired stations accounted for 44% of NAPOCOR's total generation in 1987; 25% came from hydro, 21% from geothermal, and 10% from coal. The shares of coal and hydropower in generation have increased markedly since 1983 (Figure 7-1).

Industry accounted for 35% of public consumption in 1987, while the residential and commercial sectors accounted for around 32% each. These latter sectors are relatively more developed in the Philippines than in most other Asian countries. The residential sector was responsible for much of the growth in electricity demand in 1982-1987.

### 7.2. Resources for Electricity Generation<sup>1</sup>

Relative to its neighbors in Southeast Asia, the Philippines is not well endowed with indigenous energy resources that can be economically developed. Proven oil reserves amount to only 4 million tons, and production has been declining since 1983. Geothermal reserves are considerable and are found throughout the country, though the majority of known fields remain largely unexplored. Potential reserves are estimated at 8 GW, of which 1.6 GW are proven so far and 4.4 GW are considered probable. The total potential coal resource is estimated at about 1500 million tons, but most of it is low-grade and expensive to mine. Proved reserves have been placed at 300 million tons (1 billion BOE). Hydro resources have a theoretical potential in excess of 10 GW, but the better sites are distant from the grid and thus expensive to use. Hydro development in Luzon and Mindanao is also constrained by socio-political considerations.

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<sup>1</sup> Source: World Bank, *Philippines: Energy Sector Study*, Sept. 1988.

**Table 7-1**  
**Power Sector Statistics for the Philippines**  
 (Not including self-producers)

	1987	1987 (%)	AAGR 1970-79	AAGR 1979-87
<b>Installed Capacity (GW)</b>				
Hydro	2.1	37	4.2% <sup>a</sup>	10.9%
Thermal	3.3	48	2.1% <sup>a</sup>	-0.7%
Coal-fired	0.4	7	-	-
Oil-fired	2.4	41	2.1% <sup>a</sup>	-2.3%
Geothermal	0.9	15	-	19%
Total	5.8	100	3.2% <sup>a</sup>	4.5%
<b>Generation (TWh)</b>				
Hydro	5.2	25	7.8%	7.8%
Thermal	11.2	54	8.0%	0.7%
Coal-fired	2.1	10	-	-
Oil-fired	9.2	44	8.0	-1.9%
Geothermal	4.5	21	-	27%
Total	21.0	100	8.5%	5.0%
<b>Consumption (TWh)</b>				
Industry	5.3	35	11.8%	-3.6%
Residential	4.8	32	7.7%	8.6%
Commercial	5.0	33	9.5%	7.0%
Total	15.1	100	10.3%	2.4%

Sources: NAPOCOR, Philippines Statistical Yearbooks, Bureau of Energy Utilization, Asian Development Bank

Installed capacity refers to year-end.

(a) 1973-1979

**Self-producers' generation** in 1987 was an estimated 3.4 TWh.

**Electricity consumption per capita** in 1987 (including self-production) was around 325 kWh.

# ELECTRICITY GENERATION BY SOURCE Philippines

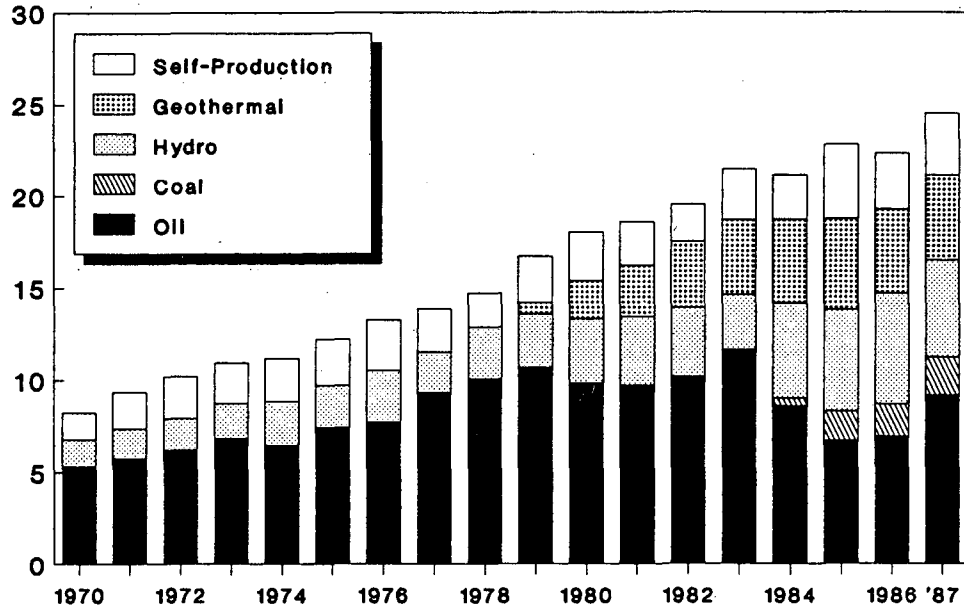


Figure 7-1

### 7.3. Forecast of Electricity Demand

Forecasts developed by NAPOCOR in February 1988 show total electricity generation growing at an average annual rate of 5.8% in the 1987-2000 period from 21.0 TWh to 43.5 TWh. This forecast reflects the strong increase in demand that occurred in 1987, and is somewhat higher than the previous forecast. The forecast growth for the three main regions is shown below.

Table 7-2  
NAPOCOR Forecast of Electricity Generation  
February 1988

	1987		2000	
	TWh	%	TWh	%
Luzon	16.0	76	32.5	75
Visayas <sup>a</sup>	1.7	8	3.7	9
Mindanao	3.3	16	7.3	17
Total	21.0	100	43.5	100

(a) Includes systems of Cebu, Negros, Leyte-Samar, Panay, and Bohol.

### 7.4. Plans for Power Sector Development

NAPOCOR's Power Development Program of June 1987 showed total installed capacity increasing from 6.4 to 9.8 GW in the 1987-2000 period. The needed capacity and the likely mix of power sources has changed since then. A review of the Philippines power sector development conducted by the World Bank in 1988 found that lifetime levelized generation costs of various base-load options for Luzon were lowest for several geothermal projects, followed by imported coal, fuel oil and local coal, and then hydro.<sup>2</sup> The least-cost development program recommended by the Bank program thus did not include three hydro projects (with a total capacity of 833 MW) that were under consideration by NAPOCOR.

Firm plans as of early 1989 included only 798 MW of new capacity divided among geothermal, gas turbines, and coal.<sup>3</sup> Possible future projects (recommended by the World Bank) include development of a major geothermal project (Tongonan) with undersea transmission to Luzon, expansion of pumped hydro storage, and a substantial amount of coal-fired units, the timing of which will depend on the availability of geothermal energy. The coal-fired units are to be based on a mixture of imported and domestic coal. Short-term shortages in generating capacity will be met by installing gas turbines.

For the Visayas grids, plans call for interconnections between islands that will allow exploitation of geothermal potential in Negros, thus reducing reliance on fossil fuels. For Mindanao, it is proposed to diversify the generation mix by installing geothermal and coal-based units as well

<sup>2</sup> World Bank, *op cit.*

<sup>3</sup> NAPOCOR, *1988 Annual Report.*

as gas turbines and some additional hydro capacity.

The figures in the table below represent the authors' estimate of what may be installed by 2000, based on various sources. It is possible that there could be more hydro in Luzon, or further reliance on gas turbines.

Table 7-3  
Philippines Power Development Program (Estimated)  
Mid-1989  
(Installed capacity in MW)

	1987 <sup>a</sup> Actual	%	2000 <sup>b</sup>	%
Geothermal	894	15	2566	24
Coal	405	7	2105	20
Hydro	2124	37	2525	24
Oil	2365	41	3295	31
Total	5788	100	10491	100

(a) Reflects derating of some geothermal and oil-based plants.

(b) Values were estimated by the authors based on information from the World Bank, NAPOCOR's June 1987 Power Development Program, and NAPOCOR's 1988 Annual Report.

### 7.5. Financial Issues<sup>4</sup>

The economic recovery begun in 1986 has brought about a growth in electricity demand that has exceeded NAPOCOR's previous expectations. At the same time, the decision to mothball the Philippine Nuclear Power Plant has denied NAPOCOR additional capacity to meet the growth in demand. As a result, NAPOCOR faces a period of ambitious investment. The projected total cost of NAPOCOR's June 1987 development plan is US\$ 11.1 billion, while the projected capital cost is US\$ 3.5 billion. The plans adopted since 1987 will require somewhat less capital.

The situation is made difficult by NAPOCOR's chronic shortage of local currency investment funds. This has caused implementation delays and introduced a bias in favor of investments with large foreign exchange components which can be financed externally. But NAPOCOR projects that about 45% of its investment requirement for the 1987-1995 period will involve local currency expenditures. Financial analysis by NAPOCOR shows that existing tariff levels and structures clearly cannot sustain the planned expansion program. Average revenues per kWh would have to increase by 60-70% in the 1987-96 period in order to meet minimum standards of financial performance, but even smaller increases would meet with stiff resistance. As the ability of the government to provide financing from direct budgetary allocations is limited, NAPOCOR

<sup>4</sup> Based on discussion in World Bank, op cit.

will need to mobilize long-term funds through the local capital markets. Alternatively, NAPOCOR could reduce its own investment requirements by encouraging investment by private parties in "Build, Operate and Transfer" schemes. This latter option is in fact taking place with respect to gas turbines for Luzon.

## 7.6. Electricity Supply and End-Use Efficiency

A prolonged period of budget constraints has caused several of the oil-fired thermal plants to suffer derating, as well as loss of operating efficiency. Distribution losses have also increased in the 1980s. For MERALCO, which distributes about 75% of the electricity in Luzon, total system losses have risen from only around 8% in 1980 to 21% in 1987.<sup>5</sup> This is primarily due to theft of electricity, mostly by some of the large consumers of power. A campaign against pilferage has made some headway, however, and rehabilitation of two thermal units and several hydro-power facilities is ongoing or planned.<sup>6</sup>

The Philippines has had a strong program promoting energy conservation for more than 10 years.<sup>7</sup> Regulations that have been implemented to promote conservation include requirements that large energy users monitor their energy consumption and submit energy management plans and energy audits to the government; and mandatory labeling of machinery and appliances to show their energy requirements. The government has provided technical assistance, including free energy audits, since the late 1970s, and financial incentives for energy conservation include loans, import duty and tax exemptions, and tax allowances. Since 1987, the government has been implementing the Technology Transfer for Energy Management program, which includes a loan program for the demonstration of technologies as well as technical assistance and training.

## 7.7. Environmental Issues

The environmental impact of geothermal power plants is less than those of both oil and coal-fired plants because of the absence of a boiler and its emissions. The coal-fired plants recommended by the World Bank mission include precipitators to remove 99.5% of particulates, but do not include flue gas treatment equipment. The SO<sub>2</sub> emissions per kWh of energy from the coal-fired plants will be about half of those from the existing oil-fired plants, which are using oil with sulfur contents of about 3%.

## 7.8. Conclusion

The growth in demand forecast in February 1988 may turn out to be low if economic activity continues to expand as it has in 1988 and 1989. In this case, the timely expansion of generating capacity will be important to prevent constraining demand. NAPOCOR is relying on gas turbines as a stop-gap solution to the impending power shortage in Luzon (which is primarily due to the mothballing of the Bataan Nuclear Power Plant). Some of these units may be constructed on a "Build-Operate-Transfer" basis. New guidelines for participation of private investors in power generation through cogeneration, "Build-Operate-Transfer," and "Build-Operate-Own"

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<sup>5</sup> World Bank, *op cit*.

<sup>6</sup> NAPOCOR, *1988 Annual Report*.

<sup>7</sup> RCG/Hagler, Bailly, Inc., *Energy Inefficiency in the Asia/Near East Region and its Environmental Implications*, U.S. Agency for International Development, June 1989.

schemes are in process of implementation.

The financial situation of NAPOCOR may slow the government's plans to reduce the share of oil in power generation, especially if oil prices do not rise significantly. The extent of coal use for power generation will be shaped by the ability of NAPOCOR to tap the geothermal resources in Luzon and at Tongonan. If geothermal resources cannot be committed on time, more coal-fired capacity than now envisioned may be needed.

In the long run, NAPOCOR's Master Plan calls for interconnection of all major islands in the country by the year 2010. This would enable NAPOCOR to tap the vast hydropower potential in Mindanao and the geothermal power in Negros and Leyte.



## **8. SOUTH KOREA**

### **8.1. Background**

All public electricity in the Republic of Korea (South Korea) is supplied by Korea Electric Power Co. (Kepeco), a public corporation that will soon have about 20% private ownership. Installed capacity has grown rapidly from 8.0 GW in 1979 to 19.9 GW in 1988. Over the past decade the government has pursued a policy of decreasing the reliance of the power sector on oil, which is imported. The sector's rapid expansion has been based on nuclear power and imported coal. Nuclear power capacity grew from only 587 MW in 1981 to 5716 MW in 1987. At the end of 1987, the Kepeco system consisted of 2.2 GW in hydro power stations, 9.9 GW in thermal power stations, 5.7 GW in three nuclear power stations, and 1.2 GW in internal combustion power stations.

Electricity generation by Kepeco grew at an average annual rate of 9.7% in the 1979-1987 period, while GDP growth averaged 7.1% per year. Recent years have seen even faster growth: generation in 1987 grew by 14.4% over 1986, and there was an increase of 15.4% in 1988. The rapid growth in demand has led to reduction in Kepeco's previously substantial reserve capacity. 53% of Kepeco's generation in 1987 came from nuclear power, 23% came from coal, and 16% came from oil and LNG. The shares of nuclear power and coal have increased rapidly since 1983 (Figure 8-1).

Total electricity consumption per capita (including estimated self-production) was around 1860 kWh in 1988, which is higher than in other Asian developing countries but much lower than in Taiwan. Industry accounted for 65% of public consumption in 1988, but demand in the residential and commercial sectors is growing faster than in industry.

In 1987 South Korea had considerable reserve capacity: firm capability was 15.2 GW, while peak demand was only 11.0 GW. With faster-than-expected growth in electricity demand and possible delays in nuclear power projects, however, this situation is changing to one of potential shortage by the mid-1990s.

### **8.2. Resources for Electricity Generation**

Like Japan and Taiwan, South Korea is poorly endowed with energy resources relative to its demand. Anthracite is the sole fossil fuel available domestically, with total recoverable reserves estimated at 400 million tons. South Korea has to import all its bituminous coal, oil, and uranium requirements. Offshore exploration for oil is in progress, and private firms are being encouraged to participate in oil, coal, and uranium development in other countries. There is a small amount of hydropower remaining to be developed.

Table 8-1  
**Power Sector Statistics for South Korea**  
 (Not including self-producers)

	1987	1987 (%)	AAGR 1970-79	AAGR 1979-87
<b>Installed Capacity (MW)</b>				
Hydro	2.2	12	12.0%	11.8%
Thermal	11.1	58	13.0%	6.8%
Coal-fired	3.7	19	5.7%	19.5%
Oil-fired	4.8	25	14.7%	-2.0%
Gas-fired	2.6	14	-	-
Nuclear	5.7	30	-	33%
Total	19.0	100	13.8%	11.4%
<b>Generation (TWh)</b>				
Hydro	5.3	7	7.4%	10.9%
Thermal	29.4	40	16.0%	-0.3%
Coal-fired	17.2	23	5.6%	18.6%
Oil-fired	2.7	4	19.3	-25%
Gas-fired	9.5	13	-	-
Nuclear	39.3	53	-	37%
Total	74.0	100	16.3%	9.7%
<b>Consumption (TWh)</b>				
Industry	42.2	66	16.7%	8.7%
Residential	11.5	18	23%	11.0%
Commercial	9.4	15	11.5%	11.1%
Transportation	1.0	2	22%	12.7%
Total	64.2	100	16.6%	9.5%

Sources: Ministry of Energy, KEPCO  
 Installed capacity refers to year-end.

**Self-producers' generation** in 1987 was an estimated 5.1 TWh.  
**Electricity consumption per capita** in 1987 (including self-production)  
 was 1645 kWh.

# ELECTRICITY GENERATION BY SOURCE South Korea

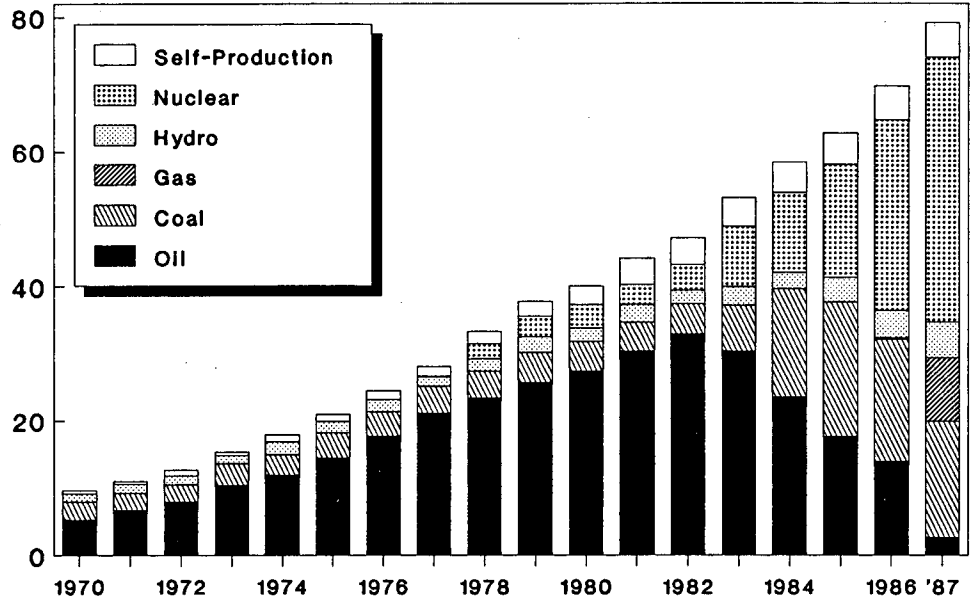


Figure 8-1

### 8.3. Forecast of Electricity Demand

The Ministry of Energy released a "Long-Term Power Development Plan" for the period through 2001 in mid-1989. The forecast used in this plan shows peak demand growing from 11.0 GW in 1987 to 29.2 GW in 2001. Average growth is projected to slow from 11.0% per year in the 1987-1991 period to 6.2% per year in the 1992-1996 period to 5.3% per year in the 1997-2001 period. The GNP growth assumed in this forecast is 7.7% per year in the 1989-1991 period, 6.7% per year in the 1992-1996 period, and 6.0% per year in the 1997-2001 period.

The demand growth forecast for different sectors is shown in Table 8-2. The forecast average growth in consumption for the 1987-2001 period is 6.7% per year. Growth in demand is expected to be faster in the residential and commercial sectors (7.7% and 8.3% per year, respectively) than in industry (5.9%). In part this is due to increasing use of cogeneration by industry.

