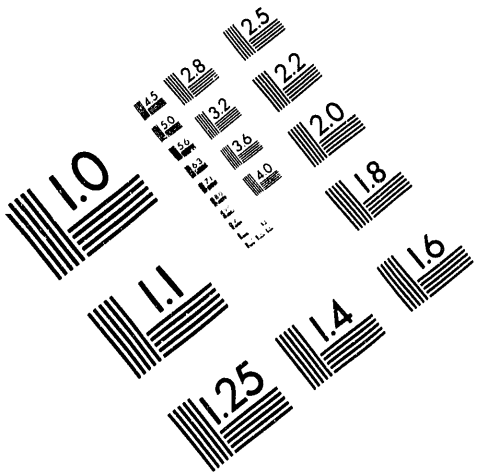

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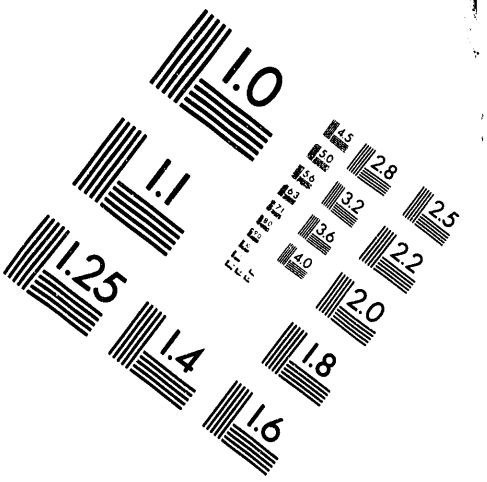

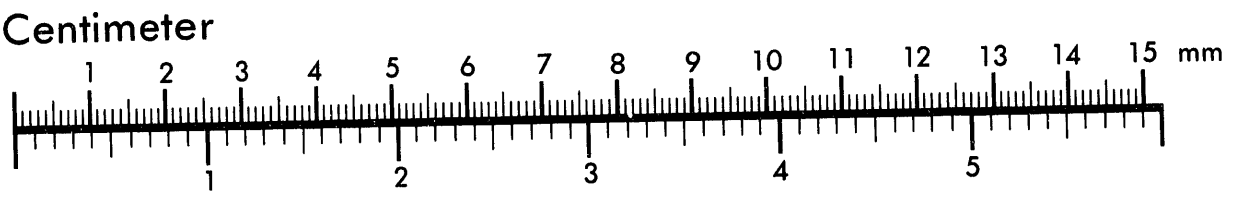

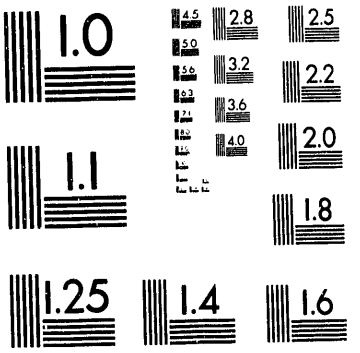

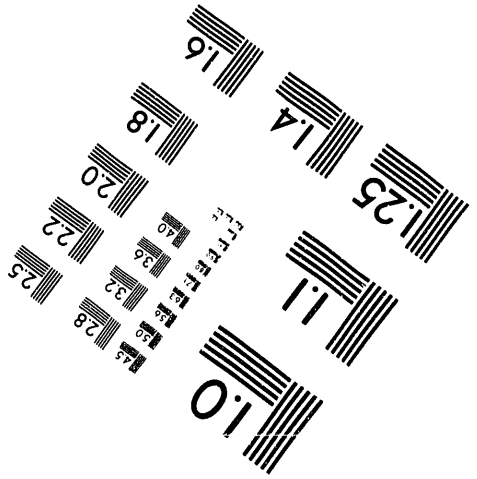

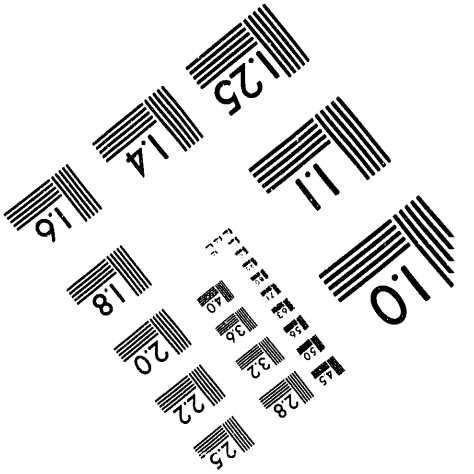

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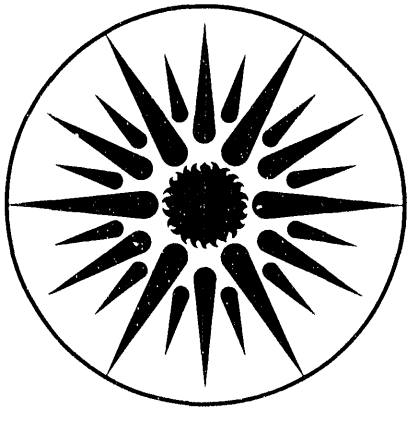
ENERGY & ENVIRONMENT DIVISION

Trends in Electricity Demand and Supply in the Developing Countries, 1980-1990

S. Meyers and C. Campbell

November 1992



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TRENDS IN ELECTRICITY DEMAND AND SUPPLY IN THE DEVELOPING COUNTRIES, 1980-1990

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Lawrence Berkeley Laboratory
University of California
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November 1992

Abstract

This report provides an overview of trends concerning electricity demand and supply in the developing countries in the 1980-1990 period, with special focus on 13 major countries for which we have assembled consistent data series. We describe the linkage between electricity demand and economic growth, the changing sectoral composition of electricity consumption, and changes in the mix of energy sources for electricity generation. We also cover trends in the efficiency of utility electricity supply with respect to power plant efficiency and own-use and delivery losses, and consider the trends in carbon dioxide emissions from electricity supply.

This work was supported by the Office of Environmental Policy Analysis of the U.S. Department of Energy through the U.S. Department of Energy Contract No. DE-AC03-76SF00098.

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1. INTRODUCTION

This report provides an overview of trends concerning electricity demand and supply in the developing countries (LDCs) in the 1980-1990 period. It updates an earlier report on the same topic that covered trends in the 1970-1987 period.[1] We first describe the evolution since 1980 with respect to electricity generation and installed capacity for the LDCs as a whole and for the major regions. The rest of the report provides more detailed information on electricity demand and supply for 13 of the largest developing countries for which we have assembled consistent data series. Together, they account for about 70% of total LDC electricity generation. They are:

ASIA:	China, India, Indonesia, Malaysia, Pakistan, Philippines, South Korea, Taiwan, Thailand
LATIN AMERICA:	Argentina, Brazil, Mexico, Venezuela.

Section 3 describes the linkage between electricity demand and economic growth, and portrays the changing sectoral composition of electricity consumption. Section 4 describes changes in the mix of power sources for electricity generation. Section 5 covers the efficiency of utility electricity supply with respect to power plant efficiency and own-use and system losses. Section 6 considers the trends in carbon dioxide emissions from electricity supply. The report is largely descriptive in nature, and much of the information is presented in the form of graphs. The intent is to provide an overview of important trends concerning electricity; in-depth analysis of those trends is beyond the scope of this report.

1.1. Data Sources

The data presented in Section 2 have been assembled from various issues of the United Nations *Energy Statistics Yearbook*. The more detailed data presented in Sections 3 and 4 have been compiled by LBL from statistical reports issued by the electric utilities or government agencies of the respective countries. In a few cases, we have made estimates where official statistics were insufficient. A listing of the main data sources is presented in the Appendix.

There are several reasons for not relying on international sources such as the UN's *Energy Statistics Yearbook* or the International Energy Agency's publication, *Energy Statistics and Balances of Non-OECD Countries*. The UN does not present statistics on electricity generation by fuel type or on electricity consumption by sector. The IEA does, but our comparison of the IEA statistics with those from national sources shows discrepancies in many cases. In many cases, we know from working with national sources that some of the values given in the IEA balances are estimates, but it is not clear how the estimates were derived or who made them. This is not a criticism of the IEA staff, who must deal with numerous limitations in attempting to publish energy balances for dozens of countries. The IEA data are roughly accurate, but by using primary sources we are able to check for problems, incomplete data, and differences among sources, and can document necessary estimates. In addition, we are able to obtain statistics more quickly from country sources.

We have included data on industrial self-generation from either national or international sources. The accuracy of these data is uncertain.

---

[1] S. Meyers and C. Campbell, *Electricity in the LDCs: Trends in Supply and Use, 1970-1987*, LBL-26166 (Rev.), Berkeley, CA: Lawrence Berkeley Laboratory, March 1990.

2. OVERVIEW OF ELECTRICITY SUPPLY IN THE DEVELOPING COUNTRIES[1]

2.1. Electricity Generation[2]

The average annual growth rate for LDC electricity production in 1980-1990 — 6.9% — was over twice the rate of 2.8% recorded in the OECD countries. As a result, the share of world electricity production accounted for by the LDCs grew from 16% in 1980 to 22% in 1990 (Figure 2-1). Per capita annual electricity generation in the LDCs increased from 0.40 MWh to 0.66 MWh between 1980 and 1990, but this is still well below the average of 8.2 MWh in the OECD countries.

Growth rates have varied among regions. Generation has risen fastest in Asia, followed by China, Africa, and Latin America (Table 2-1).[3] Relative to the 1970s, there was considerable decline in the growth rate in the 1980s in Latin America, Africa, and to a lesser extent in China, but growth in Asia was nearly as fast in the 1980s. In the latter half of the 1980s, the average growth was faster than the full-decade average in China, slower than the average in Latin America, and about the same in Asia and Africa.

Table 2-1
Average Annual Growth in Electricity Generation (%)

	1970-80	1980-90	1985-90
Asia	9.7	8.7	8.8
China	10.0	7.5	8.6
Latin America	9.3	4.7	4.0
Africa	7.9	5.4	5.5
Total LDCs	9.4	6.9	7.1

The share of LDC electricity generation accounted for by Asia increased from 34% in 1980 to 40% in 1990 (Figure 2-2). In 1990, Latin America accounted for 24%, China for 24%, and Africa for 12%. (South Africa accounts for about half of total African electricity production.)