Table 8-2  
Ministry of Energy Forecast of Electricity Demand  
Mid-1989  
(TWh)

	1987	%	2001	%
Residential	11.5	18	32.5	20
Commercial	10.4	16	31.8	20
Industry	42.4	66	94.5	60
Total	64.2	100	158.8	100

### 8.4. Plans for Power Sector Development

The "Long-term Plan for Power Development" calls for growth in installed capacity from 19.0 GW in 1987 to 35.7 GW in 2001. The Plan calls for considerable expansion in coal-fired and nuclear power plants, as shown below. Nuclear capacity is planned to grow from 5.7 GW in 1987 to 12.3 GW in 2001, while coal-fired capacity is planned to grow from 3.7 GW to 12.5 GW. If the plan is implemented as scheduled, South Korea will have 13 nuclear power plants by the end of the century. Kepco also plans to increase LNG-fired capacity from 2.6 GW to 3.7 GW. The oil-fired capacity is to decline from 4.8 GW to 3.6 GW, though the LNG capacity is dual-fuel-capable and burns oil in the winter months when LNG is needed for space heating.

Table 8-3  
 Ministry of Energy Plan for Electricity Supply  
 Mid-1989  
 (Installed capacity in MW)

	1987	%	2001	%
Hydro <sup>a</sup>	2232	11.7	3599	10.1
Coal	3700	19.5	12520	35.0
Oil	4822	25.3	3640	10.2
Gas/LNG	2550	13.4	3650	10.2
Nuclear	5716	30.1	12316	34.5
Total	19021	100.0	35725	100.0

(a) Includes 1000 and 1600 MW respectively of pumped storage.

The new plan not only accelerates the building of nuclear power plants, it also calls for a progressively higher level of local content in the power plants (including design engineering and equipment).

The expected share of nuclear power in generation (47.0% in 2001) is much higher than nuclear's share of capacity, since the plants are operated as base load units. The forecast coal share of generation (39.2%) is also higher than its share of capacity, while the shares of LNG and hydro in generation are much less than their share of capacity.

### 8.5. Financial Issues

Kepeco has been operating on a sound financial footing. The new plan calls for a substantial investment of Won 14.9 trillion (US\$ 21.7 billion) through 2001. Moreover, the policy of requiring a progressively higher level of local content in new nuclear power plants is already straining the resources of the South Korean contractors, and could lead to project delays and cost overruns.<sup>1</sup> The estimated cost of the two reactors to be built at Yeongkwang (scheduled for operation in 1995 and 1996) has already risen from US\$ 3.3 billion in the summer of 1987 to US\$ 4.4 billion in mid-1989, according to estimates by sources familiar with the project. To help finance the ambitious expansion program, in mid-1989 the government sold about 21% of Kepeco to the public.

### 8.6. Electricity Supply and End-Use Efficiency

The thermal efficiency of Kepeco's steam power plants and the level of distribution losses are on a par with those of industrialized countries.

The government has given considerable attention to energy conservation in the 1980s, particularly in the industrial sector. There has been a strong program of energy auditing, as well as development of energy standards for new commercial buildings.

<sup>1</sup> "A Nuclear Falling Out," *Far Eastern Economic Review*, May 18, 1989.

## 8.7. Environmental Issues

There is mounting opposition to nuclear power in Korea. Some observers believe that the anti-nuclear movement is likely to grow beyond sporadic local protests to become a national movement.<sup>2</sup> Whether this will affect the government's plans for nuclear power is not yet clear.

Korea's coal-fired power plants use electrostatic precipitators to control particulate emissions, but technologies to control NOx and SOx emissions are not used currently. The government's goal is to make emissions standards by the year 2000 comparable to those currently introduced in advanced countries.

## 8.8. Conclusion

Growth in demand in 1988 was much higher than had been envisioned (partly due to activities surrounding the Summer Olympics). In 1989 South Korea is facing some economic difficulties due to increasing labor costs and the appreciation of its currency, and slower economic growth is forecast in the 1990-1991 period than has occurred in recent years. This will likely affect industrial electricity demand more than residential and commercial demand, which have been growing faster than industrial demand in the 1980s. Overall, the growth in demand is such that there may be shortage of electricity in the future if the nuclear units scheduled to begin construction in 1989 (Yeongkwang No. 3 and 4) fall very far behind schedule.<sup>3</sup>

The government's power expansion plans call for the addition of one nuclear plant every year from 1995 to 1999. The policy of requiring a progressively higher level of local content in new nuclear power plants is already straining the resources of the South Korean contractors, however, and could lead to project delays and cost overruns. The increasing costs of nuclear power could add fuel to the growing anti-nuclear movement. The Ministry of Energy's analysis shows that the cost advantage of nuclear power over imported coal is small, though this could change somewhat as emissions standards for coal-fired power plants are tightened or costs of new nuclear units increase. It is possible that some portion of the nuclear capacity scheduled for the late 1990s could be substituted by coal, though planning for these nuclear units is fairly advanced.

Cogeneration seems likely to play an increasing role. So far most of the electricity generated has been for internal use with minimal sales to Kepco, but this situation could change in the future.

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<sup>2</sup> *Far Eastern Economic Review*, op cit.

<sup>3</sup> K. Ikeda, "Nuclear Situations in Taiwan and Republic of Korea," *Energy in Japan*, Sept. 1989. Opposition among the local community near these planned units is very strong. The government is examining a system of benefits comparable to that used in Japan to provide compensation to communities located near nuclear power plants.

## 9. TAIWAN

### 9.1. Background

All public electricity in Taiwan is supplied by Taiwan Power Company (Taipower). The total installed capacity grew rapidly from 8.2 GW in 1979 to 16.0 GW in 1985, but has only increased to 16.6 GW through 1988. The growth has come primarily from a mixture of coal-fired and nuclear power plants. The plant mix at end-1988 consisted of 2.6 GW in numerous hydro power stations, 4.0 GW in coal-fired power stations, 5.1 GW in three nuclear power stations (with two units each), and 4.0 GW in oil-fired capacity. There is also about 1.4 GW of installed capacity of industrial self-producers. In 1988, 41% of public electricity generation came from nuclear power, 32% came from coal, and the remainder came from oil and hydro (including pumped storage).<sup>1</sup>

Electricity generation by Taipower grew at an average annual rate of 7.2% in the 1979-87 period, while GDP growth averaged 7.4% per year. Growth has been more rapid in recent years, however: generation grew by 11.0% in 1987 and by 9.4% in 1988. The rapid growth has necessitated greater use of oil (Figure 9-1).

The industrial sector accounted for 57% of public electricity consumption in 1988, followed by the residential and commercial sectors with 22% and 18%, respectively. Residential and commercial sector consumption have been growing much more rapidly due in large part to increasing use of air-conditioning. As a result, peak demand has grown faster than generation.

The overall growth in electricity demand since 1985 has exceeded expectations, with the result that Taipower's reserve power capacity has fallen from 55% in 1985 to just over 21% in early 1989.<sup>2</sup> With no new sources of power due to come on line until 1993, greater curtailment of electricity supply is possible, particularly if there are unplanned outages in the nuclear units that provide base-load power.

### 9.2. Resources for Electricity Generation

Taiwan's only indigenous resource useful for significant power generation is hydro, but this will be able to supply only a very small part of the future electricity demand. Currently there is 1.6 GW of installed hydro capacity on rivers (and 1.0 GW of pumped storage). Plans call for another 350 MW by 2000 (not including new pumped storage to be built).

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<sup>1</sup> The share of oil-fired plants increased in 1988 due to fast growth in peak demand and outage of a nuclear unit.

<sup>2</sup> "Joining the fan club," *Far Eastern Economic Review*, March 30, 1989.

Table 9-1  
**Power Sector Statistics for Taiwan**  
 (Not including self-producers)

	1987	1987 (%)	AAGR 1970-79	AAGR 1979-87
<b>Installed Capacity (MW)</b>				
Hydro	2.6	16	5.0%	7.9%
Thermal	8.9	54	13.1%	6.1%
Coal-fired	4.0	24	-	22% <sup>a</sup>
Oil-fired	4.9	30	-	-1.3% <sup>a</sup>
Nuclear	5.1	31	-	19%
Total	16.6	100	13.0	9.2%
<b>Generation (TWh)</b>				
Hydro	7.1	10	5.3%	5.7%
Thermal	28.1	41	11.3%	-0.2%
Coal-fired <sup>b</sup>	22.1	32	21%	21%
Oil-fired <sup>b</sup>	6.0	9	11.3%	-15.9%
Nuclear	33.1	48	-	23%
Total	68.4	100	12.4%	7.2%
<b>Consumption (TWh)</b>				
Industry	36.0	60	12.6%	5.5%
Residential	11.9	20	12.9%	6.8%
Commercial	9.6	16	13.3%	11.3%
Agriculture	1.8	3	11.6%	14.1%
Total	59.6	100	12.8%	6.8%

Source: Ministry of Energy

Installed capacity refers to year-end.

(a) 1980-1987

(b) Estimated by LBL based on fuel consumption for 1970-1983

**Self-producers' generation** in 1987 was an estimated 2.3 TWh.

**Electricity consumption per capita** in 1987 (including self-production) was 3177 kWh.



# ELECTRICITY GENERATION BY SOURCE Taiwan

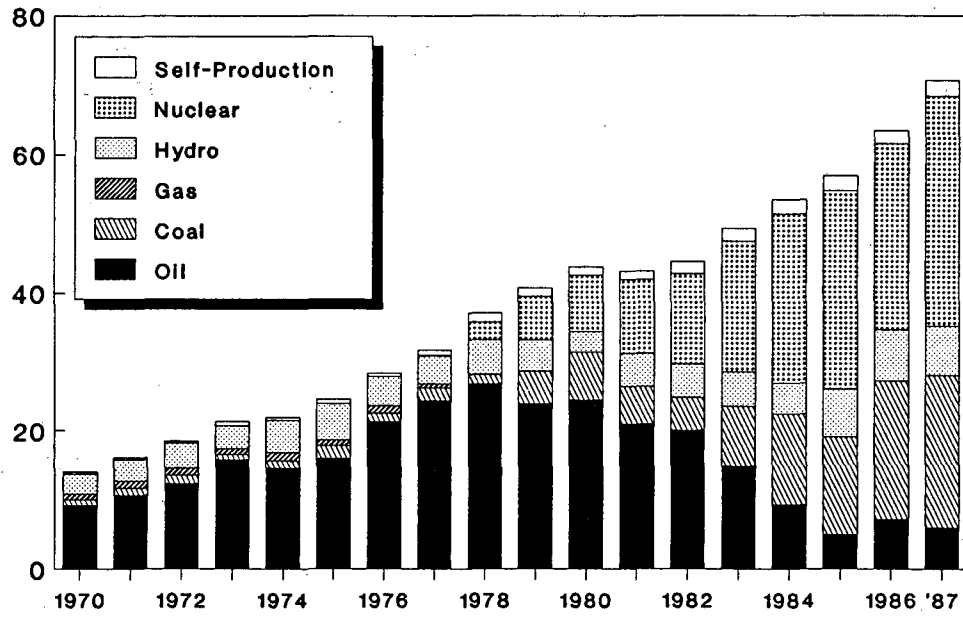


Figure 9-1

### 9.3. Forecast of Electricity Demand

In its Long Range Power Development Program (1988-2000) released in September 1988, Taipower projected peak demand to grow at an average annual rate of 5.6% between 1988 and 2000. This forecast included the impact of load management, without which peak demand was projected to grow at a rate of 6.4% per year. The forecast was based on an average annual growth rate of GDP of 6.4%, as projected by the Council for Economic Planning and Development in March 1988. Taiwan is thus in a position comparable to many industrialized countries in that electricity demand is growing at about the same pace as GDP.

Since the official forecast was made, demand has grown faster than expected. Consumption increased by 10.3% in 1988, and has grown rapidly in 1989 also. Growth has been especially strong in the residential and commercial sectors.

### 9.4. Plans for Power Sector Development

Taipower's Long-Range Power Development Program calls for growth in total installed capacity from 16.6 GW in 1987 to 29.9 GW in 2000. Most of the growth is to come from coal-fired plants. Of the 14.5 GW of planned additions to the system in the 1988-2000 period, 8.5 GW are coal-fired, and coal-fired capacity is planned to grow from 24% to 40% of installed capacity. Taipower also plans to begin using LNG (imported from Indonesia) in 1990; the plans call for addition of 2.7 GW of LNG-fired stations by 2000. Two new nuclear units (1.0 GW each) are scheduled for operation in 1998-99, but plans for these units have been suspended by the government in the wake of public opposition. The composition of generating capacity in 1987 and as planned for 2000 (including the uncertain nuclear units) is shown below.

Table 9-2  
Taipower Plan for Electricity Supply  
September 1988  
(Installed capacity in MW)

	1987	%	2000	%
Hydro <sup>a</sup>	2558	15	4484	15
Thermal	8887	54	18271	61
Coal	3955	24	11925	40
Oil	4932	30	3611	12
LNG	0	0	2685	9
Nuclear	5144	31	7144	24
Total	16589	100	29928	100

(a) Includes pumped storage: 1000 MW in 1987, 2600 MW in 2000.

## 9.5. Financial Issues

The financial situation of Taipower is relatively sound. This situation is partly due to the fact that no capital-intensive projects have been initiated in recent years, though the company has not experienced difficulty in financing its power system expansion in the past.

## 9.6. Electricity Supply and End-Use Efficiency

The thermal efficiency of Taipower's power plants (35% in 1987) is comparable to that in industrialized countries. Taipower has reduced its line losses from nearly 7% in 1980 to 5.7% in 1987.

Taiwan has had a strong energy conservation program since 1980. This has included an Energy Service Corps that provides information and technical assistance to small and medium-sized firms, a number of financial incentives to encourage investment in energy conservation, and efficiency standards on electric appliances and electric motors. The National Energy Committee has estimated that 795 MW of generating capacity has been saved through efficiency improvement of new appliances since 1980.<sup>3</sup> Implementation of efficiency standards for new buildings is in the planning stage.

The recent reduction in reserve capacity has increased interest in load management and special peak-period pricing.

## 9.7. Environmental Issues

Environmental issues are playing an increasingly important role in shaping the evolution of Taiwan's power sector. Opposition to nuclear power has become widespread in recent years, prompting the government to suspend the planned construction of two additional nuclear units. Proposed coal-fired power plants are also facing increasing local opposition. New standards for air emissions and wastewater discharge from power plants are due to take effect in 1993 (which will increase the cost of electricity from coal-fired plants), but local opposition may nonetheless curtail the current plans for coal use.

## 9.8. Conclusion

Taiwan's economy is undergoing a gradual transition toward less energy-intensive activities, but electricity demand in the residential and commercial sectors is growing rapidly as consumer income and the services sector grow. The net result of these two forces will depend on local and international economic developments (since Taiwan's economy is heavily dependent on exports). In the near-term, however, growth in electricity demand is such that Taipower is faced with the possibility of a less-than-adequate reserve margin.

On the supply-side, the degree of opposition to nuclear power makes it unlikely that the two new units will be built as scheduled. Reliability problems with the existing nuclear units have also dampened enthusiasm for current nuclear technology. The plans calling for nearly 12,000

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<sup>3</sup> Li-Min Hsueh, "An Evaluation of Taiwan's Energy Conservation Policy," in Proceedings of the 11th Annual Conference of the International Association for Energy Economics, Caracas, Venezuela, June 1989.

MW of coal-fired capacity by the year 2000 will also be difficult to realize, given the extent of local opposition to new plants. It is likely that there will be greater use of imported LNG than is currently planned, though construction of the necessary infrastructure makes this option much costlier than coal (not including the environmental benefits of LNG *vis a vis* coal).

In order to increase power supply, the government is placing a strong emphasis on developing the considerable potential for cogeneration by industries. Regulations specifying attractive terms for power purchase (based on Taipower's avoided cost) are being implemented in late-1989. Electricity generation by third parties for sale to the grid are not yet allowed, but this may come eventually. As the infrastructure for LNG use improves, cogeneration using LNG will become an even more attractive option. The difficulties in expanding supply are also bringing greater interest in demand-side management.

## 10. THAILAND

### 10.1. Background

Most public electricity in Thailand is supplied by the Electricity Generating Authority of Thailand (EGAT), a State-owned corporation which is considered to be one of the most successful state enterprises in Asia. The Metropolitan Electricity Authority and the Provincial Electricity Authority are the chief distributors of electricity to customers. EGAT's total installed capacity more than doubled from 3.0 GW in 1979 to 7.0 GW in 1987. Expansion of capacity since 1980 has come mainly from gas-fired steam plants that utilize Thailand's natural gas resources, though there has also been increase in hydro and combined-cycle capacity. The plant mix at the end of 1987 consisted of 2.3 GW in hydro power stations, 3.6 GW in thermal power stations, 0.8 GW in combined-cycle plants, and 0.3 GW in gas turbine and diesel units.

Public electricity generation grew at an average annual rate of 9.4% in the 1979-1987 period. (GDP averaged growth of 5.1% per year in this period.) Generation in 1987 grew by 13.8% over 1986, reflecting the strong growth in the economy, as well as results of the 1987 "Visit Thailand Year." Growth in demand in 1988 was around 15%. In terms of the fuel mix for generation, natural gas has grown from zero in 1980 to account for 55% of total generation in 1987 (Figure 10-1). Generation from lignite has grown to 23% of the public total. 16% of generation came from hydro in 1987, and 11% was from oil.

Industry is the largest consuming sector (45% of public consumption in 1987), but the residential and commercial sectors are also important (25% and 29%, respectively), and their demand is growing faster than industry's.

The EGAT system in the past has had sufficient reserve margin (40% in 1986), but the faster-than-anticipated growth in demand has led to a situation where power shortages are anticipated in the early 1990s.

### 10.2. Resources for Electricity Generation

Thailand has substantial **natural gas** resources. Estimates of proven and probable recoverable reserves range between 4-13 TCF (27-87 billion BOE), reflecting the uncertainty regarding both geology and future price. Production in 1987 was 0.18 TCF. Only a minute reserve of oil has been found so far. The total probable reserve of **lignite** is estimated at 1700 million metric tons; 900 are proven (1.5 billion BOE). Lignite production in 1987 was 6.9 million tons.

The total theoretical **hydro** power resource has been estimated at 8.3 GW, of which 2.3 GW has been tapped to date. (The total includes 1.0 GW of mini- and micro-hydro.) A World Bank mission in 1987 appraised the realistic potential for new hydro developments at about 1.8 GW. In addition to in-country resources, there exists around 17 GW of potential hydro power on international rivers bordering Thailand.

**Table 10-1**  
**Power Sector Statistics for Thailand**  
(Not including self-producers)

	1987	1987 (%)	AAGR 1970-79	AAGR 1979-87
<b>Installed Capacity (MW)</b>				
Hydro	2.3	33	8.1%	12.0%
Thermal	4.7	67	10.9%	11.0%
Total	7.0	100	10.0%	11.3%
<b>Generation (TWh)</b>				
Hydro	4.1	14	6.9%	2.8%
Thermal	24.6	86	15.1%	11.7%
Coal-fired	6.7	23	14.2%	23%
Oil-fired	2.3	8	15.2%	-15.8%
Gas-fired	15.6	55	-	47% <sup>a</sup>
Total	28.7	100	12.5%	9.4%
<b>Consumption (TWh)</b>				
Industry	11.3	45	14.1%	8.3%
Residential	6.3	25	15.2%	10.9%
Commercial	7.3	29	13.2%	8.7%
Total	24.9	100	14.6%	9.1%

Source: National Energy Administration  
 Installed capacity refers to year-end.  
 (a) 1981-1987

**Self-producers' generation** in 1987 was an estimated 1.3 TWh.  
**Electricity consumption per capita** in 1987 (including self-production) was 489 kWh.

# ELECTRICITY GENERATION BY SOURCE Thailand

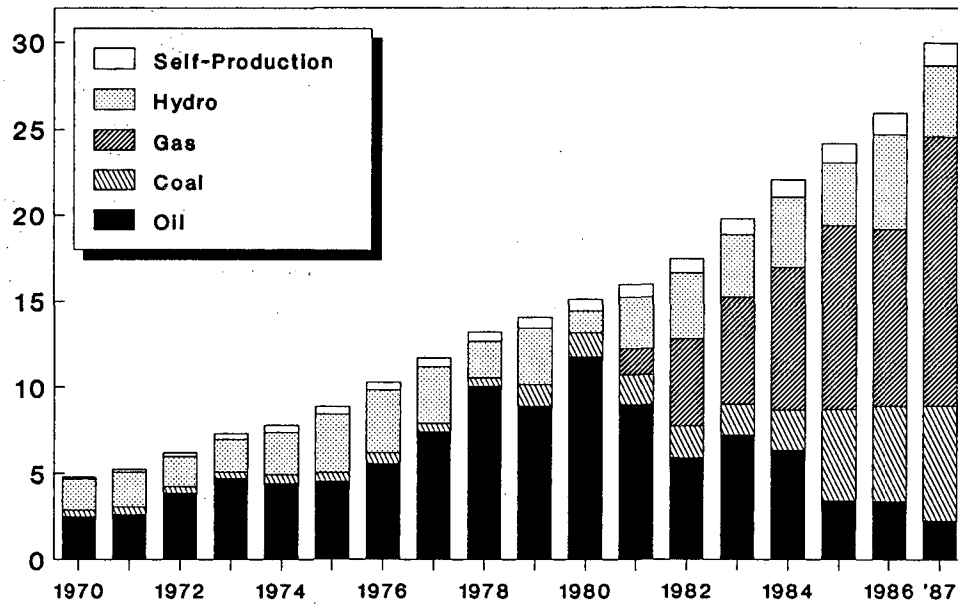


Figure 10-1

### 10.3. Forecast of Electricity Demand

The high rate of growth in electricity demand in late 1987 and early 1988 led the government to substantially revise the load forecasts that had been made in October 1987. The July 1988 load forecast (Base Case) shows peak demand growing from 4733 MW in 1987 to 15,112 MW in 2001, and generation growing from 28,193 GWh to 96,373 GWh. (The October 1987 load forecast had peak demand growing to 11,821 MW in 2001, over 3,000 MW less than in the revised forecast.) Generation grows at 12.7% per year in the 1987-1991 period, at 8.9% per year in the 1992-1996 period, and at 6.9% per year in the 1997-2001 period. The average for the entire period is 9.2% per year. Peak demand grows slightly slower than generation.

The average annual growth in GDP used in the July 1988 load forecast was 6.7% for the period 1987-2000. There were sub-forecasts as well: 7.4% for 1987-1991; 7.0% for 1992-1996; and 5.6% for 1997-2001. The average elasticity between electricity demand and GDP is forecast to decline from 1.7 in the 1987-91 period to 1.3 in the 1992-96 period and to 1.2 in the 1997-2001 period.

Table 10-2  
Thai Government Forecast of Electricity Demand  
July 1988 (Base Case)

	Peak Load (GW)	Generation (TWh)
1987	4.73	28.19
1991	7.44	45.06
1996	11.07	69.07
2001	15.11	96.37

The forecast growth in electricity sales for different sectors between 1988 and 2000 is shown below. Projected growth is fastest in the commercial sector, followed by the residential. The share of industry in total sales is forecast to decline from 48% to 44%, while the commercial and residential sectors will account for about 25% each.



Table 10-3  
 Thai Government Forecast of Electricity Sales by Sector  
 July 1988

	1988 TWh	2000 TWh	AAGR
Industry	13.37	35.22	8.4%
Commercial	6.15	20.63	10.6%
Residential	6.39	19.10	9.5%
Public	1.68	4.29	8.1%
Total <sup>a</sup>	27.67	79.47	9.2%

(a) Includes agriculture.

#### 10.4. Plans for Power Sector Development

EGAT's Power Development Plan issued in August 1988 shows installed capacity growing from 6.9 GW to 17.4 GW during the 1987-2000 period. Most of the new capacity in the 1990s is to come from lignite-fired power plants (about 4.5 GW spread between 1988 and 1999) and gas combined-cycle power plants (1.7 GW in the 1990-1992 period). The lignite-fired capacity will mainly be located near the Mae Moh mining area in northern Thailand. Hydro capacity is to grow gradually, mostly in the late-1990s. After 1993, there is no increase planned in use of natural gas for power generation, as the extent of domestic supply is uncertain. The plan shows coal-fired power plants based on imported coal coming on line in 1998, and totalling 1.8 GW of capacity by 2000. (An additional 1.2 GW of coal-fired capacity is planned for commissioning in 2001.)

Table 10-4  
EGAT Plan for Thailand Electricity Supply  
August 1988  
(Installed capacity in MW)

	1987 Actual	%	1994	%	2000	%
Hydro	2250	32	2646	22	3550	20
Oil	774	11	1718	14	1687	10
Gas-thermal	2000	29	2300	19	2300	13
Gas-combined-cycle	772	11	2532	21	2532	15
Lignite	865	12	2700	23	5400	31
Coal	-	-	-	-	1800	10
Gas turbine	265	4	100	1	100	1
Total	6926	100	11995	100	17369	100

In response to the very rapid growth in electricity demand, EGAT is in the process of accelerating its development program.

### 10.5. Financial Issues

EGAT's total capital expenditure in the 1987-1991 period, based on the plan described above, amounts to Baht 100 billion (US\$ 3.9 billion). The foreign exchange requirement is approximately US\$ 2.0 billion. In the five-year period beginning in 1992, the utility is expected to need Baht 170 billion (US\$ 6.6 billion).<sup>1</sup> In order to help fund this scale of investment, the National Energy Planning Committee established in April 1989 a policy that encourages private investment in power plants. A target was set for the private sector to handle 30% of the total requirements in the 1992-1996 period.

### 10.6. Electricity Supply and End-Use Efficiency

The thermal efficiency of Thailand's steam power plants is on average relatively good. Transmission and distribution losses are around 10%, which is relatively low by developing country standards.

Thailand's energy conservation program has concentrated mostly on the industrial sector, though it is being expanded to cover buildings. The program includes free industrial energy audits, loan programs for demonstration projects, and reduction of the import duty on energy conservation materials and equipment.<sup>2</sup> The Energy Conservation Center of Thailand (ECCT), which is managed by the private sector under government supervision, began operation in 1988 and is

<sup>1</sup> "Politics of power," *Far Eastern Economic Review*, July 13, 1989.

<sup>2</sup> RCG/Hagler, Bailly, Inc., *Energy Inefficiency in the Asia/Near East Region and its Environmental Implications*, U.S. Agency for International Development, June 1989.

providing training, energy audits, and information services. An Energy Management Law, which will support the ECCT and promote other energy efficiency activities, is awaiting enactment by the government.

#### **10.7. Environmental Issues**

Opposition to hydroelectric development is beginning to have an impact on power sector development. The Upper Quae Yai Hydro project, a planned 580 MW power plant, was shelved due to opposition in 1988. It was replaced in the plan by a proposed 600 MW coal-fired plant.

Impacts of lignite mining and combustion are a concern in affected regions.

#### **10.8. Conclusion**

With the rapid pace of economic growth, the situation in Thailand is shifting to one where growth in electricity demand may be constrained by lack of supply. Conservation and load management efforts are being given greater emphasis in order to slow growth in demand. Private investment in power generation is also being encouraged, though cogeneration projects have reportedly run into resistance from EGAT.

Lignite and natural gas will play the major role in new power generation in the 1990s. There is untapped hydro potential, but also public opposition to large-scale hydro development. EGAT has generally been able to bring on new capacity in a timely manner, but the scale of expansion called for in the 1990s will test its ability to coordinate many different types of projects. The most important part of the planned expansion, especially after 1995, is based on lignite. Increased use of natural gas for power generation after 1993 is not envisioned due to the uncertainty of supply. In the long-term, if new domestic energy resources are not available, imported coal will likely become a major source for power generation.

## 11. ARGENTINA

### 11.1. Background

Various Federal government organizations are responsible for most of the bulk power supply in Argentina. They own and operate the large hydroelectric power plants, the two nuclear power plants, and the power transmission grid that interconnects the various power supply systems. About 90% of public electricity generation is linked into the National Interconnected System (NIS). Another Federal organization, SEGBA, distributes electricity in and around the nation's capital, Buenos Aires, and also generates electricity. Five utilities account for most of the country's electricity generation, with each having a share in the 15-20% range.

The total installed capacity (not including self-producers) grew from 9.6 GW in 1979 to 14.1 GW in 1985, the last year for which the government has published overall electricity statistics for the country. Most of the growth was from construction of large hydroelectric projects; total installed hydropower capacity nearly doubled from 3.1 GW in 1979 to 6.0 GW in 1985. This period also saw addition of a 648 MW CANDU nuclear power station and construction of around 1 GW of thermal capacity.

The country's effective capacity is much less than the nominal installed capacity. At the end of 1987, the effective capacity of the National Interconnected System amounted to 12.1 GW: 5.3 GW of hydropower plants, 4.3 GW of steam power stations, 1.3 GW of gas turbines, and 1.0 GW in two nuclear units.<sup>1</sup> There is also 0.8 GW of pumped hydro storage.

Public electricity generation grew at an average annual rate of 4.8% in the 1979-87 period despite a small net decline in real GDP.<sup>2</sup> Generation in 1987 grew by 6.5% over 1986. The growth in electricity generation has come mainly from hydro and nuclear energy (Figure 11-1). There has also been substitution of gas for oil in thermal plants (many of which are dual-fuel capable) since 1980. In 1987, hydropower provided 45% of total public generation, thermal plants provided 42%, and nuclear power supplied 13%.

Industry accounted for 47% of public electricity consumption in 1987 (the same as in 1980), while the residential and commercial sectors accounted for 30% and 21%, respectively. Unlike in many other developing countries, residential and commercial demand has averaged about the same growth as industrial demand in the 1980s.

In 1989, a combination of factors led to loss of a large portion of generating capacity, plunging the country into a severe power crisis. These included repairs on a major dam, outage of some thermal capacity due to chronic lack of maintenance, low rainfall, and non-availability of the Atucha I nuclear power plant led to a situation where only 6000-7000 MW were available for use.<sup>3</sup> The power shortage necessitated rotating blackouts and power curtailment to large industrial users, as well as greater dependence on fossil-fired generation. The situation has improved since the first part of 1989, but remains difficult.

<sup>1</sup> "Despacho Nacional de Cargas," Agua y Energia Electrica, 1988.

<sup>2</sup> In contrast, during 1973-1980 GDP grew at 2.2% per year and electricity consumption grew at 5.4% per year.

<sup>3</sup> U.S. Department of Energy, "Evaluation of Argentina's Electricity Situation", Report from a technical team sent by the U.S. Government to Argentina, Feb. 1989.

Table 11-1  
**Power Sector Statistics for Argentina**  
 (Not including self-producers)

	1985 (GW)	1985 (%)	AAGR 1970-79	AAGR 1979-85
<b>Installed Capacity (GW)</b>				
Hydro	6.0	43	20.6%	8.3%
Thermal	7.1	50	3.9%	2.7%
Nuclear	1.0	7	-	18.4%
Total	14.1	100	7.8%	6.6%
	1987 (TWh)	1987 (%)	AAGR 1970-79	AAGR 1979-87
<b>Generation</b>				
Hydro	21.8	45	24.3%	9.5%
Thermal	19.8	41	2.9%	0
Coal-fired	n.a.	2 <sup>a</sup>	-1.4%	- <sup>b</sup>
Oil-fired	n.a.	16 <sup>a</sup>	1.5%	-7.0% <sup>b</sup>
Gas-fired	n.a.	23 <sup>a</sup>	9.3%	10.5% <sup>b</sup>
Nuclear	6.5	14	-	11.6%
Total	48.1	100	7.8%	4.8%
<b>Consumption</b>				
Industry	18.1	47	12.2%	3.8%
Residential	11.3	30	5.4%	4.3%
Commercial	8.1	21	4.9%	4.9%
Others	6.5	2	3.8%	-
Total	38.1	100	8.0%	4.1%

Source: Secretary of Energy

Installed capacity refers to year-end.

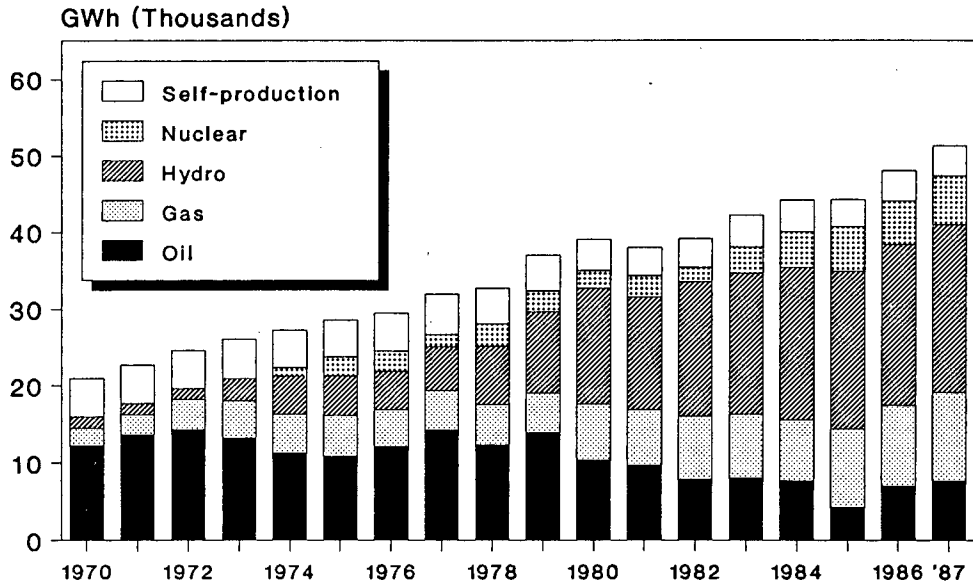
(a) 1985 estimated shares

(b) 1979-1986; estimated by LBL based on fuel consumption

**Self-producers' generation in 1987 was an estimated 3.9 TWh.**

**Electricity consumption per capita in 1987 (including self-production) was about 1330 kWh.**

# ELECTRICITY GENERATION BY SOURCE Argentina



1987 Gas, Coal, Oil disaggregation  
estimated based on '86 totals

Figure 11-1

## 11.2. Resources for Electricity Generation

Argentina's proved reserves of oil amount to approximately 2 billion barrels, with a reserve-production ratio of 13 years. Natural gas reserves represent about 4.8 billion BOE. Potential hydro resources are around 40 GW. Uranium resources are sufficient to supply 8000 MW of capacity for 30 years.

## 11.3. Forecast of Electricity Demand

A new forecast of electricity demand is being prepared by the new government. Given the magnitude of the economic crisis in which Argentina finds itself, any forecast of electricity demand must be highly uncertain. The issue is how deep a recession the country will fall into, for how long, and what effect this will have on demand for electricity. It is significant that electricity consumption continued to grow in the 1980-1987 period despite the lack of growth in GDP. This was true of industrial consumption as well as residential and commercial demand. Consumption did decline in the worst year (1985), however. But the general trend suggests that electricity demand could continue to grow (though at a slow rate) even if the economy is stagnant. The limits of this phenomenon are uncertain.

## 11.4. Plans for Power Sector Development

The crisis of the power system has come at a time when it is very difficult for the utilities to raise new capital. Officials responsible for the power sector are understandably concentrating their efforts on improving the condition of the existing system. This involves completion of repairs on damaged facilities, rehabilitation of several thermal units, and implementing a system for improved maintenance.

Plans for the power sector are being formulated by the newly-elected government as of October 1989. The old plans from 1986, which showed a nearly 2-fold increase in installed capacity between 1988 and the year 2000 and considerable growth in hydro capacity, have been rendered obsolete by the economic crisis.

Current planning is shaped by the belief that growth in demand in coming years will be slow due to the serious economic problems, and by the lack of capital to take on costly new projects. In the near-term, efforts will focus on rehabilitation of existing thermal power plants and completion of plants that are now under construction. It is estimated that 1 to 1.5 GW can be added to the currently-available capacity through the rehabilitation of thermal plants between 1989 and 1991.<sup>4</sup> Improvement of the reliability of the power system will require better coordination between Federal and Provincial organizations in order to provide adequate funds for maintenance and system expansion.

Under the circumstances, it is fortunate that two large hydroelectric projects are in advanced stages of construction with World Bank and IDB financing. The first, Yacyreta, will have a total installed capacity of 1400 MW and is due to begin to come on line in 1991. The second, Piedra del Aguila, will have a total installed capacity of 2700 MW (which will eventually be partly shared with Paraguay), and is due to begin to come on line in 1993. A joint hydroelectric project with Uruguay, from which Argentina will use most of the power for the near-future, is also under

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<sup>4</sup> ATEC S.A. de Asesoramiento Tecnico, "Situacion y Perspectivas del Suministro Electrico", Buenos Aires, 1988.

construction. In addition to these facilities, a 700 MW nuclear power plant is scheduled for operation in 1993, though whether this unit will be completed by then is uncertain.

Given the expected slow growth in electricity demand resulting from the country's economic difficulties, it is likely that the power sector will have sufficient capacity once much of the new hydro capacity comes on line. For the mid-1990s and beyond, power sector planners face a choice between utilizing more of the country's natural gas resources or constructing new hydroelectric facilities. Several hydro projects are under study, but it is likelier that new capacity after 1995 will be based on natural gas. The hydroelectricity from these projects would probably not be competitive with gas, and the debt situation would make them difficult to finance.

### **11.5. Financial Issues**

The economic crisis facing Argentina limits the ability of the power sector to raise funds for expansion. Although the government raised the price of electricity 6-fold in 1989, inflation may well erode the value of this increase. The lack of internal funds and the difficulty of attracting external financing are factors that shape the plan to focus on rehabilitation of existing capacity rather than construction of new capacity.

### **11.6. Electricity Supply and End-Use Efficiency**

The efficiency of thermal power plants is low due to chronic poor maintenance practice. In addition to the problems with the generating system, losses in electricity transmission and distribution appear to have increased in recent years (partly due to theft). As discussed above, improving the capability and efficiency of the existing generation system is a high priority.

Improving end-use efficiency has not received much attention to date, though there are plans to devote more effort to this in the future.

### **11.7. Conclusion**

Argentina's economic crisis greatly constrains power sector planning. Efforts are focused on improving the output from the existing capacity more than on planning for the more distant future. The effectiveness of the new government's economic policies and the outcome of upcoming negotiations on Argentina's debt will shape the demand for electricity and the ability of utilities to provide reliable electricity service. Improvement of the reliability of the power system will require better coordination between federal and provincial utilities in order to provide adequate funds for maintenance and system expansion. In the near-term, electricity consumption will be constrained by the lack of supply. In the medium-term, the amount of natural gas available for new power stations will depend in part on the price received by producers. Gas pricing and prioritization of supplies are receiving attention from the new government.