[1] In this section, we use the term "developing countries" broadly to include all non-OECD countries outside of Europe and the former Soviet Union. We do not include countries in Europe that are classified as "middle-income economies" by the World Bank, but do include the "high-income economies" that are located in developing regions.

[2] The UN statistics used in this section nominally include self-generation by industries.

[3] Asia includes the Middle East and Pacific developing countries but excludes China, which because of its large size is reported separately. Latin America includes the Caribbean. Africa includes South Africa.

Figure 2-1

World Electricity Generation
1980-1990

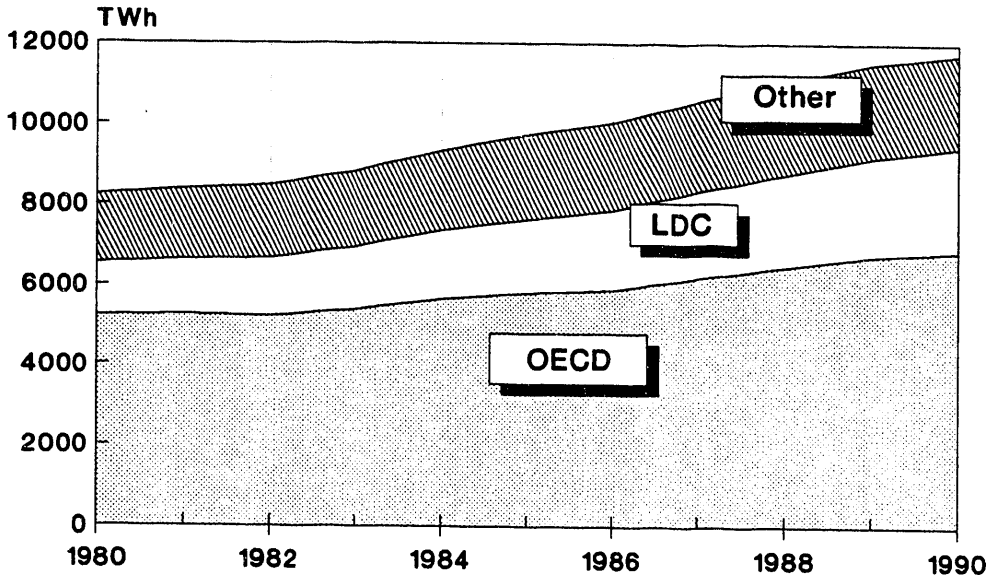
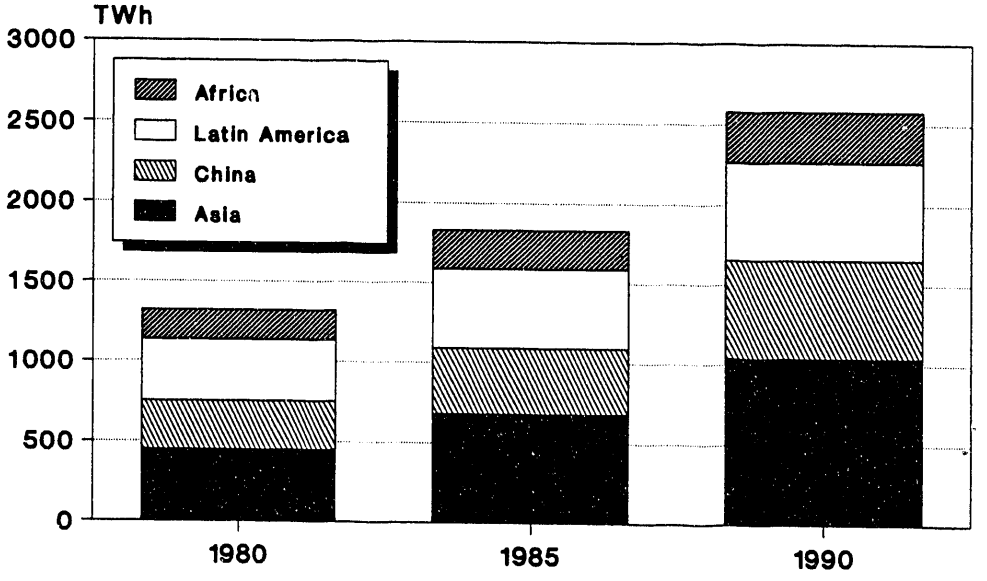


Figure 2-2

Electricity Generation
Developing Countries by Region



Per capita electricity production in Latin America is over twice as high as that in the other LDC regions (Figure 2-3). Asia and China are at about the same level, with Africa slightly below. Growth in per capita electricity production in the 1980s was much higher in Asia and China than in Latin America and Africa (Table 2-2).

Table 2-2
Average Annual Growth in
Per Capita Electricity Generation (%)

	1970-80	1980-90
Asia	7.2	7.1
China	8.0	6.3
Latin America	6.6	2.7
Africa	4.9	2.4
Total LDCs	6.9	5.2

The share of total LDC electricity production derived from fossil fuels has remained at about 65% since 1980 (Figure 2-4). In contrast, the fossil fuel dependency of electricity production in the OECD countries has declined from 76% to 64% as a result of growing use of nuclear power. Among the LDC regions, China and Africa are the most dependent on fossil fuels for electricity production (around 80%), followed by Asia (73%) (Table 2-3). (The share of fossil fuels in Africa drops if South Africa is excluded.) Latin America is the only region where hydropower dominates electricity production. Its share there increased slightly from 57% to 60% between 1980 and 1990. Hydro's role has increased in China since 1980, but has declined in Asia and Africa. Asia is the only region where nuclear power has come to play a modest role: it accounted for 9% of total electricity generation in 1990.

Table 2-3
Electricity Generation in LDCs
According to Power Source, 1990 (%)

	Fossil Fuel	Hydro	Other*
Asia	73	18	9
China	82	18	0
Latin America	37	60	2
Africa	83	16	1
Total LDCs	68	27	5

* Primarily nuclear power; includes some geothermal.

In the LDCs as in the OECD countries, there has been a shift away from oil to coal, natural gas, and to a lesser extent, nuclear power. We describe this further in Chapter 4.

Figure 2-3

Per Capita Electricity Generation

Developing Countries

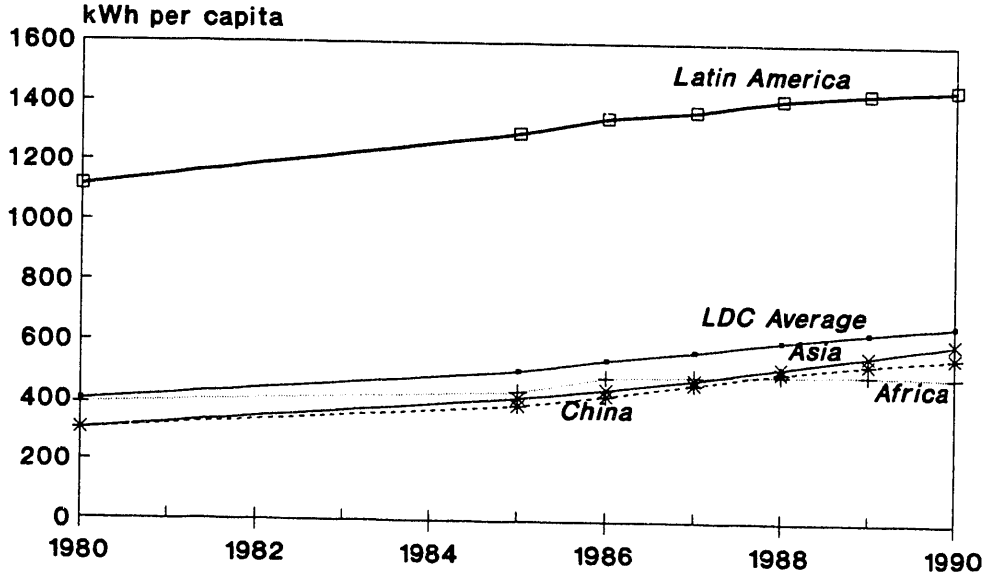
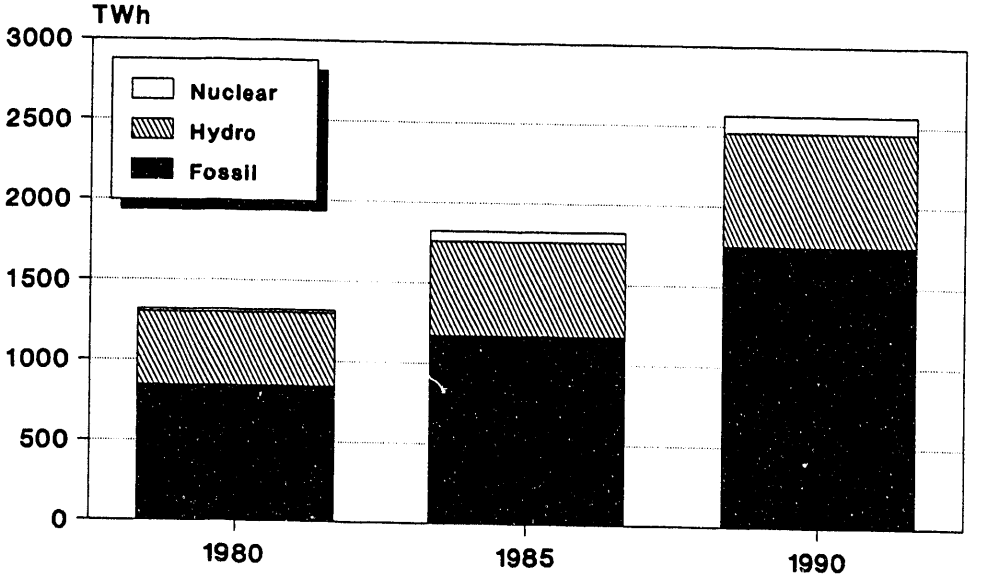


Figure 2-4

Electricity Generation

Developing Countries by Source



2.2. Installed Generating Capacity

The total installed capacity of *utility* generating plants in the LDCs in 1990 was around 600 GW. (This may be compared to the total in the U.S. of 685 GW.) Asia had 41% of total LDC installed power capacity in 1990. Latin America accounted for 25% of the total, followed by China with 23% and Africa with 11% (Table 2-4).[4] Installed capacity statistics for some LDCs are somewhat misleading because they include power plants that are unable to produce at rated capacity.