## 12. BRAZIL

### 12.1. Background

Some of these companies are exclusively responsible for distribution grids, while others are predominantly generating electricity. Planning for the power sector is coordinated by Eletrobrás, a federal holding company, and the Ministry of Mines and Energy.

Between 1979 and 1987, total public installed capacity grew from 27.2 GW to 43.9 GW. Hydropower accounts for 90% of the total. In addition to 3.8 GW in oil- and coal-fired power stations, there is a 657 MW nuclear power station.

Ninety-five percent of the electricity supplied for public use comes from hydropower. Public electricity generation grew at an average annual rate of 6.9% in the 1979-1987 period, during which GDP averaged growth of 3.5% per year. Generation in 1987 grew by only 3.5% over 1986, as industrial output experienced little or no growth, and a preliminary estimate put growth in 1988 at 2.0%. Self-production by industry is equivalent to about 5% of total public generation. There was a substantial increase in oil-fired generation in 1986, though it declined in 1987 (Figure 12-1).

Industry is the leading consuming sector with 56% of total public consumption in 1987. The residential sector accounted for 21% of total consumption, the commercial sector for 20%. Industrial electricity consumption grew rapidly in the 1970s as a result of the government's campaign to encourage substitution of electricity for oil. In recent years, the residential sector has had a somewhat higher rate of growth than the other sectors. Considerable electrification has occurred in the past; around 80% of the population now has access to electricity, though some of these households are connected illegally.

### 12.2. Resources for Electricity Generation

Brazil has **hydro** resources sufficient to meet electricity demand for several decades. Around 55% of the economic resources are in the North (Amazon) region; their development will require long transmission lines to supply power to the demand centers in the southeast. Among fossil fuels, reserves are 2.2 billion barrels for **oil**, 0.6 billion BOE for **natural gas**, and 0.01 BOE for **coal**.

Table 12-1  
**Power Sector Statistics for Brazil**  
 (Not including self-producers)

	1987	1987 (%)	AAGR 1970-79	AAGR 1979-87
<b>Installed Capacity (GW)</b>				
Hydro	39.5	90	12.1%	6.6%
Thermal	3.8	9	9.2%	0.7%
Coal-fired	n.a.	n.a.	1.9%	-2.2% <sup>a</sup>
Oil-fired	n.a.	n.a.	11.8%	0.2% <sup>a</sup>
Nuclear	0.7	1	-	-
Total	43.9	100	11.7%	6.1%
<b>Generation (TWh)</b>				
Hydro	199	95	12.8%	7.2%
Thermal	9.2	4	1.6%	3.5%
Coal-fired <sup>b</sup>	3.6	2	3.1%	3.7%
Oil-fired <sup>b</sup>	5.6	2	0.8%	3.4%
Nuclear	1.0	1	-	-
Total	209.0	100	11.8%	6.9%
<b>Consumption (TWh)</b>				
Industry	102.3	56	13.7%	7.2%
Residential	38.4	21	10.8%	7.8%
Commercial	36.1	20	10.8%	6.4%
Others	7.0	4	10.2%	14.9%
Total	183.9	100	12.3%	7.4%

Sources: Eletrobras, Ministry of Mines and Energy

Installed capacity refers to year-end.

(a) 1979-1985

(b) Estimated by LBL based on fuel consumption for 1970-80

**Self-producers' generation in 1987 was an estimated 10.1 TWh.**

**Electricity consumption per capita in 1987 (including self-production) was around 1380 kWh.**

# ELECTRICITY GENERATION BY SOURCE Brazil

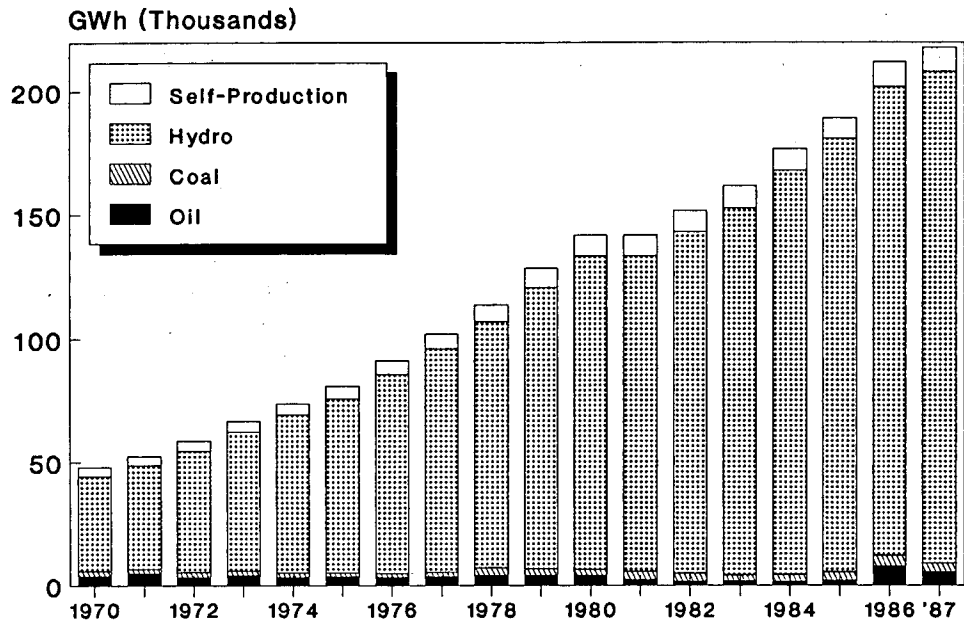


Figure 12-1

### 12.3. Forecast of Electricity Demand

"Plano 2010", published in December 1987 by the Ministry of Mines and Energy and Eletrobras, is the most recent official planning document for the Brazilian power sector. Future electricity demand was projected using macroeconomic and demographic variables as well as information on specific industrial projects. The projections were carried out separately for each region and for each class of consumers. Each of the major industrial sectors were treated separately.

The projections show electricity demand (including self-producers) growing from 186 GWh in 1986 to 432 GWh in 2000 and to 680 GWh in 2010. The projected growth rates for different sectors and for GDP are shown in Table 12-2. Overall, growth in demand was projected to gradually slow from 7.4% per year in the 1986-1990 period to 4.4% per year in the 2006-2010 period. The projected average growth rate over the entire period was 5.5% per year. The assumed average GDP growth was 5.8% per year. The elasticity between electricity demand and GDP was projected to decline from 1.07 in the 1985-1990 period to 0.91 in the 2006-2010 period. Industrial demand was projected to grow slightly faster than residential.

Table 12-2  
Projections of Brazil Electricity Demand<sup>a</sup>  
December 1987  
(Average annual growth per year)

	1986-90	1991-95	1996-00	2001-05	2006-10
Industrial	7.4	6.7	5.7	5.2	4.5
Residential	6.8	6.5	5.7	5.0	4.3
Others	7.9	6.0	5.4	4.8	4.2
Total	7.4	6.5	5.6	5.1	4.4
GDP	6.8	6.1	5.8	5.4	4.7

(a) Excluding self-producers.

The projection of future household electricity demand in "Plano 2010" has been criticized for its assumptions regarding growth.<sup>1</sup> The Plan assumes a low current level of urbanization (68% vs. 76% shown by other statistics); it uses a low estimate of the population with electricity (59% vs. 81% shown by government statistics);<sup>2</sup> and it assumes a high rate of growth in total population (1.7% per year) relative to other estimates. Consequently, there appears to be more room for growth in residential electricity demand than may actually be the case.

<sup>1</sup> Gilena Graca, "Demand and Production of Electricity in Brazil, 1970-1985," Instituto de Eletrotecnica e Energia, University of Sao Paulo.

<sup>2</sup> The analysis in "Plano 2010" bases electrification on the number of residential customers. Since many households are illegally electrified (i.e., not considered as customers), it understates the actual level of electrification.

## 12.4. Plans for Power Sector Development

"Plano 2010" calls for growth in total capacity (including industrial self-producers) from 42.7 GW in 1986 to 103.0 GW in 2000 and to 160.0 GW in 2010 (Table 12-3). Most of Brazil's electricity will continue to come from hydropower. The plan calls for increase in installed hydro capacity from 38.5 GW in 1986 to 93.3 GW in 2000 and to 141.8 GW in 2010. Coal-fired capacity is planned to grow from 0.7 GW to 3.0 GW in 2000 and to 6.5 GW in 2010. Nuclear capacity is projected to increase from 0.6 GW to 3.1 GW in 2000 to 8.1 GW in 2010.

Table 12-3  
Official Plan for Brazil Electricity Supply  
December 1987  
(Installed capacity in GW)

	1986	%	2000	%	2010	%
Hydro	38.5	90	93.3	91	141.8	89
Thermal	3.6	8	6.6	6	10.1	6
Coal	0.7	2	3.0	3	6.5	4
Other <sup>a</sup>	2.9	7	3.6	4	3.6	2
Nuclear	0.6	1	3.1	3	8.1	5
Total	42.7	100	103.0	100	160.0	100

(a) Mostly oil.

According to Eletrobras, hydro resources with estimated production costs under \$0.05/kWh could provide a total of 63 GW-years of firm energy.<sup>3</sup> (This excludes resources already in use or where construction has begun.) Tapping resources with estimated costs less than \$0.10/kWh could provide an additional 11 GW-years of firm energy.

The planned hydro development would make use of 54% of the yet-to-be-exploited resources with costs under \$0.05/kWh by the year 2000, and 86% by 2010. About half of the planned hydro development between now and the year 2000 is in the Southeast/Central West region. Most of the new hydro production after 2000 will come from the North region, with long 600 kV transmission lines (2000-2400 km) connecting the S-SE and N-NE grid systems. There are studies concerning the reduction in transmission costs by raising tension up to 800 kV.

There is also an expansion program aimed at the development of small-scale hydro plants (units with less than 30 MW nominal capacity). Total estimated potential coming from these plants is 7 GW with an output of 3.5 GW-years.

<sup>3</sup> The total given includes inventoried and estimated resources. Costs do not include transmission from site.

## 12.5. Financial Issues<sup>4</sup>

Between 1974 and 1986, around \$48 billion was invested in electricity generation, transmission, and distribution; this amounted to 9% of all public and private investment. The expansion of the power sector was accompanied by steep reductions in real electricity prices that were not justified by corresponding cost reductions. With limited resources for self-financing, the power sector paid for its expansion with foreign loans. Whereas in 1975 the sector was able to raise 60% of its total financial requirements from revenues, by 1985 it could only raise 30%. It owed some \$22 billion abroad by 1986, about one-fifth of Brazil's foreign debt. The rate of return on its investments fell from a high of 11.4% in 1976 to only 4.2% in 1986.

The current financial problems come at a time when resources on the order of \$250 billion would be needed between 1988 and the year 2010 in order to implement "Plano 2010." The situation is made more difficult given the severe decline in domestic savings and the increasing scarcity and higher interest rates of foreign financing. Much of the necessary capital will have to be raised by the power sector, necessitating considerable increase in electricity prices.

## 12.6. Electricity End-Use Efficiency

Interest in improving electricity end-use efficiency has grown in Brazil in recent years, and programs to conserve electricity are probably more advanced than in any other Latin American country. An important step was the creation in 1985 of a National Electricity Conservation Program (PROCEL). In collaboration with other organizations, PROCEL has been involved in: (1) Creation of a laboratory for testing home appliances; (2) Testing and subsequent labelling of new labeling of refrigerators as to their electricity use; (3) A nation-wide program to replace incandescent street lights with mercury vapor and high-pressure sodium lamps; (4) Energy auditing of industrial facilities and commercial buildings; (5) A national campaign on TV and in radio and print media to make the public more aware of efficiencies of appliances; and (6) Other educational programs.

In addition to the activities of PROCEL, the lighting industry has introduced more efficient incandescent lamps, which have penetrated some 25% of the existing stock in just two years.

Studies of electricity end-use efficiency have indicated a considerable potential for saving electricity at costs much lower than those required for new supplies. According to one major study, improved efficiency could save nearly 19 GW of installed capacity by the year 2000.<sup>5</sup> Achieving significant savings will not be simple, however. Key barriers to electricity conservation in Brazil include low electricity prices, high inflation, shortage of capital to invest in conservation measures, and lack of conservation technology. PROCEL's budget is very small relative to expenditures on conventional supply expansion activities, but there is a good prospect for a significant increase in its funding via the World Bank's power sector loans.

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<sup>4</sup> Based on: D. Christodoulou and R. Hukai, "The Formation and Use of Capital in the Brazilian Electrical Sector," paper presented at the Inaugural Seminar of the Fernand Braudel Institute of World Economics, Sao Paulo, August 1988.

<sup>5</sup> H. Geller, J. Goldemberg, J. Moreira, R. Hukai, C. Scarpinella, and M. Ysohizawa, "Electricity Conservation in Brazil: Potential and Progress," *Energy* Vol. 13, No. 6, 1988.

## 12.7. Environmental Issues

Much of Brazil's planned hydro capacity would entail loss of agricultural land, disruption of river ecosystems, and resettlement of people. Many past hydroelectric projects have had severe environmental and social impacts.<sup>6</sup> The benefits for local populations have been minimal. Opposition to hydropower development is growing both within and outside of Brazil.

Brazilian critics of nuclear energy have posed questions of management of radioactive wastes and protection of the population against the consequences of a serious nuclear accident.

## 12.8. Conclusion

The official plan envisions levels of economic growth that seem rather optimistic in light of the current economic situation in Brazil. For the 1986-1990 period, the assumed average GDP growth was 6.8% (falling to 6.1% in 1991-1995 and 5.8% in 1996-2000). The actual average growth in the 1986-1987 period was 5.5% per year, but there was little if any growth in 1988. The possibility of considerable increase in electricity prices (to finance the called-for development) may also lead to slower growth in demand, especially if efforts at improving end-use efficiency are successful.

The enormous expansion in hydropower capacity envisioned in the Plan — from 39.5 GW in 1987 to 93.3 GW in 2000 and 142 GW in 2010 — is extremely ambitious in engineering terms. Given the country's foreign debt situation and the high capital costs of new hydro (\$1500 to \$3000 per installed kW), such an expansion would seem to be very difficult to finance. Similar problems apply for the planned increase in nuclear capacity, especially in light of the experience with the second nuclear power plant (Angra 2).<sup>7</sup>

Critics of the Plan argue that its emphasis on large, capital-intensive hydroelectric projects with long construction times is inappropriate under the present financial circumstances.<sup>8</sup> They call for reducing the capital requirements of the power sector by seeking to increase end-use efficiency and pursuing a stronger non-nuclear thermo-electric program. Gas turbines and combined-cycle plants are substantially less capital-intensive than new hydroelectric supplies, and there are also opportunities to utilize excess bagasse from the alcohol sector and heavy oil from refineries. In addition, smaller-scale thermo-electric projects are more likely to attract private investors than are the giant hydroelectric projects currently under consideration, thus tapping an additional source of capital.

With increasing interest in electricity end-use efficiency, and prospects for funding from the World Bank, it is possible that it will have a greater effect than envisioned in the "Plano 2010" forecast, and thereby reduce the need for new power plants. It is less likely, though of course

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<sup>6</sup> Itaipu, Brazil biggest hydroelectric plant, entailed resettlement of 8200 families and flooding of 1400 km<sup>2</sup> that included farmland, archaeological sites, and forests. Other hydro projects were even worse. The Tucuruí plant in Para State resulted in a flooded area of 2400 km<sup>2</sup>, inundation of three Indian reservations, and the displacement of about 17,000 people; the Sobradinho plant resulted in the world's largest artificial lake (4214 km<sup>2</sup>), and relocation of 60,000 people.

<sup>7</sup> Angra 2 is part of a cooperative project between Brazil and the Federal Republic of Germany that also involves uranium enrichment. After 11 years and \$5 billion, the plant is still under construction.

<sup>8</sup> Christodoulou and Hukai, op cit.

possible, that the emphasis on large hydropower projects will change substantially. Hydroelectric development generates considerable demand for many products of Brazilian industry, and the construction industry is politically powerful. Hydro development also has the effect of opening areas to general development for mining, cattle ranching, and forestry, which are supported by powerful political groups. On the other hand, hydro development in the Amazon is generating increasing opposition within and outside Brazil. Since the opposition outside Brazil could affect financing of projects, it could well have some effect, particularly on those projects with the most severe environmental impacts.



## 13. MEXICO

### 13.1. Background

Public electricity is supplied by Comision Federal de Electricidad (CFE), a federally-owned company. The installed capacity of the CFE system increased from 14.3 GW in 1979 to 23.1 GW in 1987. CFE has added capacity at a faster rate than consumption has grown, with the result that the system has a fairly comfortable reserve margin. Most of the growth has been in dual-fuel-capable (oil and gas) and coal-fired power plants, though about 1000 MW of new hydroelectric capacity was added in 1987. At the end of 1987, the plant mix included 14.9 GW in thermal power stations, 7.5 GW in hydro power stations, and 0.6 GW in geothermal power plants. The first unit of Mexico's controversial Laguna Verde nuclear power plant is scheduled to begin operation in 1989.

Public electricity generation grew at an average annual rate of 6.5% in the 1979-1987 period, much faster than GDP growth, which averaged only 1.7% per year in the same period.<sup>1</sup> Generation in 1987 grew by 7.7% over 1986. Except for an increase in use of coal (from the Northern region of the country), the fuel mix of electricity generation has not changed greatly since 1980 (Figure 13-1). In 1987, 77% of public generation was from thermal plants (7% from coal), and about 21% was from hydropower.

Industry is the main consuming sector (52% in 1987), followed by the residential sector (18%), the commercial sector (13%), and agriculture. The residential sector led the growth in electricity demand during the 1970s and the first part of the 1980s, but its growth has diminished as a consequence of the economic crisis. Demand in the industrial sector has experienced the fastest rate of growth since the economic crisis of 1982 (5.9% per year). In contrast, commercial electricity demand grew at only 1.3% per year during that period.

### 13.2. Resources for Electricity Generation<sup>2</sup>

Mexico's **hydropower** potential is estimated at 19.6 GW for sites with more than 1 MW, and 60 GW including micro-hydro sites. Hydro resources are distributed throughout the country, but potential for large developments is concentrated in the South-West of the country, a region in which the country's tropical rainforests are concentrated. **Oil** reserves are 53 billion barrels, with a current reserves/production ratio of 40 years. **Natural gas** reserves represent approximately 14.6 billion BOE. Proven reserves of **coal** (98% bituminous) amount to approximately 9 billion BOE. **Geothermal** energy resources have not been carefully assessed, but probable and possible reserves are estimated at around 11 GW. estimated at 0.1 billion BOE.

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<sup>1</sup> Most of this period was characterized by one of the worst recessions in Mexico's history. For comparison, the growth rate of the Mexican economy in the 1973-1980 period was 6.5% per year, while electricity demand grew at 7.8% per year.

<sup>2</sup> References for energy resources are as follows: for oil and gas, Petroleos Mexicanos, *Memoria de Labores 1988*; for hydro, J. Viqueira, "La Energia Hidroelectrica en Mexico", *Ciencia* 37, 1986; for coal and geothermal, P. Mulas, "Energy in Mexico", Instituto de Investigaciones Electricas, 1982.

Table 13-1  
**Power Sector Statistics for Mexico**  
 (Not including self-producers)

	1987	1987 (%)	AAGR 1970-79	AAGR 1979-87
<b>Installed Capacity (MW)</b>				
Hydro	7.5	32	5.5%	4.7%
Thermal	14.9	65	13.6%	6.7%
Coal-fired	1.2	5	-	26% <sup>a</sup>
Oil-fired	n.a.	n.a.	-	-
Geothermal	0.7	3	-	20%
Total	23.1	100	10.0%	6.2%
<b>Generation (TWh)</b>				
Hydro	18.2	19	2.7%	0.3%
Thermal	73.7	77	14.9%	8.2%
Coal-fired	7.3	8	-	-
Oil-fired <sup>b</sup>	56.7	59	17.7%	8.6%
Gas-fired <sup>b</sup>	9.7	10	9.7%	-0.4%
Geothermal	4.4	4	-	20%
Total	96.3	100	9.0%	6.5%
<b>Consumption (TWh)</b>				
Industry	44.6	57	9.1%	6.0%
Residential	15.8	20	10.9%	7.0%
Commercial	11.4	15	6.7%	3.5%
Agriculture	6.0	8	10.5%	7.7%
Total	77.7	100	9.0%	5.9%

Sources: CFE, PEMEX

Installed capacity refers to year-end.

(a) 1981-1987

(b) Estimated by LBL based on fuel consumption

**Self-producers' generation** in 1987 was an estimated 8.0 TWh.

**Electricity consumption per capita** in 1987 (including self-production) was around 1055 kWh.

# ELECTRICITY GENERATION BY POWER SOURCE Mexico

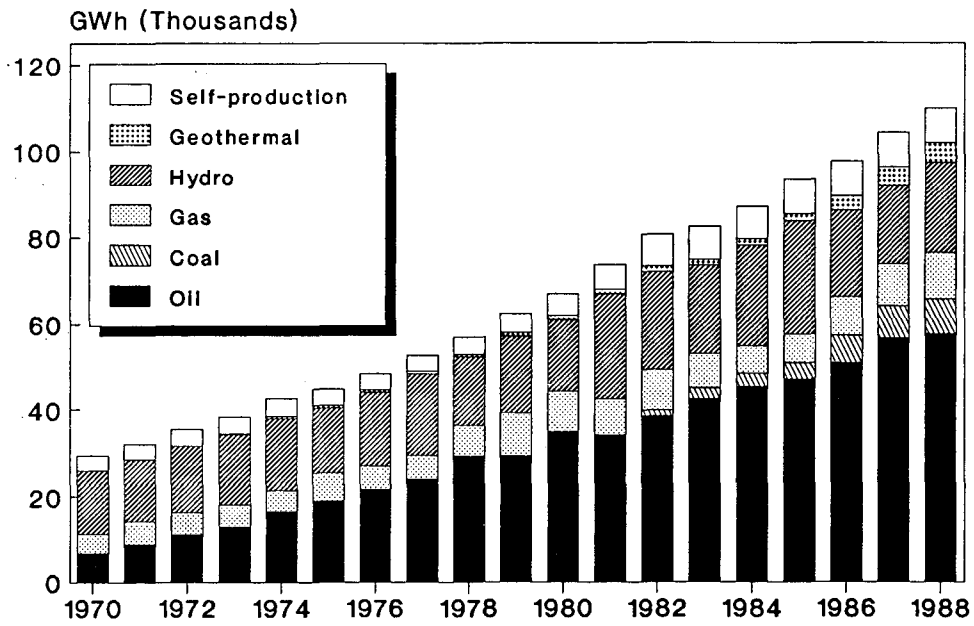


Figure 13-1

### 13.3. Forecast of Electricity Demand

Electricity consumption has continued to grow since 1981 despite the economic stagnation. Only the commercial sector has seen a marked slowing in demand. Growth in consumption in 1988 (5.3%) was less than in 1987 (6.8%), but this was much more than the growth in GDP of around 1.1%.<sup>3</sup>

CFE's forecast from early 1989 estimates that public sales will grow at an average rate of 6.3% per year between 1987 and 1998.<sup>4</sup> It assumed an average rate of growth of GNP of 4.8% per year between 1988 and 1998. In the *Plan Nacional de Desarrollo 1989-1994*,<sup>5</sup> which is the document that outlines the main policies for the federal government, the annual growth rate for electricity demand was projected at 4.5-5.5% for 1989-90, and 6.8-7.5% thereafter.

Given the uncertainties surrounding Mexico's debt situation and the political fate of the government's economic policies, it is difficult to forecast growth in demand with confidence. Many local experts consider the projected growth to be high, and growth in GDP of nearly 5% per year seems quite optimistic in light of the current situation. Despite the new debt accord reached in July 1989, there is much uncertainty whether the plan offers enough relief to let Mexico resume substantial real growth after years of stagnation.<sup>6</sup>

Growth in demand will depend in part on the evolution of electricity prices. Government plans call for the elimination of electricity subsidies, but there is fear that this could have a significant inflationary effect. Given the political challenge coming from the populist movement, raising residential rates could be difficult for the government.

One potential source of considerable growth in demand is air conditioning. In the northern part of the country, the hot climate and relative economic prosperity (due partly to the proximity to the U.S.) have already combined to bring rapid growth in home air conditioning.

### 13.4. Plans for Power Sector Development

CFE's expansion of its electricity generating capacity has in the past tended to proceed at a much faster pace than growth in the economy. In part this is because growth in demand was well above the rate of increase in GDP, but it also reflects the ability of CFE, supported by the utility's union and construction companies, to gain resources from the government.

CFE's *Programa de Obras e Inversiones del Sector Electrico*, released in 1988, projected growth in total installed capacity from 23.4 GW in 1987 to between 34.2 and 36.0 GW in 1995. This increase of about 12 GW in eight years is equivalent in magnitude to the increase that occurred between 1977 and 1988. CFE's schedule for construction of new capacity (as of 1989) shows a further addition of about 5 GW between 1995 and 1998. The total addition includes 3.0 GW of new hydro capacity, 7.2 GW of coal-fired capacity (which includes 5.1 GW of "dual-fuel" capacity), 4.0 GW of oil-fired capacity, and 1.4 GW and 0.5 GW of nuclear and geothermal, respectively. Completion of these plants as scheduled would result in a total installed capacity of 39.7 GW in 1998. Based on CFE's schedule, we estimate that the installed capacity in the year

<sup>3</sup> American Embassy in Mexico, *Economic Trends Report*, May 1989.

<sup>4</sup> CFE, "Desarrollo del Mercado Electrico 1984-1998," 1989.

<sup>5</sup> Poder Ejecutivo Federal, "Plan Nacional de Desarrollo 1989-1994"

<sup>6</sup> "Mexico feels squeeze after years of austerity," *New York Times*, July 27, 1989.

2000 would be 25% hydro, 25% coal-fired, and 33% fuel oil-fired (Table 13-2).

Coal-fired plants using domestic coal are the cheapest alternatives for electricity generation, according to CFE's estimates.<sup>7</sup> The dual-fuel plants, which are designed to give CFE flexibility in case oil prices fall, are likely to use imported coal due to the insufficient quality of domestic coal.

New hydroelectric supplies are attractive on a per kWh basis but are also very capital-intensive. Given the financial situation of CFE, this may make their exploitation difficult.<sup>8</sup>

Table 13-2  
Plan for Mexico Electricity Supply<sup>a</sup>  
1988/89  
(Installed capacity in GW)

	1987	%	1995	%	2000	%
Hydro	7.7	33	9.6	27	11.0	25
Coal	1.2	5	5.8 <sup>b</sup>	16	11.1 <sup>b</sup>	25
Fuel oil	10.3	44	14.0	39	14.6	33
Geothermal	0.7	3	1.1	3	1.5	3
Nuclear	0	0	1.4	4	1.4	3
Other <sup>c</sup>	3.6	15	3.9	11	4.1	9
Total	23.4	100	36.0	100	43.7	100

(a) Based on CFE schedule (1989); values for 2000 were extrapolated by the authors from 1998.

(b) Includes dual-fuel plants that are likely to use coal.

(c) Includes diesel, combined-cycle, gas turbines, cogeneration, and non-conventional sources.

### 13.5. Financial Issues

The future development of Mexico's power sector is constrained by the difficult financial situation of CFE. This situation stems from several factors. One is the huge investment in the power sector that has taken place in the past two decades. The Laguna Verde nuclear power plant has required substantial amounts of capital, much of which was financed by foreign loans. While this took place, electricity prices were maintained by the government at a level insufficient to recover costs. In 1982 the economy entered into a period of recession and stagnation from which it has still not recovered. At the same time, interest rates on foreign loans rose substantially, increasing CFE's debt. High inflation increased the cost of power projects, and CFE's operations

<sup>7</sup> CFE, "Costos y Parametros de Referencia para la Formulación de Proyectos de Inversión en el Sector Electrico", 1988.

<sup>8</sup> G. Fernandez de la Garza, "Retos Tecnológicos en el Sector Energetico," in *Cuadernos sobre Prospectiva Energetica* 115, El Colegio de Mexico, 1988.

required considerable subsidy from the government.

Increase in electricity prices in the 1982-1986 period helped the situation, but prices were frozen in 1987 as part of a "Solidarity Pact" between the government and various economic sectors. This policy has been continued (with a different name) by the present administration. As a result, the real price of electricity has declined, worsening the condition of CFE. CFE's revenues in 1988 covered only 60-65% of operating costs.<sup>9</sup> The problem of raising capital for new development is made more difficult by the severe decline in domestic savings and the increasing scarcity and higher interest rates of foreign financing.<sup>10</sup>

The financial condition of CFE and the difficulty of raising capital have important implications for the development of the power sector. One is the need for CFE to rationalize and improve the efficiency of its operations in order to reduce costs. The situation also strengthens the argument for power projects that have low capital costs and short construction times.

### 13.6. Electricity Supply and End-Use Efficiency

Although in recent years there has been some increase in the thermal efficiency of steam power plants, the efficiency of Mexico's power plants is still low (32.8%) by international standards.

The increase in electricity prices during 1983-86 has helped increase interest in improving the efficiency of electricity use. PRONURE (Programa Nacional de Uso Racional de la Electricidad), a program within CFE designed to promote the efficient use of electricity, has organized annual seminars on energy conservation and promoted various energy-saving measures like cogeneration, better use of air conditioning in the hottest zones of the country, and more efficient use of irrigation pumps. The program has very limited support from CFE, however, and its activities have had only marginal impact.

### 13.7. Environmental Issues

There are environmental problems related to oil-fired plants. Air pollution is a concern for the plants located in the outskirts of Mexico City.<sup>11</sup> Another problem has to do with lack of water for cooling in Mexico's northern region. Currently, water is taken from underground sources, just as drinking water is.

The Laguna Verde nuclear power plant has faced strong opposition from diverse sectors. Safety standards and economic evaluations made by the CFE have been heavily criticized, as has the capacity of the government to design and put in practice credible emergency plans in case of a reactor accident. Efforts to build additional nuclear plants are likely to face considerable opposition.

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<sup>9</sup> "La Comision Federal de Electricidad mantendra el subsidio a las tarifas", *La Jornada*, Mexico, August, 1989.

<sup>10</sup> A. de la Vega Navarro, "Financing Energy Development in Mexico: the External Debt of the Energy Sector," in Proceedings of the 11th Annual Conference of the International Association for Energy Economics, Caracas, Venezuela, June 1989.

<sup>11</sup> CFE has been implementing programs to reduce emissions and concentration of pollutants. Measures have included installation of 120 m. tall chimneys and burners with low NO<sub>x</sub> emissions.

### 13.8. Conclusion

CFE's projection of a 4.8% average annual rate of growth of GNP between 1988 and 1998 seems optimistic in light of the current economic situation. It is thus questionable whether the country will need the growth in installed capacity from 23.4 GW in 1987 to 34-36 GW in 1995 called for in current plans. Financing this level of expansion would be difficult in any case.

Coal-fired plants using domestic coal are the cheapest alternatives for electricity generation, according to CFE's estimates. These plants are also less capital-intensive than hydropower plants and have versatility in sizing. The use of dual-fuel power plants that can be operated with fuel oil or imported coal allows flexibility with respect to fluctuations in international oil prices.

As for nuclear power, it seems unlikely that the second Laguna Verde unit will be completed on schedule in 1994. In general, the result of difficulties in bringing new capacity on line may be greater-than-planned use of oil.

## 14. VENEZUELA

### 14.1. Background

Electricity for public use is supplied by four public and seven private companies (five of these are very small). Nine of these utilities operate on a regional level, while two of them (CADAFE and EDELCA) operate on the national level.

The total installed capacity has grown rapidly from 7.6 GW in 1979 to 18.0 GW in 1988.<sup>1</sup> About 86% of this capacity is incorporated into the National Integrated System (NIS). Most of the growth in the 1980s has come from construction of large hydroelectric projects; installed hydro capacity totalled 11.0 GW by the end of 1988, leaving the NIS with excess hydro energy. The thermal plants use a combination of oil and natural gas. In addition to the public system, there are a number of oil refineries, cement plants, and sugar mills that generate their own power.

Public electricity generation grew at an average annual rate of 7.4% in the 1979-1987 period despite no net increase in real GDP. Generation in 1987 increased 7.5% over 1986, while generation in 1988 grew by around 5.4%. The share of electricity generation coming from hydro has increased from 40% in 1980 to 63% in 1988 (Figure 14-1). Natural gas provided 21% of generation in 1988, and oil provided 16%.

Electricity reaches 85-90% of the population. Electricity consumption per capita (including estimated generation by self-producers) was around 2395 kWh in 1988 (the highest in Latin America). Industry accounted for 58% of total consumption in 1987, and its rate of growth was only slightly lower than that of the residential and commercial sectors in the 1980-1987 period. The residential sector accounted for 21% of total demand in 1987, while the commercial sector claimed 24%.

### 14.2. Resources for Electricity Generation

Venezuela is well endowed with energy resources. **Hydropower** reserves total 13.7 GW. They are mainly located on the Caroni River in the Eastern region. **Oil** reserves are 56 billion barrels, with a reserve-production ratio of 86 years. **Natural gas** reserves are also considerable, amounting to 18 billion BOE. **Coal** reserves, which are located mainly in the West, are estimated at 2.4 billion BOE.

### 14.3. Forecast of Electricity Demand

A government planning committee with representation of all major utilities (OPSIS) released projections in May 1988 that envision a more than 3-fold increase in electricity demand (excluding self-producers) between 1987 and 2006. Demand was forecast to grow from 39.8 GWh in 1987 to 78.7 GWh in 1995 and to 129.8 GWh in 2006. Average growth in demand is projected to slow from 8.9% per year in the 1987-1995 period to 4.7% per year in the 1995-2006 period. The average growth for the 1987-2000 period is 6.9% per year.

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<sup>1</sup> 1988 data are from: C.V.G.-EDELCA, "The Venezuelan Electrical Sector," 11th Annual Conference of the International Association of Energy Economists, Caracas, June 26-28, 1989.



**Table 14-1**  
**Power Sector Statistics for Venezuela**  
 (Not including self-producers)

	1987	1987 (%)	AAGR 1970-79	AAGR 1979-87
<b>Installed Capacity (GW)</b>				
Hydro	9.9	56	12.7%	17.7%
Thermal	7.7	44	12.2%	5.7%
Total	17.6	100	12.3%	11.1%
<b>Generation (TWh)</b>				
Hydro	30.8	61	14.8%	10.2%
Thermal	19.4	39	10.3%	3.9%
Oil-fired <sup>a</sup>	7.4	15	26.8%	1.8%
Gas-fired <sup>a</sup>	11.9	24	4.7%	5.5%
Total	50.2	100	12.3%	7.4%
<b>Consumption (TWh)</b>				
Industry	21.2	53	12.4%	7.2%
Residential	8.5	21	12.9%	6.4%
Commercial	9.8	25	9.7%	7.5%
Total	39.8	100	11.8%	7.2%

Sources: Ministry of Mines and Energy, CAVEINEL (Venezuela Electric Industry Association)

Installed capacity refers to year-end.

(a) Estimated by LBL based on fuel consumption; oil-fired generation has declined since 1983.

**Self-producers' generation** in 1987 was an estimated 4.0 TWh.

**Electricity consumption per capita** in 1987 (including self-production) was around 2395 kWh.

# ELECTRICITY GENERATION BY POWER SOURCE Venezuela

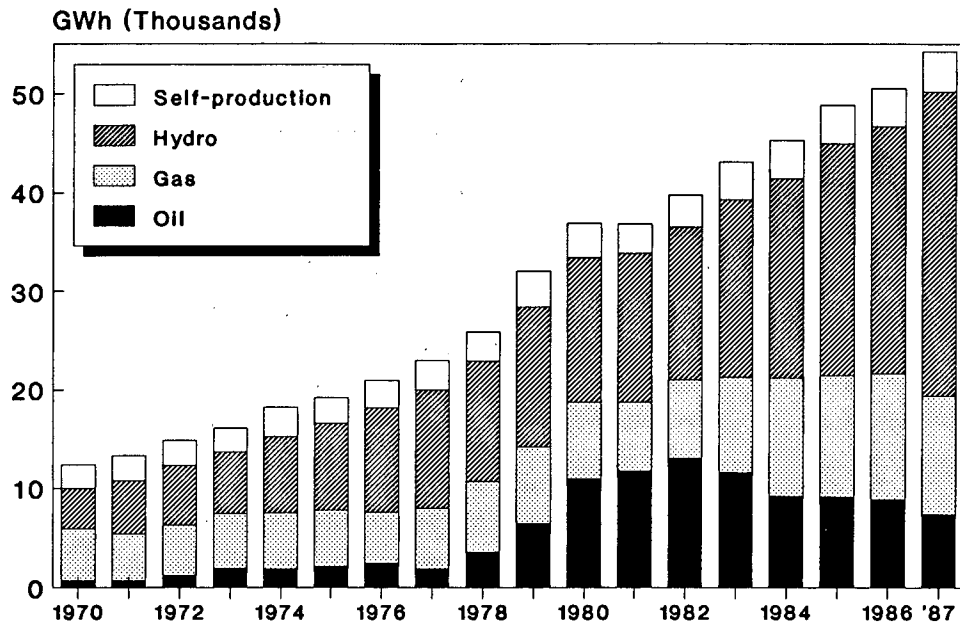


Figure 14-1

The forecast was based on a sectoral model that makes separate projections for the major classes of consumers. As shown in the table below, industrial demand is projected to grow fastest, mostly due to an assumed large increase in aluminum production. The projected industrial share of total electricity demand grows from 53% in 1987 to 59% in 2006, while the residential share remains around 20%.

Table 14-2  
Government Projections of Venezuela Electricity Demand<sup>a</sup>  
May 1988  
(TWh)

	1987		1995		2006	
Industrial	21.2	53%	48.3	61%	76.6	59%
Residential	8.5	21%	14.9	19%	26.3	20%
Commercial	5.0	13%	8.9	11%	18.0	14%
Others	5.1	13%	6.6	8%	8.9	7%
Total	39.8	100%	78.7	100%	129.8	100%

(a) Excluding self-producers.