Table 2-4
Installed Capacity of Utility
Electricity Generating Plants in LDCs, 1990

	GW	%
Asia	244	41
China	138	23
Latin America	149	25
Africa	68	11
Total LDCs	599	100

Nearly two-thirds of LDC total installed capacity uses fossil fuels. Comparison of the statistics on installed capacity (Table 2-5) with those on electricity production suggest that there was underutilized fossil fuel capacity in Latin America and underutilized hydro capacity in China and Africa. This could result from part of the nominal installed capacity being unusable, hydrological conditions, or both. Asia has the highest share of nuclear power capacity among the regions due to the buildup in Taiwan and South Korea.

Table 2-5
Installed Capacity of Utility
Electricity Generating Plants in LDCs
According to Power Source, 1990 (%)

	Fossil Fuel	Hydro	Other*
Asia	73	21	6
China	74	26	0
Latin America	38	60	2
Africa	71	27	1
Total LDCs	64	33	3

* Primarily nuclear power; includes some geothermal.

[4] The data are from Chinese government statistics rather than UN statistics.

3. ELECTRICITY DEMAND IN 13 DEVELOPING COUNTRIES[1]

3.1. Aggregate Trends

Electricity Consumption and Economic Growth

The relationship between electricity consumption and economic growth varied among the 13 countries in the 1980s. The ratio between average growth in electricity consumption and growth in real Gross Domestic Product (GDP) in the 1980-90 period was over three in Latin America and the Philippines, where GDP grew very slowly (or even declined in the case of Argentina) (Table 3-1). Among the other Asian countries, the ratio was mostly in the 1-2 range. Electricity use grew more slowly than GDP only in China, reflecting that country's strong efforts to conserve electricity and structural changes in the economy. Electricity use grew at the same pace as GDP in Taiwan, and only slightly faster in S. Korea.[2] These trends reflect the relatively developed state of the economy in these countries.

In many of the countries, the ratio between electricity growth and GDP between 1980 and 1990 was higher than in the 1970-80 period. For Korea and Taiwan, there was a decline in the ratio, which reflects the maturing of their economies and the introduction of new and more efficient manufacturing processes. In the countries with increased electricity/GDP ratios, both electricity and GDP growth were lower in the 1980s than in the 1970s, but electricity growth did not slow down nearly as much as GDP growth.

Trends in electricity consumption and GDP in each of the countries are shown in Figures 3-1 through 3-5. In some cases, electricity consumption has continued to increase during periods of little or no growth or even decline in GDP. Examples of this were Malaysia in 1985-86, the Philippines in the mid-1980s, and Brazil in 1982-83. Perhaps the main reason for this phenomenon is that industrial processes are operated at low capacity and efficiency when output is depressed, while many fixed uses continue to use electricity. In addition, residential electricity demand often continues to grow during recessionary periods due to ongoing electrification and the limited scope for reducing consumption among many households.

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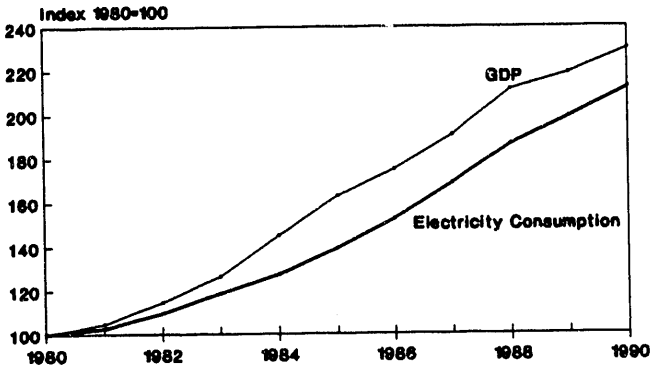
[1] The data reported in this chapter include estimates of industrial self-generation unless noted otherwise. In some countries, actual electricity consumption may be slightly higher than shown due to theft, lack of metering, and under-reporting of self-generation.

[2] The ratio would have been slightly lower in S. Korea but not for very rapid growth in electricity demand from commercial development related to the Seoul Summer Olympic Games in 1988.

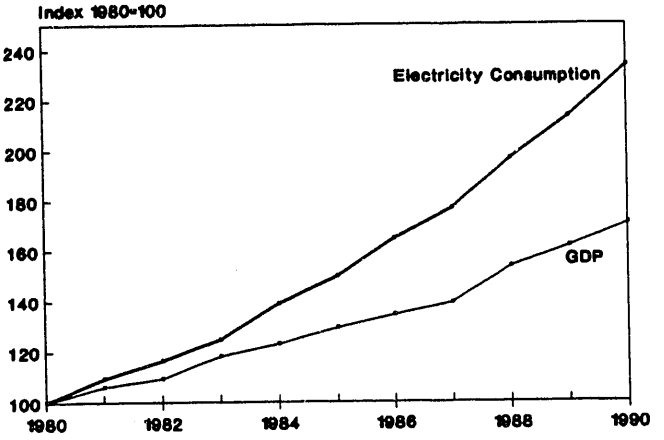
Table 3-1
Average Annual Growth in Electricity Consumption and GDP

	1970-1980			1980-1990		
	Electricity (%)	GDP (%)	Ratio Elec/GDP	Electricity (%)	GDP (%)	Ratio Elec/GDP
ASIA						
China	10.2	6.6	1.5	7.8	8.5	0.9
India	6.2	3.1	2.0	8.9	5.5	1.6
Indonesia	11.3	7.9	1.4	12.8	5.4	2.4
Malaysia	10.2	8.0	1.3	8.7	5.9	1.5
Pakistan	8.2	4.8	1.7	10.6	6.1	1.8
Philippines	7.4	6.3	1.2	4.2	1.0	4.1
South Korea	15.7	8.4	1.9	11.1	9.3	1.2
Taiwan	12.4	9.8	1.3	7.6	7.3	1.0
Thailand	13.4	7.0	1.9	11.2	7.6	1.5
LATIN AMERICA						
Argentina	6.0	2.6	2.3	2.8	-1.1	--
Brazil	11.8	8.2	1.4	5.8	1.6	3.7
Mexico	8.6	6.6	1.3	5.7	1.6	3.6
Venezuela	11.3	4.1	2.7	4.7	1.3	3.6

Figure 3-1
Electricity Use and GDP Growth
CHINA



INDIA



INDONESIA

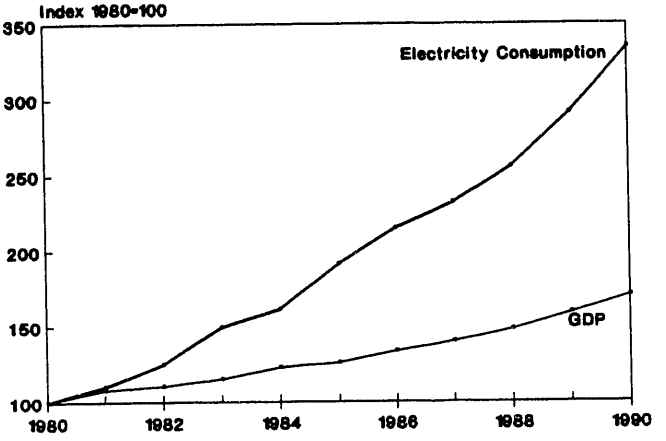
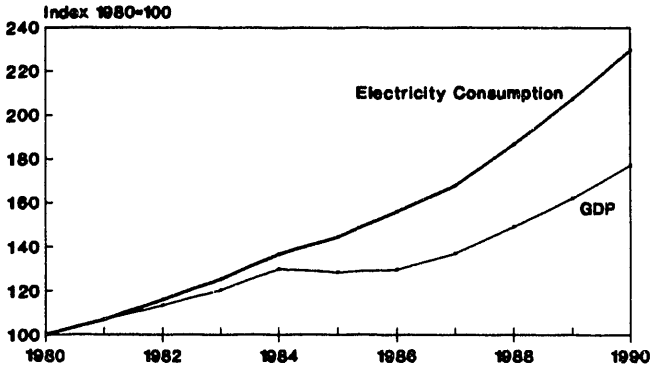
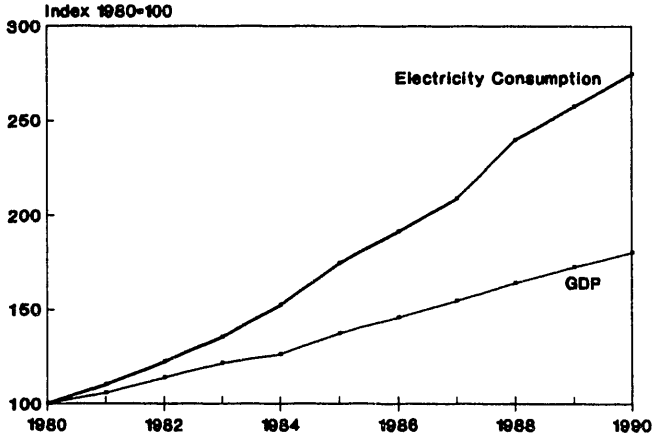


Figure 3-2
Electricity Use and GDP Growth
MALAYSIA



PAKISTAN



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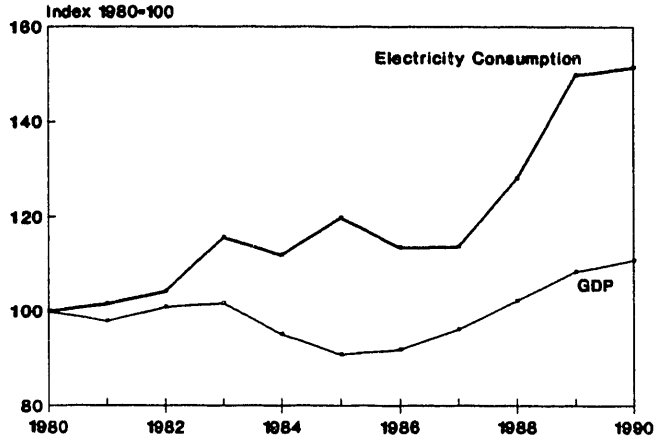
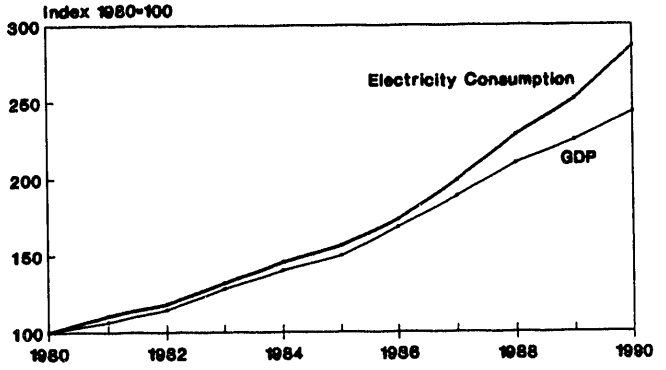
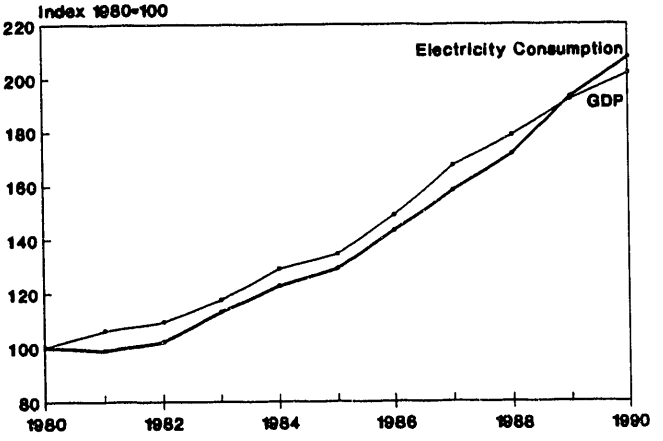


Figure 3-3
Electricity Use and GDP Growth
SOUTH KOREA



TAIWAN



THAILAND

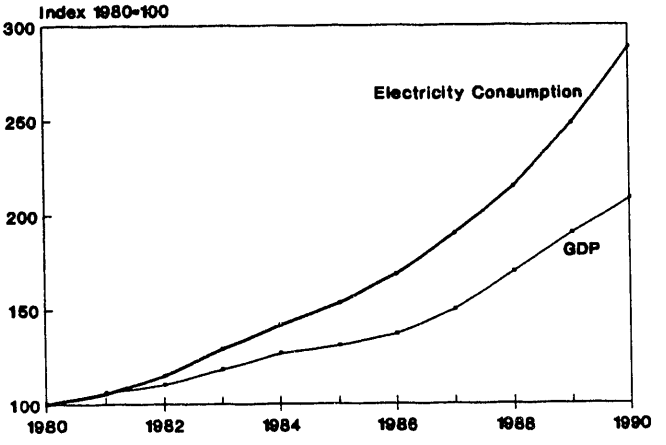
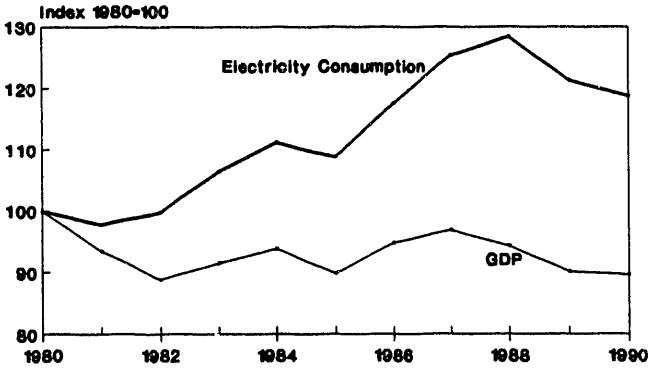
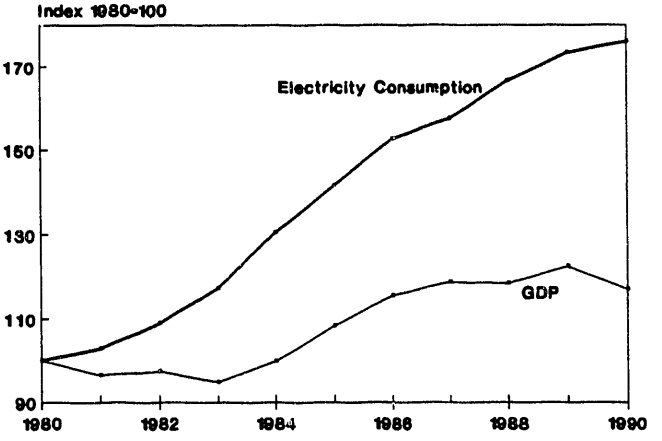


Figure 3-4
Electricity Use and GDP Growth
ARGENTINA



BRAZIL



MEXICO

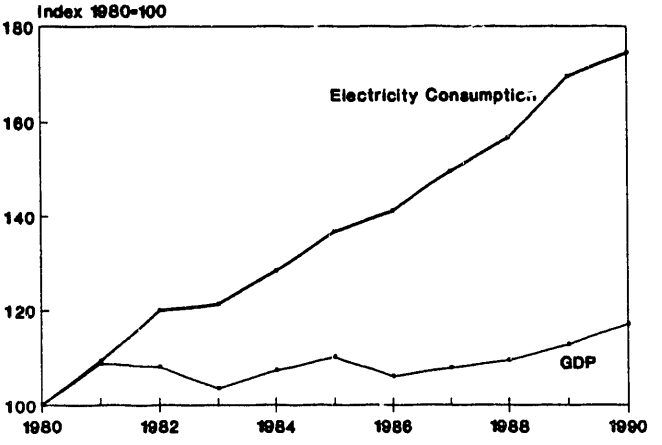
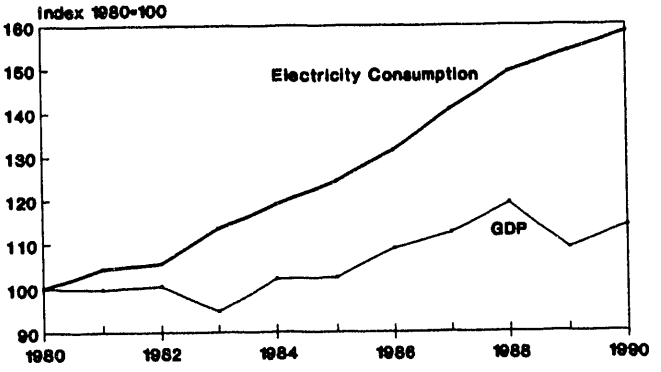


Figure 3-5
Electricity Use and GDP Growth
VENEZUELA



Per Capita Electricity Consumption

Per capita electricity use rose considerably between 1980 and 1990 in most of the Asian countries, but grew only slightly in Latin America (Figure 3-6). (It declined in 1989-90 in Argentina.) Despite the slow growth, per capita electricity use in the Latin American countries (especially Venezuela) in 1990 was much higher than in most of the Asian countries. Taiwan was well above any other country, while the level in S. Korea was higher than in any Latin American country except Venezuela. The variation in per capita use reflects differences in GDP per capita and urbanization.

3.2. Change in the Sectoral Composition of Electricity Consumption

In order to understand aggregate trends, one must look at trends in each sector. Change in the sectoral composition of electricity consumption in the 13 countries is shown in Figures 3-7 through 3-13. (We show industrial self-production separately in the figures.) The industrial sector dominates electricity consumption in nearly all developing countries, but its share of total consumption has generally declined in the face of faster growth in the residential and commercial sectors. Electricity consumption in the residential sector averaged growth of over 10% per year in most of the Asian countries (Table 3-2). The commercial sector also grew rapidly, especially in South Korea, Taiwan, Thailand, and China.

For the 13 countries together, industrial electricity consumption averaged growth of 6.7% per year in the 1980-90 period, while the residential and commercial sectors averaged 9.5% and 8.1% per year respectively. (China and India weigh heavily in the 13-country total.)

Table 3-2
Average Annual Growth in
Sectoral Electricity Consumption, 1980-1990 (%)

	Industrial*	Residential	Commercial	Total
ASIA				
China	7.1	16.6	12.7	7.8
India	6.7	12.1	9.7	8.9
Indonesia	13.9	12.0	9.2	12.8
Malaysia	8.0	10.8	8.5	8.7
Pakistan	9.8	14.8	8.3	10.6
Philippines	3.5	5.8	4.2	4.2
South Korea	10.0	12.8	14.8	11.1
Taiwan	6.2	8.0	13.0	7.6
Thailand	10.5	10.4	12.8	11.2
9-Country Total	7.5	12.4	11.1	--
LATIN AMERICA				
Argentina	1.1	1.8	3.9	1.7
Brazil	5.0	7.5	5.7	5.8
Mexico	6.0	6.6	2.8	5.7
Venezuela	4.6	4.5	5.0	4.7
4-Country Total	4.8	6.1	4.8	-
TOTAL	6.7	9.5	8.1	-

* Includes self-generation.

For the 13 countries together, the share of industry (including self-production) declined from 67% in 1980 to 63% in 1990 (Table 3-3). The residential share grew from 13% to 16%, while the commercial sector share rose from 12% to 13%. Agriculture (mostly accounted for by India) rose from 7% to 8%.