The official demand forecast envisions a four-fold increase in aluminum production between 1987 and 2000. Consumption of electricity is to grow from 7.8 TWh to 30 TWh, which is one-third of projected total electricity consumption. This scenario assumes materialization of all the new aluminum projects under consideration, which is far from assured. Combined with general economic difficulties, this means that the growth in demand may be less than projected.

#### 14.4. Plans for Power Sector Development

The main source of new electricity generation in Venezuela during the next 10 years is expected to be large hydroelectric developments on the lower part of the Caroni River. Three projects are to be developed with a total installed capacity of about 7500 MW. The first of these (Macagua II), with an installed capacity of 2570 MW, was scheduled (in 1988) to be partly operational in 1993 and completed in 1997. The other two are scheduled to begin partial operation in 1995 and 1997. In addition to the hydro development, CADAPE has proposed to add 400 MW of thermal capacity in 1995 and to commission a 2400 MW thermal plant in 1999, and ELECAR (which generates for Caracas) is considering the construction of a 600 MW gas-fired combined cycle plant to be commissioned in 1993. There is some question as to whether these thermal units will be needed, however.

Since there is currently considerable reserve capacity, there is little need for expansion in the first half of the 1990s. The official plan of November 1987 called for growth in total capacity from 17.7 GW in 1987 to 18.9 GW in 1996.<sup>2</sup> Since the development of the plan in 1987, higher

<sup>1</sup> "Programa de Expansion de Generacion y Transmision del Sistema Electrico Nacional (1987-1996)," Grupo de Trabajo de Planificacion, 1987.

growth in demand has been projected. EDELCA, the company responsible for hydroelectric generation on the Caroni River, recently stated that there is a need for 28 GW by the year 2000,<sup>3</sup> though it is not clear where such high growth in demand will come from.

#### **14.5. Financial Issues**

The plan of November 1987 estimated requirements of 57 billion Bs. (US\$ 3.9 billion) between 1988 and 1996 to accomplish the stated goals in electricity generation. To increase revenues, the government recognizes the need to raise electricity prices, which are heavily subsidized for all users, but public opposition has caused a slowdown in the planned rate of increase.

A problem in Venezuela is the lack of coordination between the utilities regarding investment needs. Some of the stated investment requirements include expenditures for expansions which may not take place. The Venezuelan Investment Fund (FIV), which provides financing to the power sector, has tried to use its influence to promote the coordination of investment planning between companies, but with little success.

#### **14.6. Electricity Supply and End-Use Efficiency**

Distribution losses are very high (24%). Much of this is due to theft and fraud. Thermal generation efficiency is very low (26%) when compared with international standards. This may be partly due to lack of incentives for improving plant efficiency, as fuel prices are low.

Interest in improving the efficiency of electricity use has grown in recent years. In 1985 a National Electricity Conservation Program was created. Among other measures, it contemplates pilot programs directed to more efficient use of energy in industries with high energy intensity (such as aluminium, steel, sugar, paper), and the establishment of systems of energy auditing.

#### **14.7. Environmental Issues**

The planned hydro developments on the Lower Caroni River do not pose major environmental problems.

#### **14.8. Conclusion**

There is rather considerable disagreement regarding future growth in electricity demand, and thus, the need for new capacity. The official forecast seems rather optimistic with respect to industrial production. Increase in electricity prices, which is necessary to finance the called-for expansion, could also result in improvement in end-use efficiency, for which the potential is considerable.

On the supply side, there is a lack of coordination of expansion plans of the various electricity companies. It seems most likely that some of the proposed thermal projects will not be needed, assuming the hydroelectric projects on the Lower Caroni River are reasonably on schedule. After completion of the three projects on the Lower Caroni River (probably in 2000-2002), there is a possibility of additional development on the Upper Caroni. Projects currently under study total 9100 MW of installed capacity. Feasibility studies of these projects are yet to

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<sup>3</sup> C.V.G.-EDELCA, op cit.

be done, and there is some question as to whether they will be cheaper than electricity generation based on associated natural gas, substantial amounts of which are likely to be available for power generation by the next century.

## 15. SUMMARY OF GENERATION EXPANSION PLANS

In this chapter we present in summary fashion the plans for expansion of electricity generating capacity through the year 2000 for the 13 countries considered in this report. In some cases (as noted), the numbers come directly from official plans, while in others they were estimated by the authors based on shorter-term plans and other information. We describe the planned growth in terms of total installed capacity and the capacity by power source, and contrast the planned evolution with what occurred in the recent past.

As discussed in the Introduction, the plans of developing countries for the power sector are often somewhat optimistic. But this feature varies among countries. For some countries, the plans are probably fairly realistic and have a good chance to be achieved; for others, the reality may fall far short of the plans. Financial and institutional difficulties will play an important role, and internal and external events that were not foreseen at the time when current plans were formulated will also shape the future course of power system expansion. We refer the reader to the country chapters for our evaluation of the countries' plans. In general, the plans will be most realizable in those countries where the financial situation of the power sector is relatively sound. This category applies to the more industrialized countries of Asia (South Korea, Taiwan, Malaysia), and to those where economic growth has been strong (Thailand). Even in these countries, however, meeting the goals for the power sector will not be an easy task.

### 15.1. Total Installed Capacity

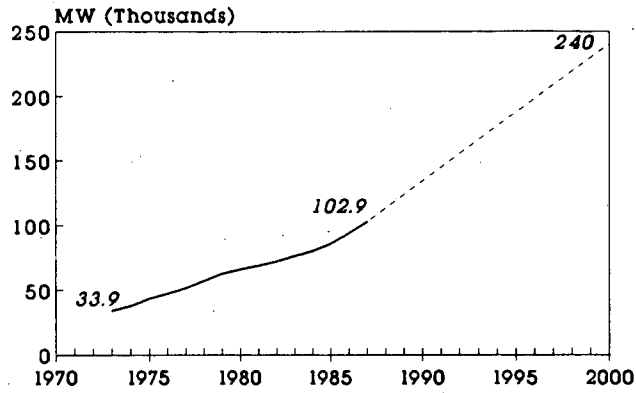
The historic growth (1970-1987) in installed electric power capacity and the growth planned for the year 2000 are shown for each of the 13 countries in Figures 15-1 through 15-4. (The values do not include self-producers, except for China, where the larger self-producers are included in the official statistics.) The historic rates of average annual growth in 1979-1987 and the implicit future rates of growth between 1987 and 2000 are shown in Table 15-1.

The implicit future rates of growth vary considerably among the 13 countries from a high of 9.8% per year in Pakistan to a low of 2.8% per year in Argentina and Venezuela. It is noteworthy that the planned future growth rate is markedly lower than that recorded in the 1979-1987 period in many of the countries: Indonesia, Malaysia, South Korea, Taiwan, Thailand, Argentina, and Venezuela. In most of the rest the planned growth is about the same as that achieved in the 1979-1987 period. Only in Pakistan and, to a lesser extent, Brazil is the planned growth higher than the historic.

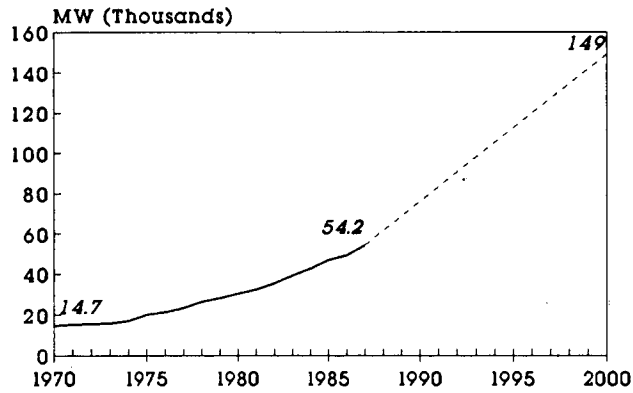
FIGURE 15-1

# Electric Generating Capacity Historic Totals and Planned Growth

## CHINA



## INDIA



## INDONESIA

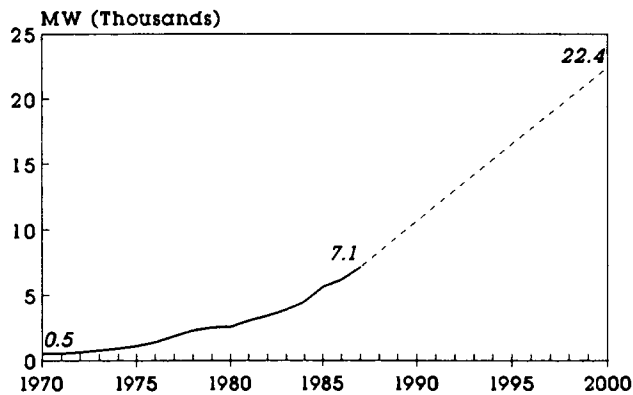
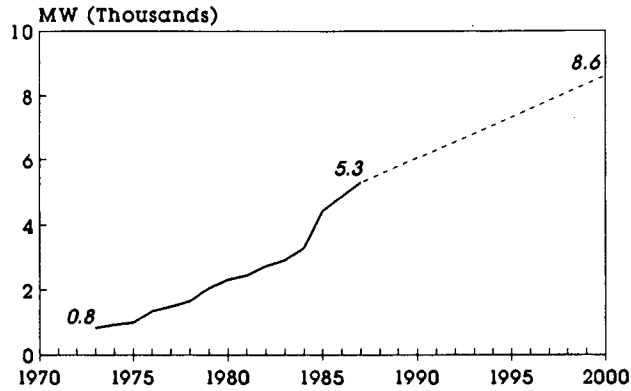


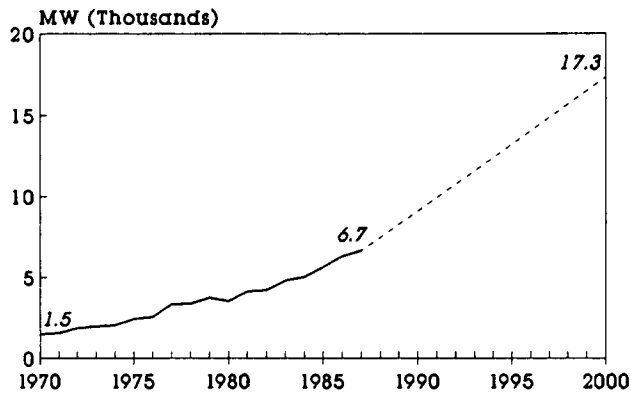
FIGURE 15-2

# Electric Generating Capacity Historic Totals and Planned Growth

## MALAYSIA



## PAKISTAN



## PHILIPPINES

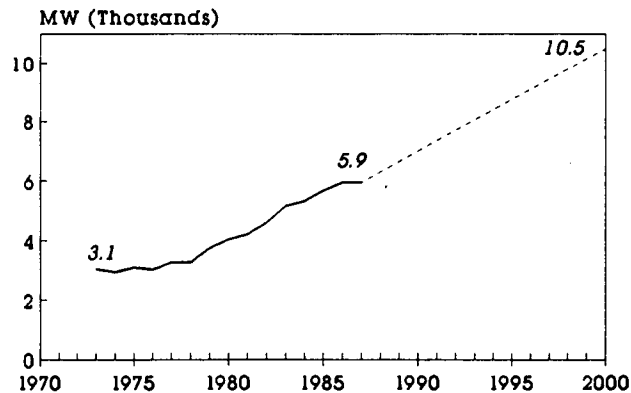
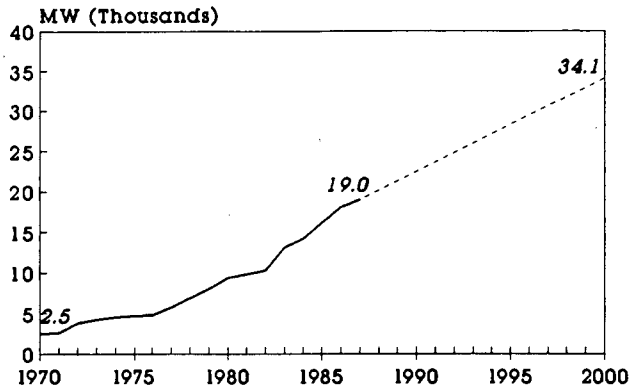




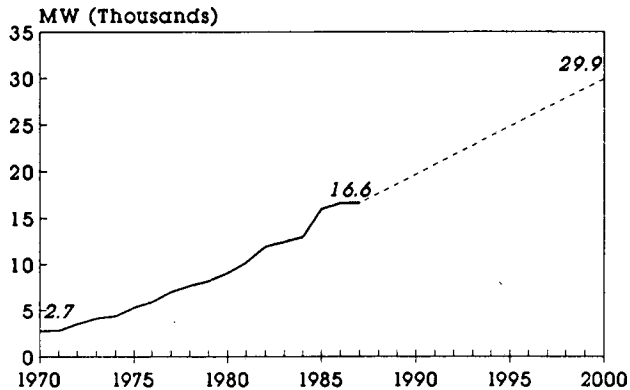
FIGURE 15-3

# Electric Generating Capacity Historic Totals and Planned Growth

## SOUTH KOREA



## TAIWAN



## THAILAND

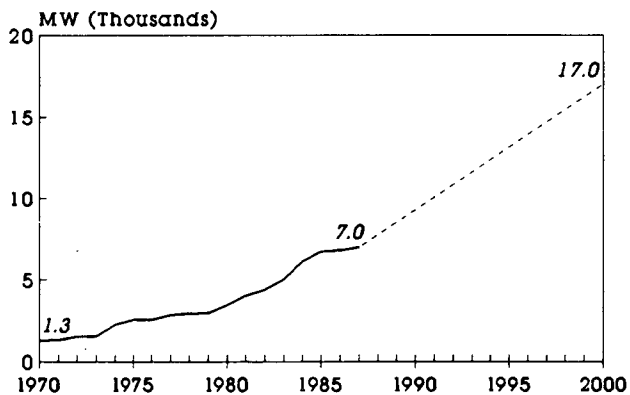
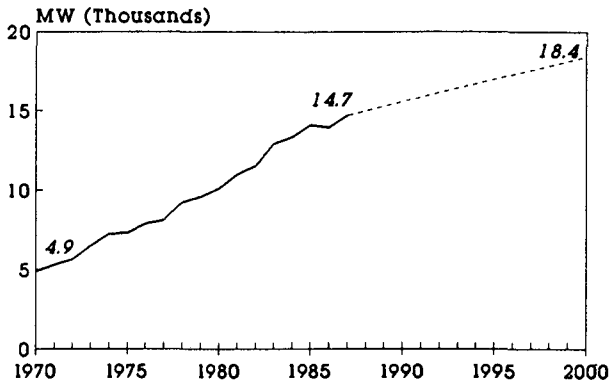


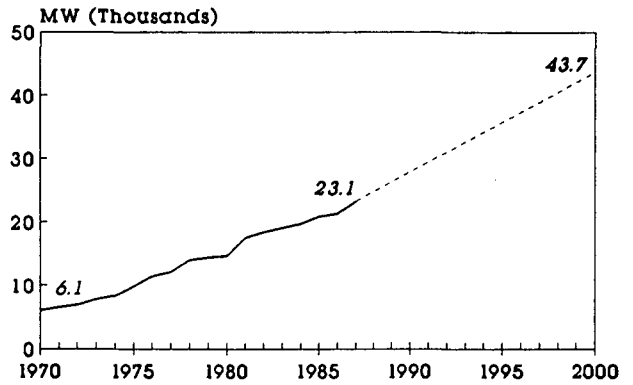
FIGURE 15-4

# Electric Generating Capacity Historic Totals and Planned Growth

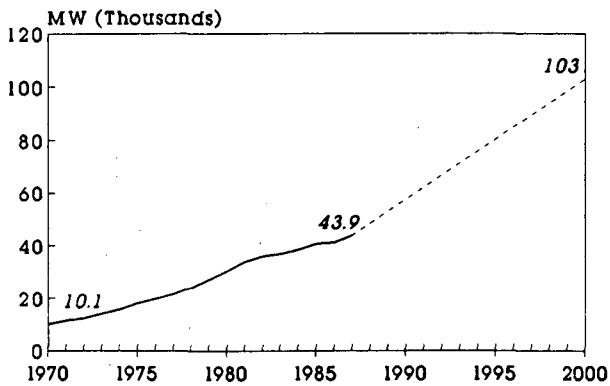
## ARGENTINA



## MEXICO



## BRAZIL



## VENEZUELA

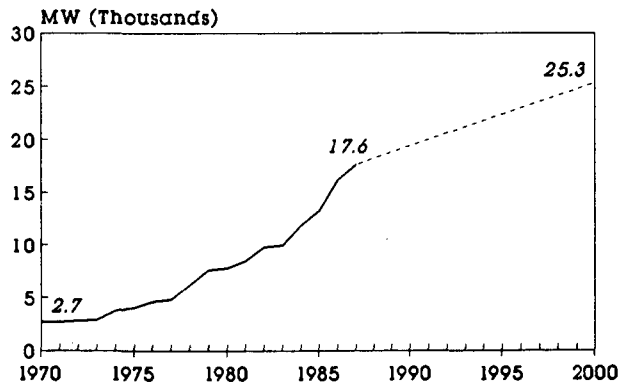


Table 15-1  
**Average Growth Rates in  
 Installed Electric Power Capacity**  
 Not including self-producers  
 (percent per year)

	Historic 1979-1987	Planned/Estimated 1987-2000
China	6.3	7.0
India	8.3	8.8
Indonesia	13.8	7.7
Malaysia	12.6	5.0
Pakistan	7.5	9.8
Philippines	4.5	4.7
South Korea	11.4	4.6
Taiwan	9.2	4.6
Thailand	11.3	7.3
Argentina	6.6 <sup>a</sup>	2.8
Brazil	6.1	6.5
Mexico	6.2	4.9
Venezuela	11.1	2.7
<b>TOTAL</b>	<b>7.5</b>	<b>6.3</b>

(a) 1979-1985

The causes of lower future growth vary among the countries where this applies, as they are in different phases of economic development and have had different experiences in the past. Some countries placed strong emphasis on developing the power sector in the 1980s: Indonesia, Malaysia, South Korea, Taiwan, Thailand, and Venezuela. Except for Indonesia and Venezuela, all of the above countries experienced strong economic growth through most of the 1980s. Indonesia's power sector began from a relatively underdeveloped situation in 1979, and both Indonesia and Venezuela directed part of their windfall oil revenues into the power sector (as did Mexico). In most of these six countries (especially Venezuela), a comfortable reserve margin was built up (though this margin is eroding in Thailand and, to a lesser extent, in South Korea and Taiwan). This buildup allows for slower expansion in the future.

One cause of the lower planned growth in the future is that several countries expect slower economic growth. This explanation applies for Malaysia, South Korea, Taiwan, and Argentina. In the case of the Asian countries, the expected slower economic growth reflects their relatively advanced stage of development. For Argentina, the depth of the current economic crisis will make growth difficult.