Table 3-3
Sectoral Shares of Electricity Consumption, 1980-90,
Combined Data for 13 Countries (%)

	1980	1990
Industry	67	63
Utility sales	58	53
Self-production	9	10
Residential	13	16
Commercial	12	13
Agriculture	7	8

Table 3-4 shows the shares of the sectors in each of the countries in 1990. The industrial sector's share ranged from around 50% in several countries to 76% in China. The share of the residential sector was mostly in the 20-25% range, although its share was much lower than that in China and India. The commercial sector was most important in Malaysia and Thailand, which reflects the considerable construction of new buildings in recent years and the high demand for air-conditioning in the hot, humid climate of that region. Other sectors (mainly agriculture) were significant in India, Pakistan, and China. The high use of agriculture in India reflects not only the rising use of irrigation by farmers, but also the practice of assessing a flat rate for electricity rather than a per-unit charge. Thus, there is no incentive for farmers to conserve electricity.

Table 3-4
Shares of Electricity Use in 1990 by Sector (%)

	Industry*	Residential	Commercial	Other**
ASIA				
China	76	9	5	10
India	51	14	10	25
Indonesia	67	22	11	<1
Malaysia	48	21	31	<1
Pakistan	40	31	13	16
Philippines	52	28	20	<1
South Korea	65	18	16	1
Taiwan	59	20	19	2
Thailand	49	20	31	<1
LATIN AMERICA				
Argentina***	50	27	22	1
Brazil	54	23	20	3
Mexico	61	19	12	8
Venezuela	60	19	21	<1

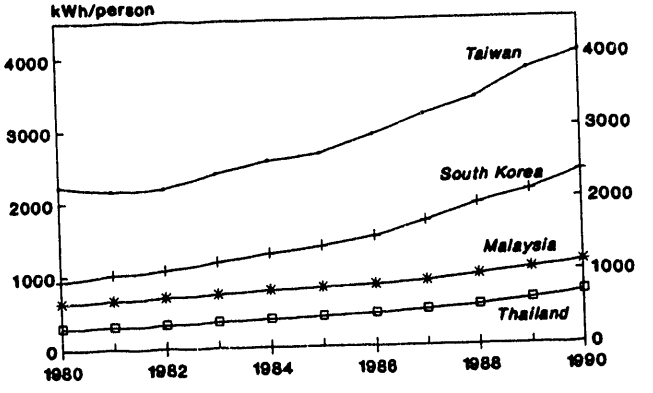
* Includes self-production.
** Mainly agriculture, some transportation.
*** Estimated based on 1988 shares.

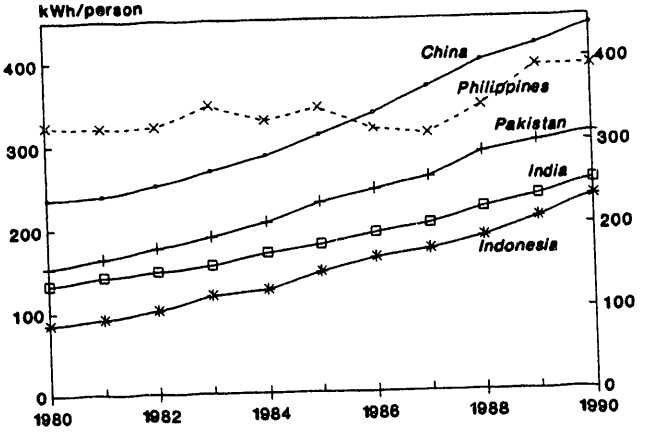
3.3. Unmet Electricity Demand

In many LDCs, electricity consumption has been less than it would have been if the supply system had been able to meet demand at all times. The extent of the shortages have varied. Countries that have been chronically short of electricity include China, India, Indonesia, Pakistan, and (in recent years) the Philippines. Argentina also had severe shortages in 1990, despite the relatively low growth in demand, due to poor hydro conditions and problems with its aging thermal power plants. In these and other countries, many industries maintain backup generators to meet their needs when the utility cannot. Use of such equipment may be partially included in the estimates of self-production. Consumers without their own generators must forego electricity use for certain periods.

Figure 3-6

Per Capita Electricity Use





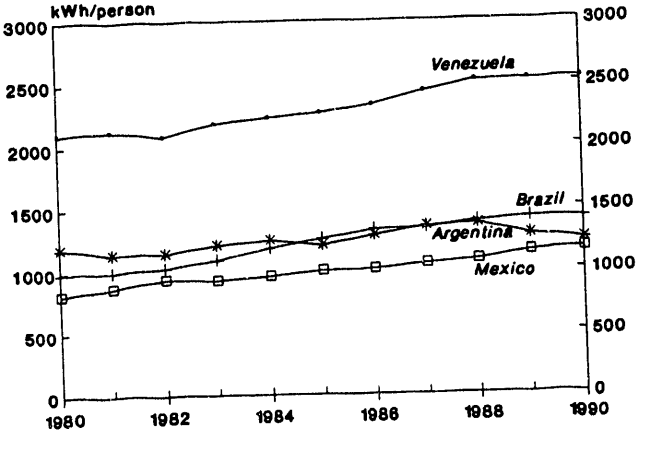
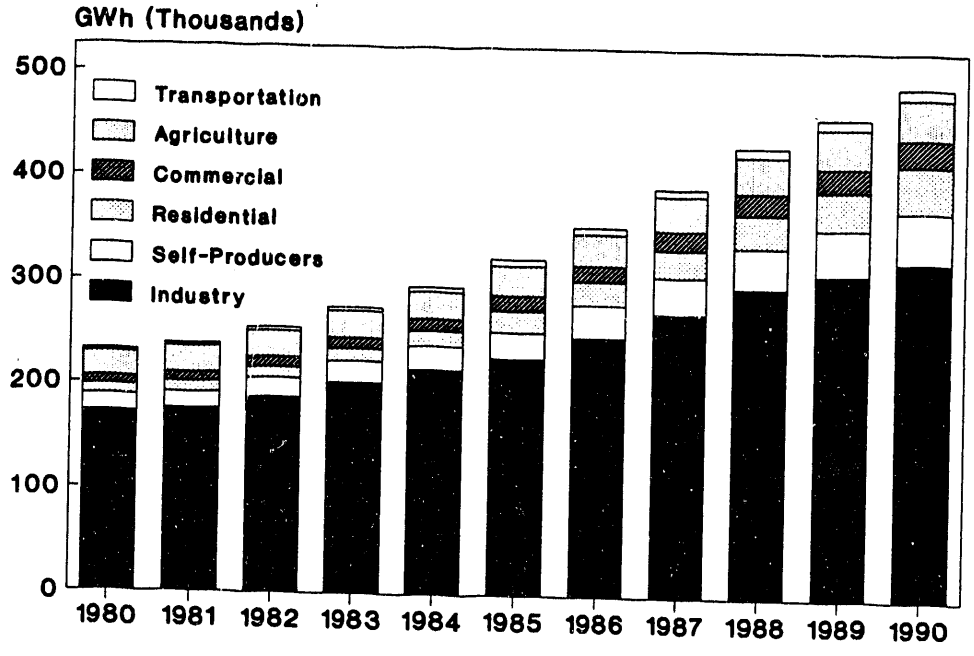


Figure 3-7

China Electricity Use by Sector



India Electricity Use by Sector

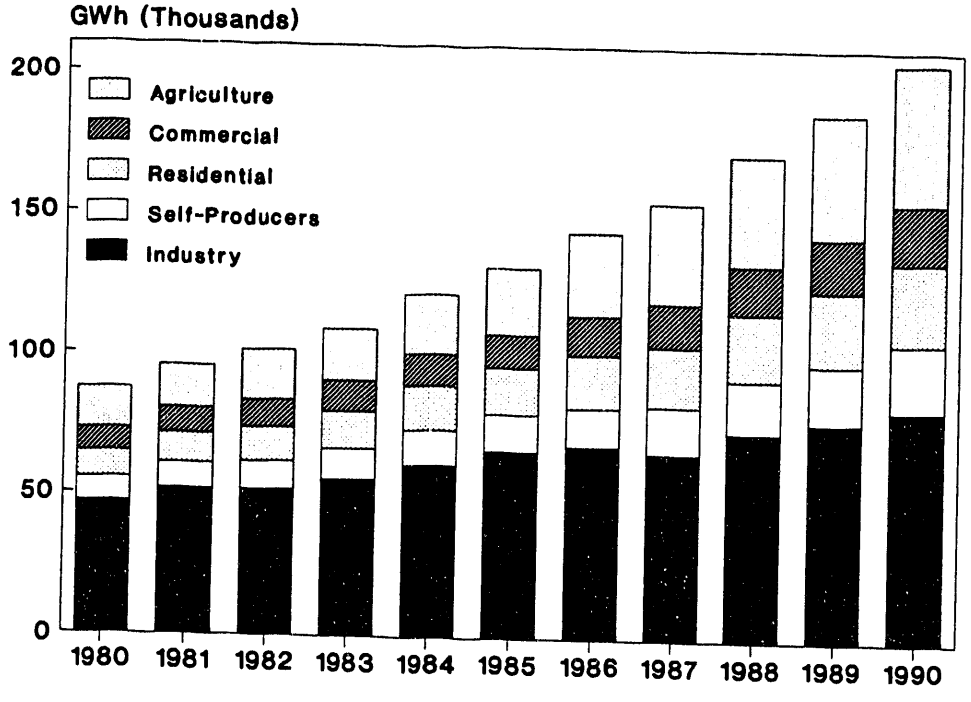
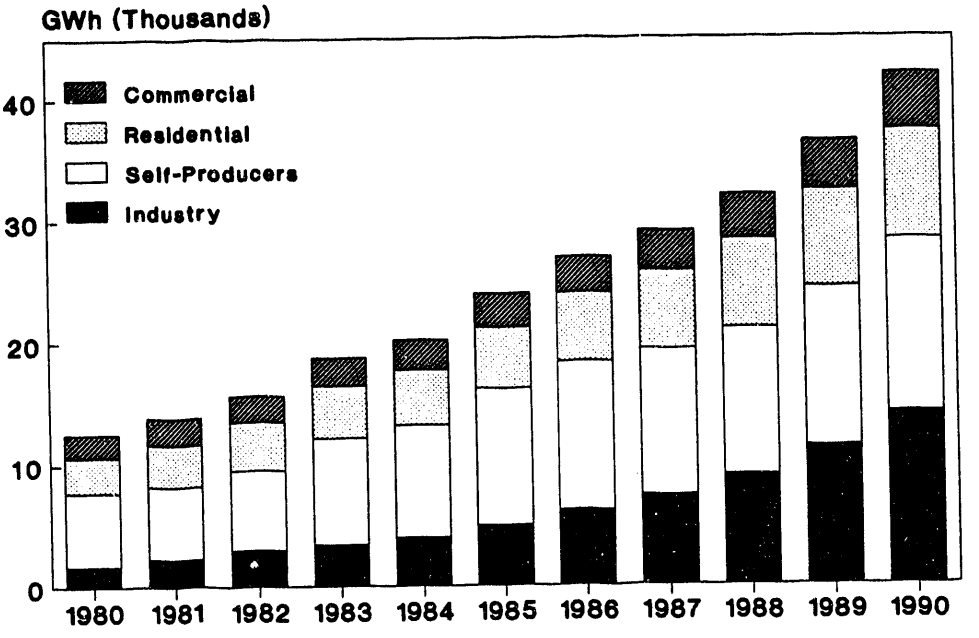


Figure 3-8

Indonesia Electricity Use by Sector



Malaysia Electricity Use by Sector

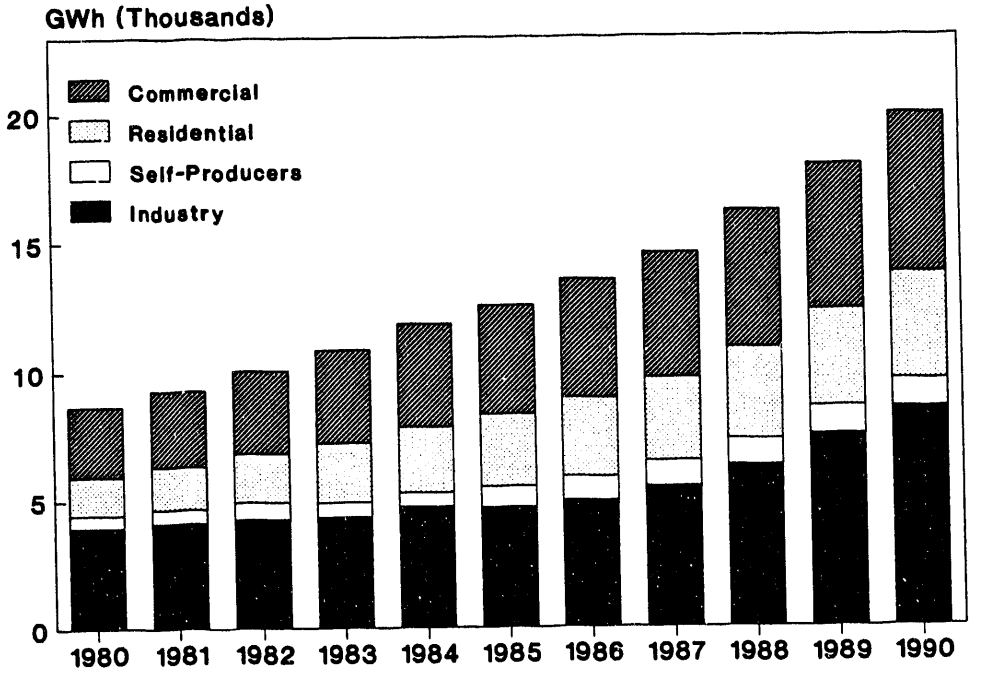
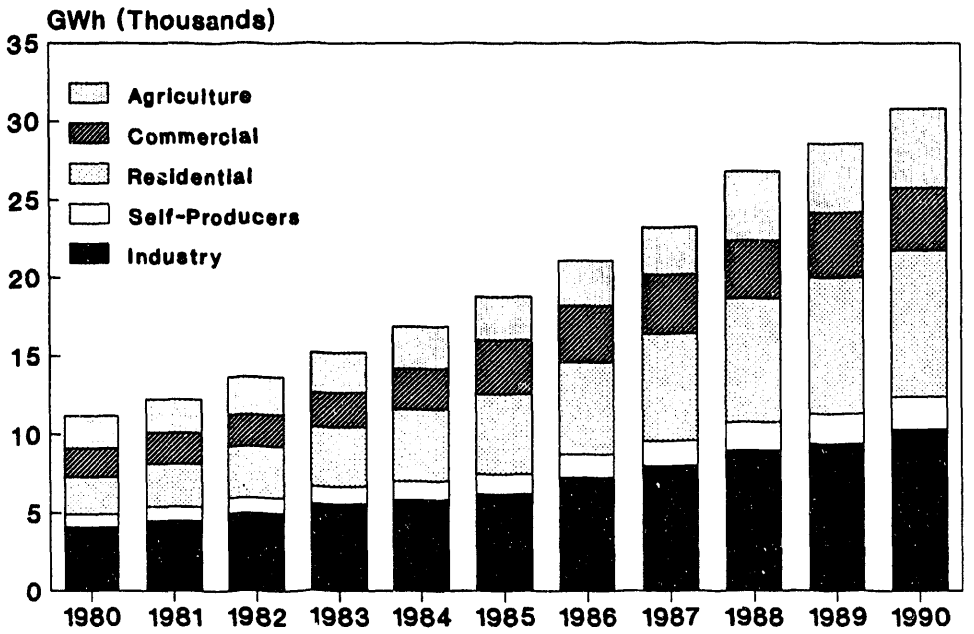


Figure 3-9

Pakistan Electricity Use by Sector



Philippines Electricity Use by Sector

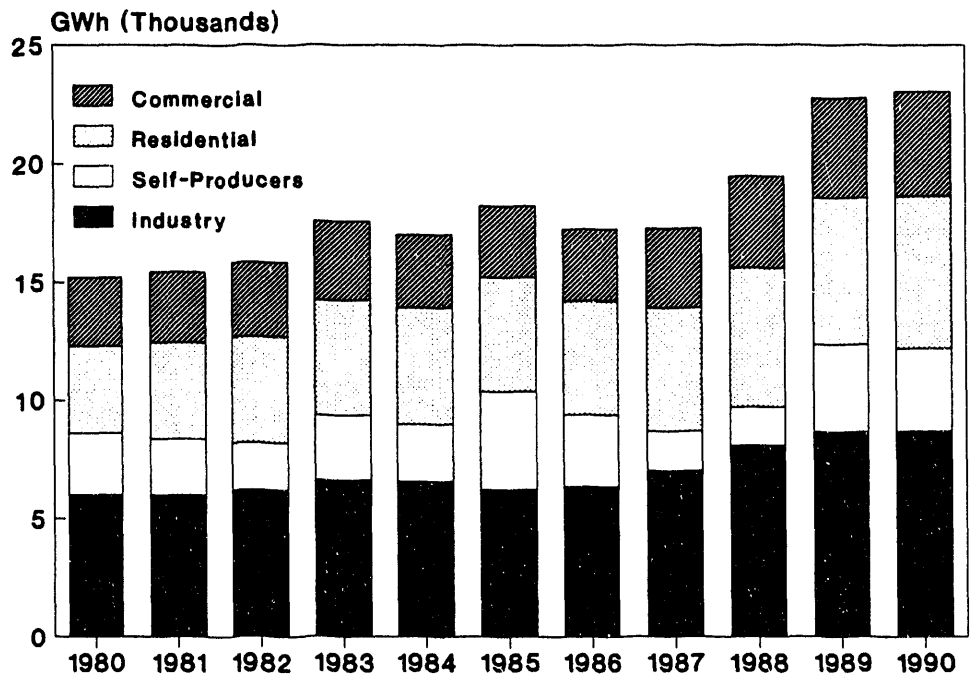
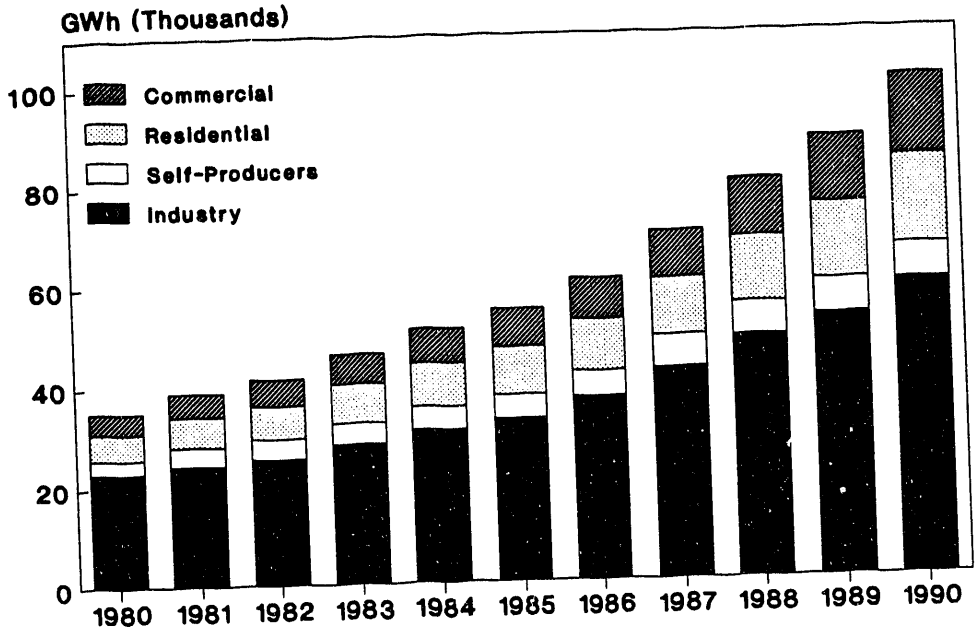