Difficulties in expanding power capacity also play a role. In some cases, the historic growth was so very rapid that such a pace of increase would be very difficult to sustain. This difficulty involves problems with siting of power plants, construction logistics, as well as the

institutional ability of electric utilities to manage system expansion while they also face greater demands for maintenance due to past expansion. Perhaps most important, financing new capacity is also more difficult now for many countries (especially in Latin America) than it was in the early 1980s. An additional factor is that some countries have developed their most favorable hydro sites, and future expansion in this area will therefore be slower.

In contrast to the slower growth planned by many countries, the two countries with the largest power systems, China and India, plan to expand their systems at a faster rate than they recorded in the 1979-1987 period, which was 6.3% per year for China and 8.3% per year for India. This rate of expansion may be difficult to achieve, however, due to the logistical difficulties referred to above, as well as to problems with coal transport (in China) and coal quality (in India).

The combined installed electric power capacity for all 13 countries planned or estimated for the year 2000 amounts to 720 GW: 529 GW in the nine Asian countries and 191 GW in the four Latin American countries. The comparable value for 1987 was 324 GW: 225 GW in the nine Asian countries and 99 GW in the four Latin American countries (Figure 15-5). (The 13 countries accounted for about 70% of total developing country installed power capacity in 1987.) Thus, the implicit average growth rate for the 13 countries is 6.3% per year. This is below the rate of 7.5% per year recorded in the 1979-1987 period. (For all developing countries as a group, installed capacity increased at an average rate of 7.1% per year in 1980-1986.)<sup>1</sup> If the planned growth rates for China and India, which together account for half of the total installed capacity for the 13 countries, were not as high as they are (7.0% and 8.8%, respectively), the 13-country average planned growth would be lower still. Given the financial, institutional, and environmental difficulties facing the power sector's expansion in many countries, it is unlikely that the growth rate of 6.3% per year will be achieved.

## 15.2. Installed Capacity by Fuel Type

The installed electric power capacity planned or estimated for the year 2000 is shown by fuel type in Tables 15-2 (in thousand MW) and 15-3 (in percent). The importance of coal is striking. The plans for China and India show coal-fired capacity accounting for around 60% of total capacity in 2000, about the same as in 1987. The share of coal is to be substantial in Indonesia (49%), South Korea (35%), Taiwan (40%), and Thailand (41%), as well. Natural gas is to be the dominant fuel in Malaysia, and will also be significant in Thailand. Oil is planned to become relatively insignificant except in Mexico, and to a lesser extent, in Pakistan and the Philippines.

Hydropower will be the dominant power source in Brazil (91%), Venezuela (70%), and Argentina (49%), and is to account for between 20% and 40% of total capacity in a number of the other countries. Nuclear power will be significant only in South Korea and Taiwan, though it will play a modest role in China, India, Argentina, Brazil, and Mexico, and a very small role in Pakistan. Geothermal energy will be an important source in the Philippines, and will play a modest role in Indonesia and Mexico.

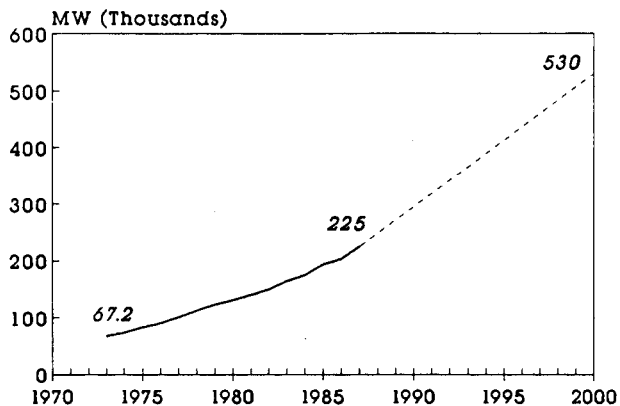
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<sup>1</sup> S. Meyers and C. Campbell, "Regional Electricity Supply and Consumption in Developing Countries, 1980-1986," Lawrence Berkeley Laboratory Report LBL-26946, March 1989.

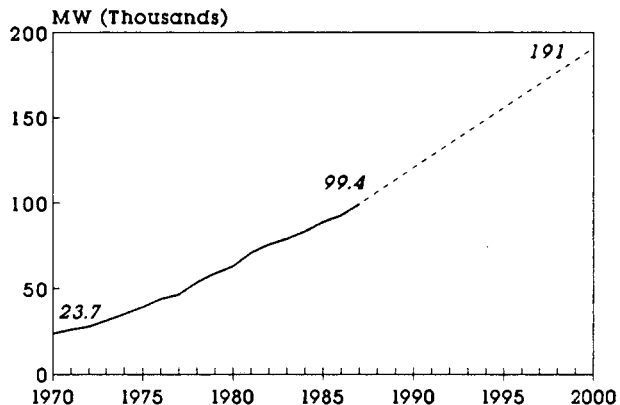
FIGURE 15-5

# Electric Generating Capacity Historic Totals and Planned Growth

## 9 ASIAN COUNTRIES



## 4 LATIN AMERICAN COUNTRIES



## 13 DEVELOPING COUNTRIES

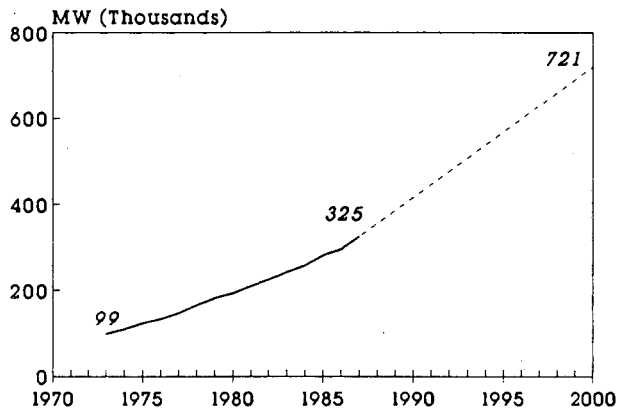


Table 15-2  
**Planned or Estimated Installed Electric Power Capacity  
in the Year 2000**  
Not including self-producers  
(thousand Megawatts)

	Hydro	Coal-fired	Gas-fired	Oil-fired	Nuclear	Geothermal	Total
China <sup>a</sup> (P)	72.0	147.0	0.0	16.0	5.0	0.0	240.0
India (E)	41.4	86.8	15.3	2.0	3.0	0.0	148.5
Indonesia (P)	4.0	11.0	2.9	4.0	0.0	0.4	22.4
Malaysia (E)	1.8	0.6	5.4	0.8	0.0	0.0	8.6
Pakistan (P)	6.4	2.4	3.2	4.9	0.1	0.0	17.1
Philippines (E)	2.5	2.1	0.0	3.3	0.0	2.6	10.5
South Korea (P)	3.6	12.5	3.7	3.6	12.3	0.0	35.7
Taiwan (P)	4.5	11.9	2.7	3.6	7.1	0.0	29.9
Thailand (P)	3.6	7.2	4.9	1.7	0.0	0.0	17.4
Argentina (E)	9.1	0.2	6.5	1.2	1.6	0.0	18.4
Brazil (P)	93.3	3.0	0.0	3.6	3.1	0.0	103.0
Mexico (P/E)	11.0	11.1	1.1	17.6	1.4	1.5	43.7
Venezuela (E)	17.7	0.0	4.8	2.8	0.0	0.0	25.3
<b>TOTAL</b>	<b>270.9</b>	<b>295.8</b>	<b>50.5</b>	<b>65.1</b>	<b>33.6</b>	<b>4.5</b>	<b>720.4</b>

Source: Country plans (see country chapters) and authors' estimates

(P) = Official plan

(E) = Estimated by authors based on various information (see notes below)

(a) Includes some self-producers

Table 15-3  
**Planned or Estimated Installed Electric Power Capacity  
in the Year 2000**  
Not including self-producers  
(percent of country total)

	Hydro	Coal-fired	Gas-fired	Oil-fired	Nuclear	Geothermal	Total
China <sup>a</sup> (P)	30	61	0	7	2	0	100
India (E)	28	58	10	1	2	0	100
Indonesia (P)	18	49	13	18	0	2	100
Malaysia (E)	21	7	63	9	0	0	100
Pakistan (P)	37	14	19	29	1	0	100
Philippines (E)	24	20	0	31	0	24	100
South Korea (P)	10	35	10	10	34	0	100
Taiwan (P)	15	40	9	12	24	0	100
Thailand (P)	20	41	29	10	0	0	100
Argentina (E)	49	1	35	7	9	0	100
Brazil (P)	91	3	0	3	3	0	100
Mexico (P/E)	25	25	3	40	3	3	100
Venezuela (E)	70	0	19	11	0	0	100
<b>TOTAL</b>	<b>38</b>	<b>41</b>	<b>7</b>	<b>9</b>	<b>5</b>	<b>1</b>	<b>100</b>

Source: Country plans (see country chapters) and authors' estimates

(P) = Official plan

(E) = Estimated by authors based on various information (see notes below)

(a) Includes some self-producers

See notes on following page.

## NOTES TO TABLES 15-2 AND 15-3

*China.* We assumed that 90% of thermal capacity will be coal-fired (same as in 1987).

*India.* Values were estimated by authors by adding estimated additions in the FY 1995-99 period to the 1995 "target" (see Table in India Chapter). In estimating additions in FY 1995-99, we assumed that the total additions would be equal to the amount given in the "National Power Plan 1985-2000" as required in that period to meet a 10% LOLP. We made this assumption because the additions proposed by the Power Ministry in the FY 1990-94 period are roughly equal to the amount given in the "National Power Plan 1985-2000" as required in that period to meet a 10% LOLP. We allocated the total capacity among fuel types by assuming that the shares found in the proposal of the Power Ministry for the FY 1990-94 period would also apply in the FY 1995-99 period. We estimated the division of "Thermal" capacity among fuels by: (1) estimating the 1988 values based on fuel consumption; (2) using the Power Ministry's proposal for 6000-8000 MW of natural gas capacity in the 1990-94 period (25% of total thermal additions); (3) assuming that 15% of estimated thermal additions in FY 1995-99 would be gas-based. We also assumed retirement of 10% of the 1988 installed coal and oil capacity by 2000, and minimal addition of oil-based capacity.

*Indonesia.* We placed gas turbines under "Oil-fired." "Other" refers to geothermal.

*Malaysia.* Peninsular Malaysia only (about 90% of country total)

*Pakistan.* Values reflect tentative plans for 1998, but are probably ambitious even for 2000. We allocated planned "Oil/gas" capacity 50/50 between "Gas" and "Oil," and place "Gas turbines" under "Oil." We assumed retirement of 0.1 GW each of Gas-fired and Oil-fired capacity.

*Philippines.* Values reflect authors' estimate based on various sources.

*South Korea.* Values refer to 2001. Hydro includes 1.6 GW of pumped storage. Gas is LNG.

*Taiwan.* Hydro includes 2.6 GW of pumped storage. Gas is LNG.

*Thailand.*

*Argentina.* Values include National Interconnected System only (which accounted for about 90% of total national capacity in 1987). Values were estimated assuming rehabilitation of existing thermal capacity, completion of hydro and nuclear projects under construction, and some addition of new thermal capacity (gas-fired).

*Brazil.* We placed "Other" under "Oil."

*Mexico.* Values were estimated by authors based on scheduled additions in the 1988-98 period. We assumed completion as scheduled and extrapolated to the year 2000. We placed all planned "dual-fuel" capacity under "Coal," and divided "Other" between "Oil" and "Gas" at a 75/25 ratio. "Other" refers to geothermal.

*Venezuela.* Values were estimated by authors based on following assumptions: (1) completion by end-2000 of La Vueltoza, La Colorada, Macagua II, Caruachi, and half of Tocoma; (2) retirement and rehabilitation as given in 1987 power sector plan; (3) 600 MW new gas-fired capacity. We estimated other oil- and gas-fired capacity assuming a 60/40 split of "Thermal" (based on generation in 1988).



Compared to 1987, the role of hydropower will decrease in India, Indonesia, Malaysia, Pakistan, the Philippines, South Korea, Thailand, and Mexico (Figures 15-6 through 15-9). (The data upon which the Figures are based are given in Table 15-4.) The only country where it will increase significantly is Venezuela. As indicated above, coal and, to a lesser extent, natural gas will see the greatest increase in importance. The share of total capacity that is coal-fired is to increase substantially in Indonesia, Malaysia, Pakistan, the Philippines, South Korea, Taiwan, Thailand, and Mexico. The role of natural gas will become more important in India, Indonesia, Malaysia, Taiwan (LNG), and Argentina.

The evolution of power sources for the **four Latin American countries** as a group shows some increase in the share of hydropower due to Venezuela (Figure 15-10). There is some growth in coal's share, though it remains below 10% of total capacity for the four countries. The shares of natural gas and oil both decline somewhat. For the **nine Asian countries** as a group, the share of hydropower remains the same, while coal and natural gas capacity show increases.

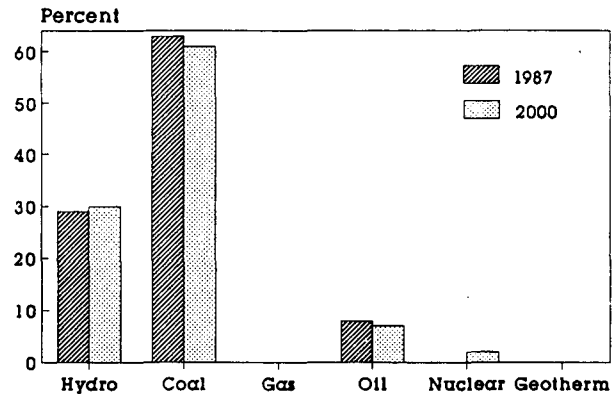
The evolution of power sources for the **13 countries** as a group shows an increase in the share of coal-fired power plants from 35% of total installed capacity in 1987 to 41% in 2000. This is the case despite no increase in the coal-fired share in the two largest coal-using countries, China and India. The share of hydropower declines slightly from 39% to 38%. The share of natural gas increases only from 6% to 7%, as growth in some countries is partly balanced by decline in others. The oil-fired share declines considerably from 16% to 9%, while the nuclear share grows from 4% to 5%.

The shares of electricity generation and the corresponding amounts of fuel consumption are and will be somewhat different from the shares of installed capacity. The extent of this phenomenon varies among countries. The amount of installed hydro capacity that is actually used varies seasonally and annually depending on rainfall and reservoir storage capacity and the role of the hydro plants in the power system. Obviously, power plants that are operated as base load facilities account for a greater share of total generation than those used to meet peak loads. This means that electricity generation from coal-fired, nuclear, and most natural gas-fired power plants will in general be more significant than indicated by their respective shares of installed capacity.

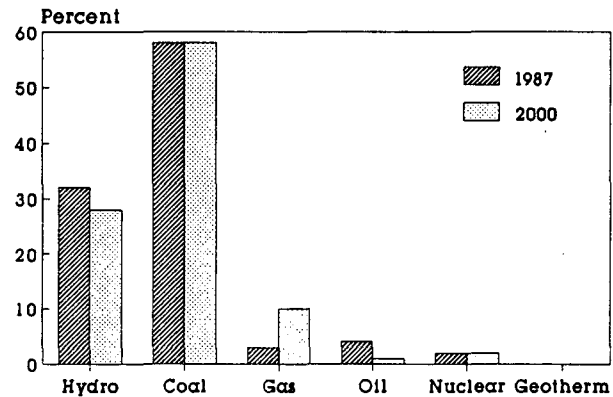
FIGURE 15-6

# Electric Generating Capacity Current and Planned, by Fuel Type

## CHINA



## INDIA



## INDONESIA

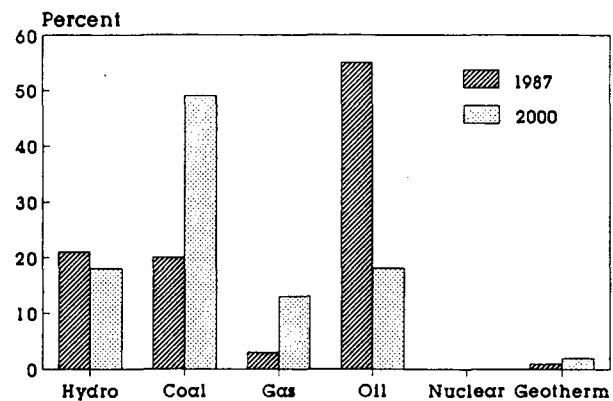
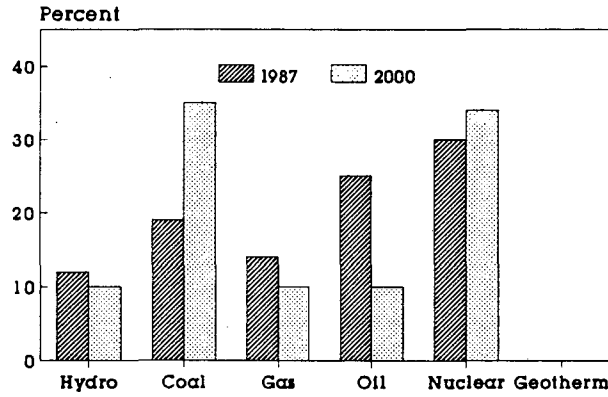


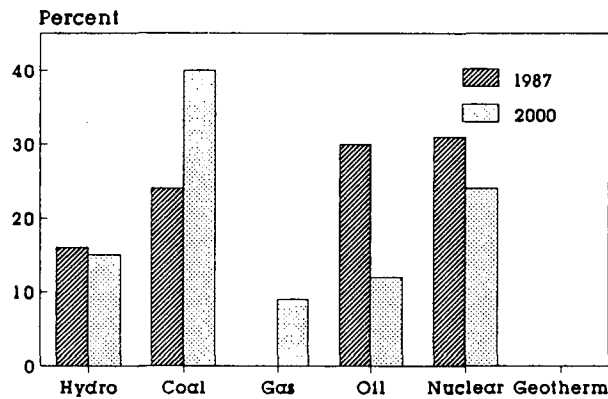
FIGURE 15-7

# Electric Generating Capacity Current and Planned, by Fuel Type

## SOUTH KOREA



## TAIWAN



## THAILAND

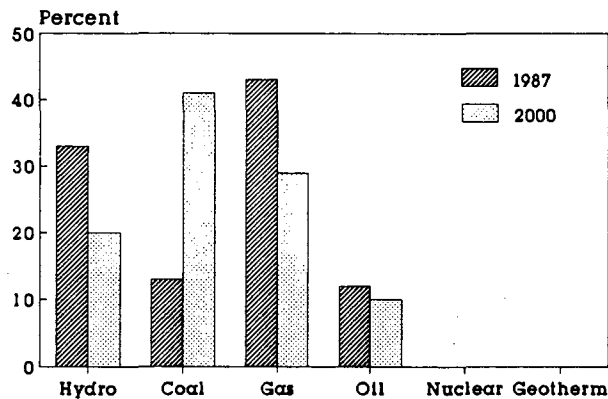
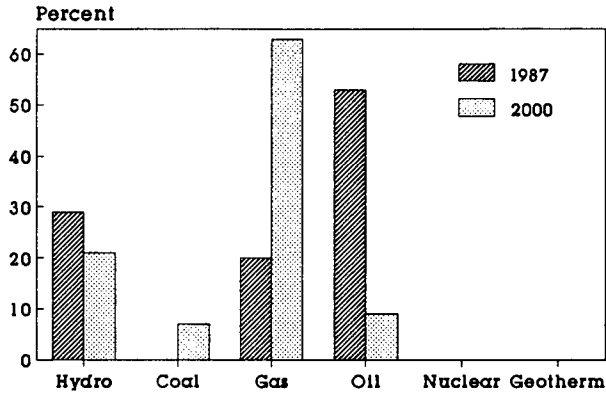