Figure 3-10

South Korea Electricity Use by Sector



Taiwan Electricity Use by Sector

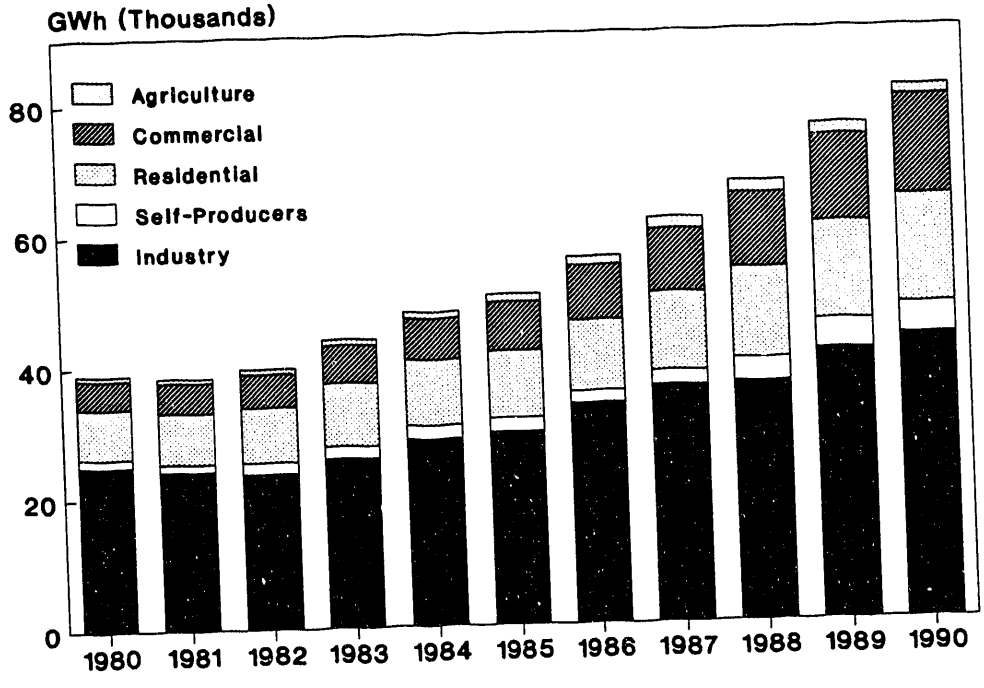


Figure 3-11

Thailand Electricity Use by Sector

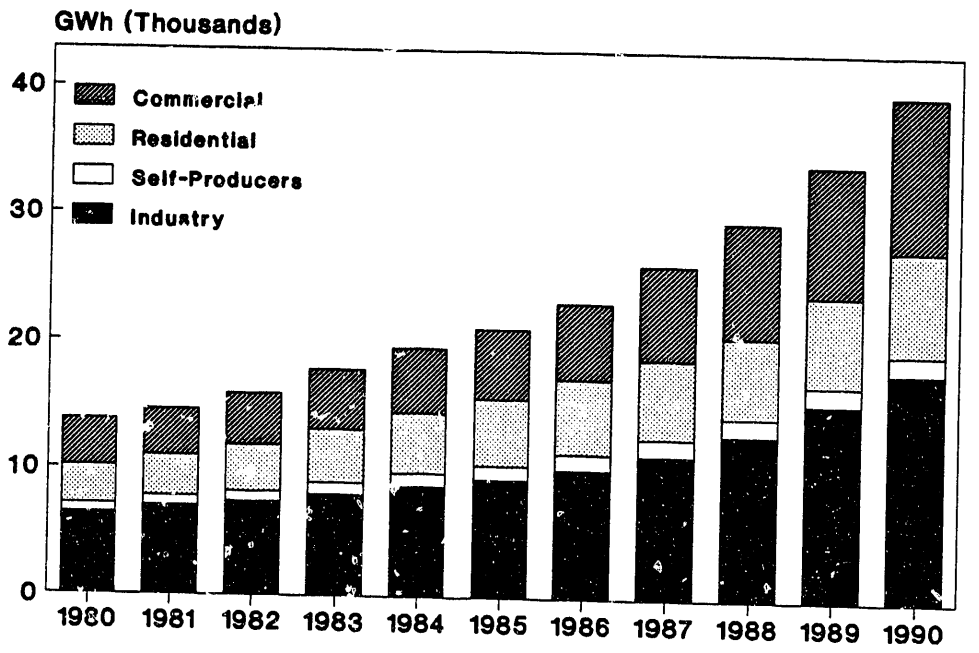
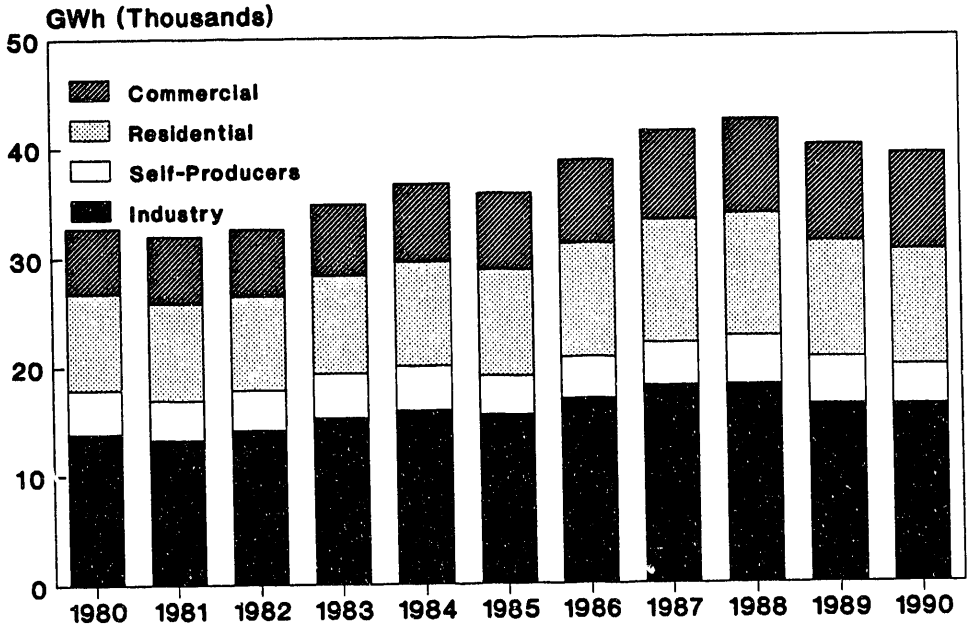


Figure 3-12

Argentina Electricity Use by Sector



Brazil Electricity Use by Sector

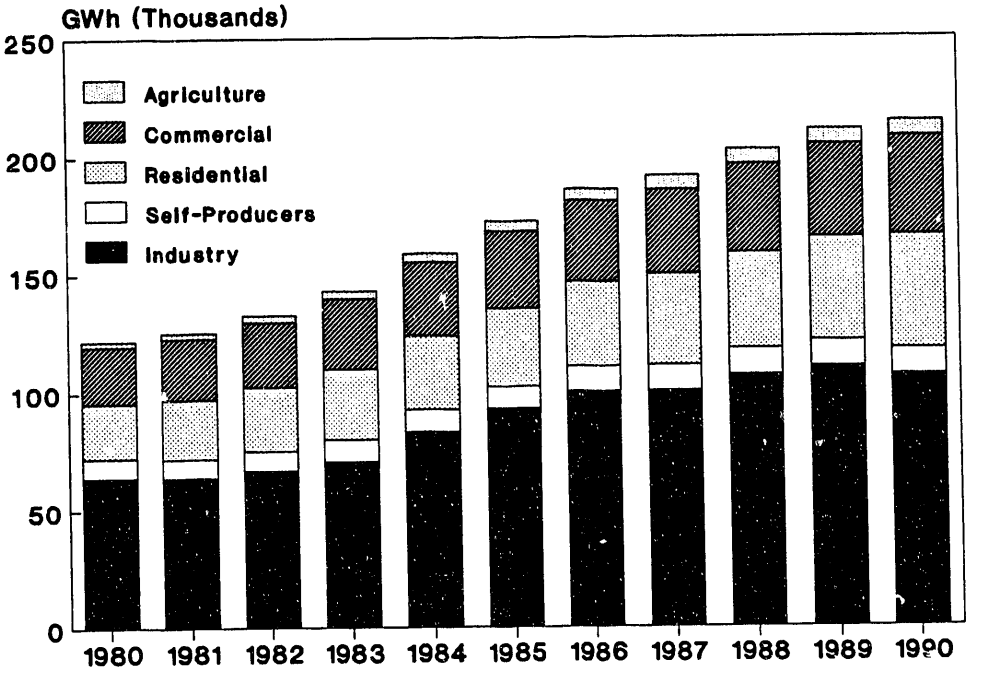
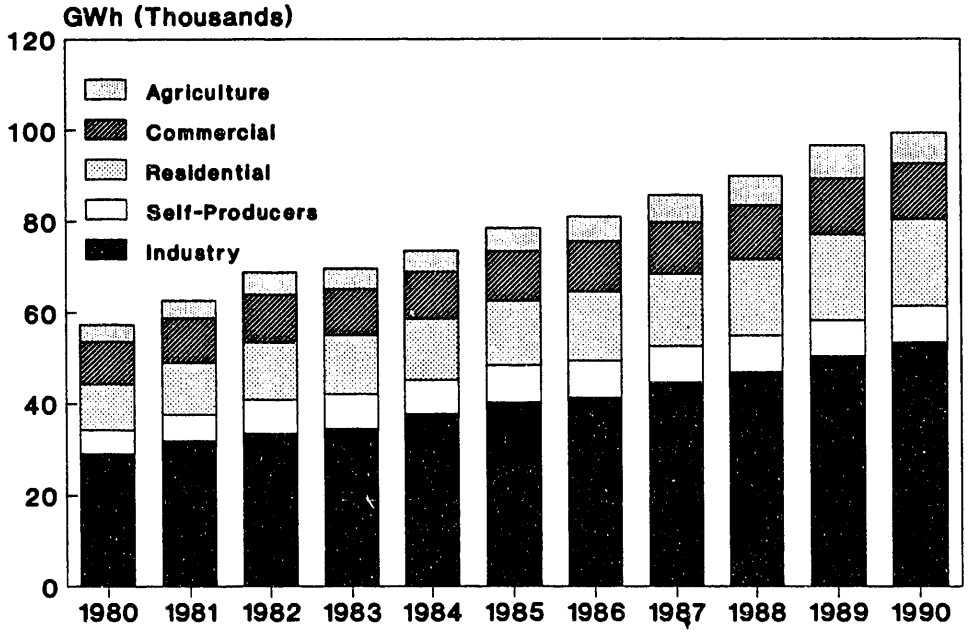
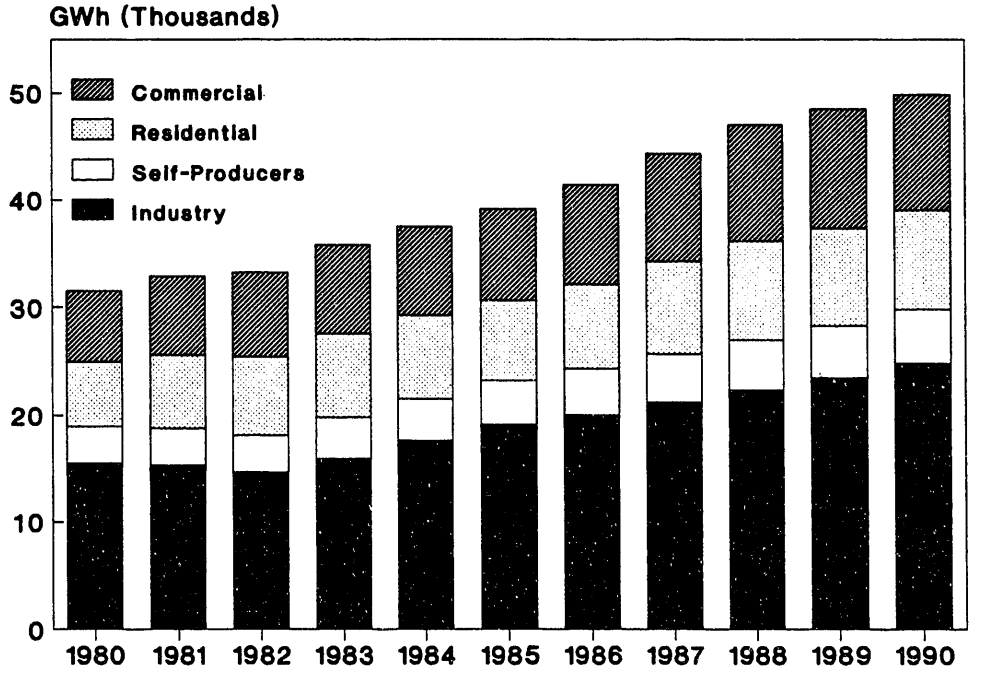