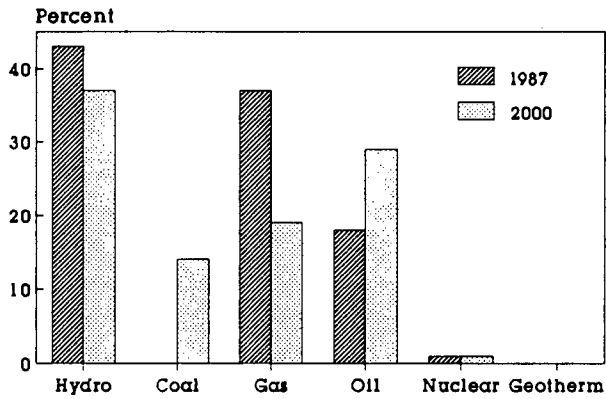
FIGURE 15-8

# Electric Generating Capacity Current and Planned, by Fuel Type

## MALAYSIA



## PAKISTAN



## PHILIPPINES

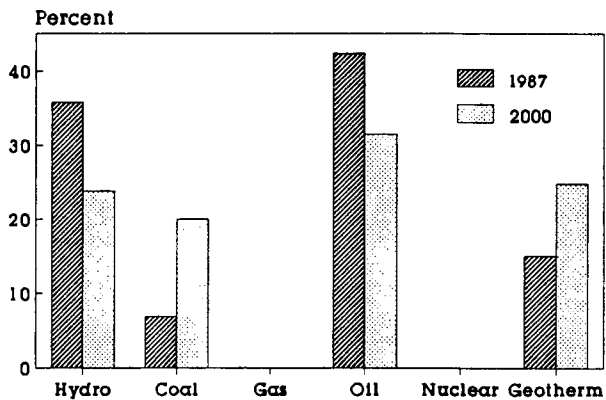
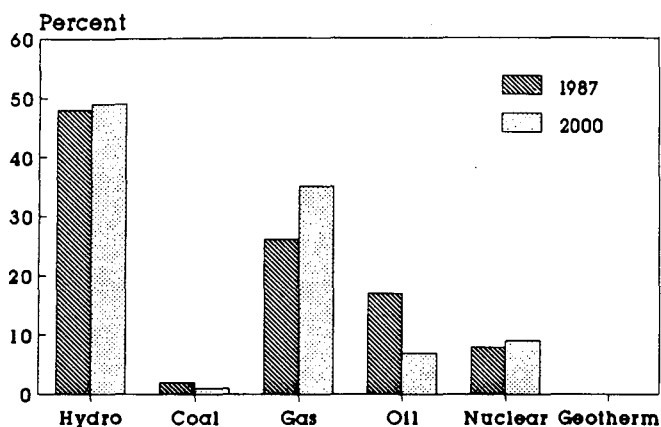


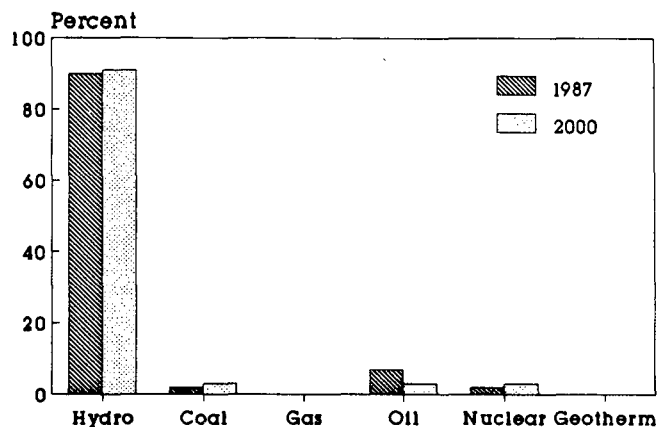
FIGURE 15-9

# Electric Generating Capacity Current and Planned, by Fuel Type

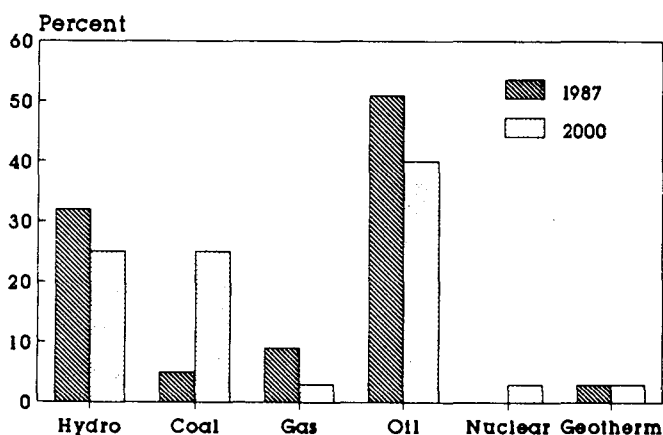
## ARGENTINA



## BRAZIL



## MEXICO



## VENEZUELA

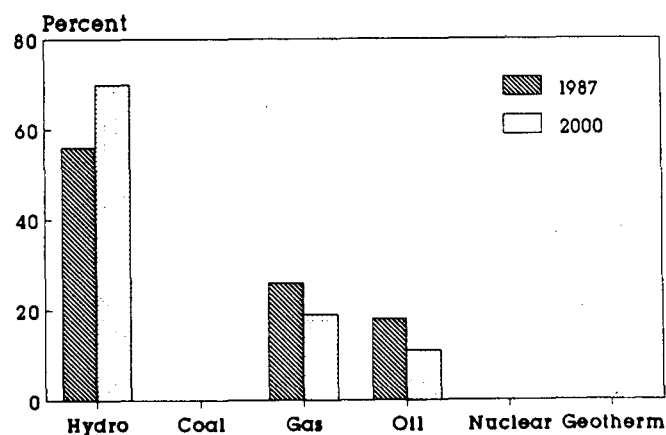
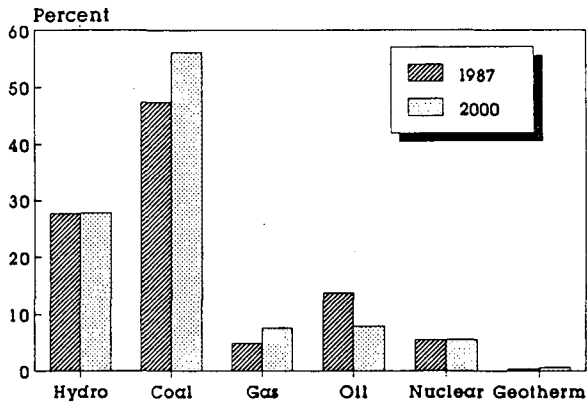


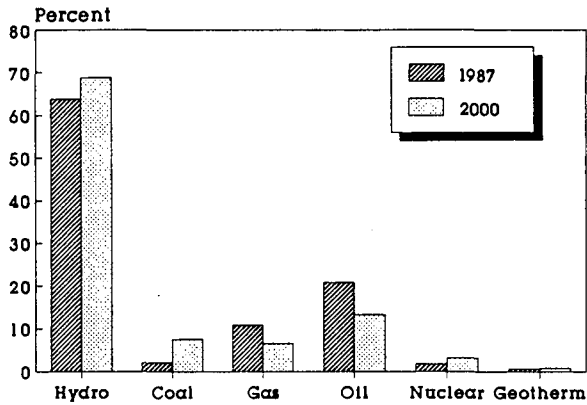
FIGURE 15-10

# Electric Generating Capacity Current and Planned, by Fuel Type

## 9 ASIAN COUNTRIES



## 4 LATIN AMERICAN COUNTRIES



## 13 DEVELOPING COUNTRIES

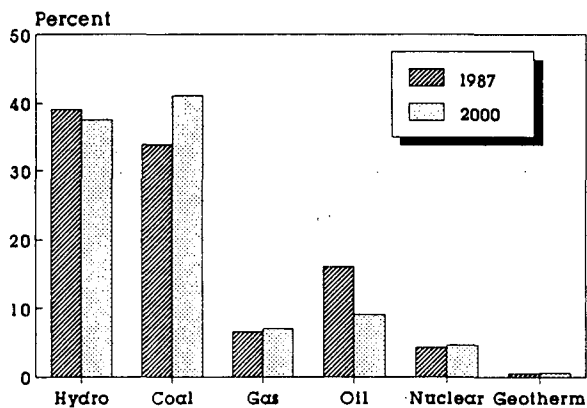


Table 15-4  
**Actual and Planned Installed Electric Power Capacity**  
 Not including self-producers  
 (percent of country total)

	Year	Hydro	Coal-fired	Gas-fired	Oil-fired	Nuclear	Geothermal	Total
China <sup>a</sup>	1987	29	63	0	8	0	0	100
	2000	30	61	0	7	2	0	100
India	1987 <sup>b</sup>	32	58	3	4	2	0	100
	2000	28	58	10	1	2	0	100
Indonesia	1987 <sup>b</sup>	21	20	3	55	0	1	100
	2000	18	49	13	18	0	2	100
Malaysia	1987	29	0	20	53	0	0	100
	2000	21	7	63	9	0	0	100
Pakistan	1987 <sup>c</sup>	43	0	37	18	1	0	100
	2000	37	14	19	29	1	0	100
Philippines	1987	37	7	0	41	0	15	100
	2000	24	20	0	31	0	24	100
South Korea	1987	12	19	14	25	30	0	100
	2000	10	35	10	10	34	0	100
Taiwan	1987	16	24	0	30	31	0	100
	2000	15	40	9	12	24	0	100
Thailand	1987	33	13	43	12	0	0	100
	2000	20	41	29	10	0	0	100
Argentina	1987 <sup>c</sup>	48	2	26	17	8	0	100
	2000	49	1	35	7	9	0	100
Brazil	1987	90	2	0	7	2	0	100
	2000	91	3	0	3	3	0	100
Mexico	1987 <sup>c</sup>	32	5	9	51	0	3	100
	2000	25	25	3	40	3	3	100
Venezuela	1987 <sup>c</sup>	56	0	26	18	0	0	100
	2000	70	0	19	11	0	0	100
TOTAL	1987	39	35	6	16	4	1	100
	2000	38	41	7	9	5	1	100

Sources: 1987 -- Lawrence Berkeley Laboratory, based on national sources;  
 2000 -- Official plans and authors' estimates based on plans

(a) Includes some self-producers

(b) The split of "Thermal" among coal, gas, and oil was estimated by the authors based on fuel consumption.

(c) The split of "Thermal" among gas and oil was estimated by the authors based on fuel consumption.

In actuality, much of the current capacity is dual-fuel capable.

## 16. CONCLUSION

The provision of adequate supply of electricity is a top priority in all of the countries considered in this report. Power shortages are a problem in many of the countries, and could develop in others if growth in consumption continues at a rapid rate. The pressure from electricity demand is most strong in Asia, but consumption has continued to grow in Latin America despite the economic difficulties of recent years. These difficulties make financing of new supplies particularly problematic in Latin America, though shortage of capital is also an issue in many of the Asian countries as well.

### 16.1. Expansion of Electric Generating Capacity

The planned expansion of electric generating capacity described in this report would more than double the total installed capacity of the 13 countries considered from 322 GW in 1987 to 721 GW in the year 2000. The implicit average growth rate, 6.3% per year, is lower than the rate of 7.5% per year recorded in the 1980-1987 period, however. Achieving the planned rate of expansion may be difficult for many of the countries, for both financial and institutional reasons. Environmental factors are also beginning to have a larger effect on power expansion plans, particularly with respect to hydropower. In some cases (mainly in Latin America), electricity demand may not grow as fast as predicted, and the capacity envisioned may not be needed, while in others (including the two largest developing countries, China and India), users will probably consume whatever the electricity system is able to deliver.

Another factor affecting system expansion is that the electric utilities are now faced with managing the systems that in many cases have grown rapidly in the past decade. Rehabilitation of existing systems, including improving the efficiency of distribution networks, is beginning to receive more attention than in the past, when the focus was more on system expansion. Success in these efforts will reduce the need to expand capacity in some cases, or lessen the problem of power shortages in others.

### 16.2. Fuel Choices for Power Generation

The rise in oil prices in 1979-1980, coupled with increased discovery and exploitation of indigenous non-oil energy resources, began a momentum away from use of oil in the power sector in many of the larger developing countries.<sup>1</sup> The plans of the countries considered in this report show that the drop in oil prices and general prognosis of relatively stable prices through the mid-1990s has not altered this direction. New electricity generating capacity is increasingly relying on indigenous resources (natural gas, coal, and hydro), on imported coal, and in South Korea, on nuclear power. The decline in oil prices, along with difficulties in financing new capacity, seems to have slowed the pace of the shift from oil, however.

The two main reasons for the continued move away from oil are: (1) In many instances, indigenous non-oil resources or imported coal are less expensive than oil even at today's lower price; and (2) Countries are reluctant to build new oil-fired capacity because of uncertainty about the future price of oil. Although fuel oil is now more competitive with coal in utility boilers,

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<sup>1</sup> See S. Meyers and J. Sathaye, "Electricity in the Developing Countries: Trends in Supply and Use Since 1970," Lawrence Berkeley Laboratory Report LBL-26166, Dec. 1988.



planners expect higher oil prices in the future, and coal is seen as a more secure choice for fueling new capacity.

Another factor that is tending to favor coal, or natural gas where it is available, is the increasing difficulty of expanding hydropower. Although significant potential still exists in many countries, the sites are often costlier to develop than those that have been exploited in the past. Further, the large up-front capital cost of hydropower has become a major drawback in today's financial environment, where many countries are of necessity minimizing their external capital borrowing. Added to this difficulty is the increasing opposition that hydro development is facing in many places. In a number of cases, the plans presented in this report show less expansion of hydro capacity than was envisioned just a short time ago.

The move toward coal seen in the countries' plans could be even stronger than the plans suggest. In South Korea, there is a possibility that some of the planned nuclear capacity could be replaced by coal-fired power plants. China may find it difficult to accomplish its ambitious plans for hydro development (for logistical and financial reasons), which would result in greater reliance on coal. A similar situation exists in India, though in this case use of natural gas could make up for a shortfall from hydropower. Coal use could also be larger than planned in the Philippines if development of geothermal resources takes longer than hoped for. As it expands, however, use of coal may run into environmental difficulties, as is occurring, for example, in Taiwan.

### 16.3. Innovative Approaches for the Power Sector

Many developing countries (including many of those not covered in this report) find themselves in a situation where lack of electricity is constraining economic development, or may in the near-future. The institutional and financial resources of the public sector to expand generating capacity are in many cases insufficient. The performance of electric utilities, as measured by a number of financial and operational indicators, has deteriorated over the past decade in many developing countries.<sup>2</sup> The gap between the demand for power and the capacity to meet it through traditional means has led to increasing interest in new approaches to serving demand for electricity. Many of these approaches have been used successfully in the industrialized countries to enhance the performance of the power sector.<sup>3</sup>

One option that is in early stages of development in a number of countries is increased reliance on the private sector to generate electricity for public consumption. In many countries there is considerable potential for sales to the grid from cogeneration by industrial facilities. Options for private sector investment in power generation projects are also being explored.<sup>4</sup> In response to the difficulties of financing public power projects, government policy has come to favor private sector participation in power generation in India, Indonesia, Pakistan, Taiwan, and Thailand, to

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<sup>2</sup> M. Munasinghe, *et al.*, *A Review of World Bank Lending for Electric Power*, The World Bank, March 1988.

<sup>3</sup> A vehicle to help facilitate implementation of new approaches is the Multi-Agency Working Group on Power Sector Innovation (MAGPI). Coordinated by the U.S. Agency for International Development, MAGPI includes representatives from the World Bank, the Asian Development Bank, the Inter-American Development Bank, the International Finance Corporation, the United Nations, and the Tata Energy Research Institute (India).

<sup>4</sup> See U.S. Agency for International Development, *Power Shortages in Developing Countries: Magnitude, Impacts, Solutions, and the Role of the Private Sector*, March 1988.

name several prominent examples.<sup>5</sup> Achieving private participation on a significant scale must surmount considerable barriers, however; in particular, there is often a lack of enthusiasm on the part of public electric utilities. They may have concerns about long-term reliability of supply from private sources, or simply resist encroachment into their domain. For its part, the private sector requires a guarantee of purchase at a price that is sufficiently high to justify investment in electricity generation relative to other areas.

The role of improving the efficiency of electricity use is also receiving increased attention in nearly all of the countries. While we have not extensively reviewed current programs, plans, and attitudes among electricity planners, it appears that increasing the efficiency of existing and future electricity-using devices is at least recognized as having a significant potential to reduce demand growth and the need to construct new capacity. Energy conservation programs are expanding in most of the countries, and more financing is becoming available for implementation of energy conservation projects. The consideration of improved end-use efficiency as a resource comparable to supply expansion, and the tools for integrating demand-side programs into overall power sector planning, are generally lacking in developing countries, however.

While the opportunities to improve end-use efficiency are great, there are also significant barriers to realizing the potential. These include lack of information, low availability of higher-efficiency devices and energy management services, lack of interest due to institutional arrangements or low electricity prices, the often higher first cost of higher-efficiency equipment, and high implicit discount rates with respect to the future savings from higher-efficiency equipment. There is also often lack of interest on the part of electric utilities in getting involved in promoting end-use efficiency. The division between electricity generating and distributing enterprises presents difficulties in some countries. Active involvement of utilities has been critical in promoting energy conservation in the industrialized countries, and is likely to be necessary in the developing countries as well. Increased promotion of and funds for financing improving electricity end-use efficiency by multi-lateral lending institutions such as the World Bank will also be important.

Activity by utilities, lending institutions, and aid agencies in the area of improving the efficiency of electricity supply is at a much more advanced stage than improving end-use efficiency. This is not surprising, since it involves areas that are traditionally within the domain of electric utilities, and it is easier to direct resources and measure results in these areas than is the case with end-use improvements. Given the increasing attention being given to supply efficiency by the World Bank and others, there may well be some progress in this area, especially in those countries where there is a current or likely future shortage of electricity.

Efforts at improving electricity supply and end-use efficiency could increase if concerns over global warming lead to greater cooperation and sharing of resources between industrialized and developing countries. International agreements to limit use of high-carbon-emitting fuels such as coal could also shift the direction of power system expansion toward more use of natural gas, nuclear power, or perhaps biomass. Assistance from the industrialized countries in resource, technology, and institutional development could play a key role in facilitating such a shift, though the impetus will have to come from the developing countries as well.

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<sup>5</sup> Taiwan in particular has placed strong emphasis on developing its cogeneration potential. Regulations that specify attractive conditions for power purchase (similar to the U.S. "PURPA" regulations) are being implemented in late-1989.

LAWRENCE BERKELEY LABORATORY  
TECHNICAL INFORMATION DEPARTMENT  
1 CYCLOTRON ROAD  
BERKELEY, CALIFORNIA 94720