Figure 3-13

Mexico Electricity Use by Sector



Venezuela Electricity Use by Sector



4. ELECTRICITY GENERATION[1]

4.1. Overview

Electricity generation in 1990 was much higher in China than in any other developing country (Table 4-1). Brazil and India are also major producers of electricity. The next largest producers — Mexico, South Korea, and Taiwan — generated less than half either Brazil or India. Developing countries not among the 13 in this study that had annual electricity generation in excess of 20 TWh are South Africa (165 TWh), Iran (56 TWh), North Korea (53 TWh), Saudia Arabia (47 TWh), Egypt (40 TWh), Colombia (36 TWh), and Hong Kong (29 TWh). (Values for these countries are from the UN.)

The average growth in electricity generation between 1980 and 1990 in the above countries varied from a low of 2.5% per year in Argentina to a high of 13% per year in Indonesia. Other countries with average growth in excess of 10% per year were Iran, South Korea, and Thailand.

4.2. Change in Power Sources for Electricity Generation

For some countries, statistics are not reported on utility fossil-fired electricity generation by fuel type. Instead, generation is reported by plant type (i.e., steam, gas turbine, diesel). In these cases (Indonesia, Malaysia, Pakistan, Taiwan, Argentina, and Venezuela; India for the split between oil and gas), we made estimates of generation by fuel based on shares of fuel consumption by utilities (expressed in a common energy value).

Figures 4-1 through 4-7 show electricity generation by source in the 1980-1990 period for the 13 countries. We present industrial self-production separately; most self-production relies on oil as a power source, but other sources are also used in some countries. The main features are briefly described below. (The percentages refer to total generation, including self-production.)

[1] Unless noted otherwise, all figures in this chapter representing electricity generation include estimated industrial generation for own use.

Table 4-1
Average Growth in Electricity Generation in 1980-1990 and Generation in 1990

	%/year 1980-90	TWh 1990
EAST ASIA		
China	7.4	615
Indonesia	13.0	49
Malaysia	8.6	23
Philippines	4.6	28
South Korea	11.1	115
Taiwan	7.5	90
Thailand	11.3	46
North Korea*	4.3	53
Hong Kong*	8.6	29
SOUTH ASIA		
India	9.2	289
Pakistan	9.7	44
MIDDLE EAST		
Saudi Arabia*	9.6	47
Iran*	12.6	56
LATIN AMERICA		
Argentina	2.5	51
Brazil	5.7	241
Mexico	6.0	121
Venezuela	5.2	61
Colombia*	4.6	36
AFRICA		
South Africa*	6.2	165
Egypt*	8.9	40

* UN data

4.2.1. Asia

CHINA. Electricity generation from coal increased its share from 55% to 64%, while the share of oil declined. While hydro generation more than doubled in absolute terms, its share remained about the same.

INDIA. The share of coal in total generation increased from 51% in 1980 to 62% in 1990. The share of hydro declined considerably from 39% to 25%. Industrial self-production has risen slightly in share to 8%. Most of the larger steel and cement plants have their own generating stations based on coal; many industries also have their own diesel generator sets.

INDONESIA. Self-generation (which primarily uses oil) plays a much larger role in Indonesia than in any of the other 13 countries for historical and geographic reasons, but its share declined from 42% in

1980 to 29% in 1990. In terms of kWh, self-generation has risen substantially, but not nearly as fast as utility generation. A small part of the increase in utility generation is due to increased supply to industries that formerly relied on self-generation. For utility generation, oil has declined in share as generation from coal rose considerably from 1985 onward.

MALAYSIA. The share of oil declined greatly from 80% in 1980 to 45% in 1990. Both natural gas and coal have to come to play significant roles (21% and 12% of generation in 1990, respectively), and the share of hydro increased considerably as well (although 1990 was a very poor year for hydropower).

PAKISTAN. In contrast to most other countries, the share of oil has increased in Pakistan, as domestic supplies of natural gas have been insufficient. The use of fuel oil was helpful since Pakistan's refineries previously had to export fuel oil in order to meet the demand slate, which was skewed toward diesel products. Hydro still plays a major role (42% in 1990), but its share has fallen since 1980.

PHILIPPINES. Dependence on oil continued its previous decline between 1980 and 1985, but has risen since then (to 41% in 1990) as gas turbines and diesel powerplants have been added to meet near-term demand. The share of geothermal rose in the 1980-1985 period, but has declined slightly since. The share of coal rose considerably in the 1983-1988 period, but has fallen since then. Hydro increased in share from 19% in 1980 to 27% in 1986, but then declined due in part to low rainfall. Self-production increased in significance in 1989-1990 as industrial output began to recover while the utility's supply situation deteriorated.

SOUTH KOREA. Dependence on oil fell sharply from 73% in 1980 to only 6% in 1987 as nuclear power and (to a lesser extent) coal came to play major roles. The share of oil rose in 1988-1990, however, as existing capacity was utilized to meet the rapid increase in peak electricity demand. The share of coal declined from its 1985 high of 28% to 17% in 1990. Natural gas (imported LNG) has accounted for 8-11% of generation since 1987.

TAIWAN. The experience in Taiwan is similar to that of South Korea. Oil declined in share for most of the 1980s as nuclear power and coal rose in importance, but generation from oil rose in the late 1980s in order to keep up with growth in power demand.

THAILAND. Here also oil's role fell greatly for most of the 1980s but then rebounded in 1988-1990. In this case it was natural gas that rose the most in share (to 55% in 1988), but its share was only 38% in 1990. Coal (lignite) increased its share in 1990 (to 24%) as new capacity came on line.

4.2.2. Latin America

ARGENTINA. The shares of different power sources fluctuated in the 1980s as hydro production varied with rainfall. The role of natural gas in thermal generation rose in the late 1980s. Problems with the nuclear powerplants have limited their output.

BRAZIL. Hydropower continued to dominate generation.

MEXICO. The share of oil has remained at about 50% since 1980. Hydro declined in share, as total generation from hydropower was roughly the same in 1990 as in 1981. The role of gas fell somewhat. Nuclear power (from the controversial Laguna Verde plant) began to play a role in 1990.

VENEZUELA. The share of hydro rose significantly as new capacity was brought on line. Oil's share fell from 33% to only 10%, while natural gas rose in share.

4.2.3. Summary

Table 4-2 shows the change in importance of different power sources for the 13 countries combined. (The total is dominated by China and India, which accounted for 35% and 16% of total generation, respectively.) While oil increased in importance from 1970 to 1980, it decreased substantially in the 1980-85 period. The fall in share from 1985 to 1990 was much smaller, however, reflecting the sharp decline on oil prices after 1986 and the greater need for use of oil-fired peaking plants in a number of countries. Hydro declined in relative importance from 1985 to 1990, but the low level in 1990 was partly due to low rainfall in several countries. The most significant increase was in the role of coal: from 28% in 1980 to 37% in 1990. The share of nuclear power grew substantially from 1980 to 1985, but rose only slightly thereafter.

Table 4-2
Power Sources for Utility Electricity Generation, 1980-1990
Combined Data for 13 Countries (%)

	1980	1985	1990
Hydro	34	35	31
Oil	24	14	12
Natural gas	3	4	5
Coal	28	33	37
Nuclear	2	5	6
Geothermal	0	1	1
Self-production	7	8	8

Table 4-3 shows the mix of power sources in each of the 13 countries in 1990. China and India are the only countries where coal dominates the picture, though it is significant (>20%) in Indonesia and Thailand. Oil is the dominant source in Indonesia, Malaysia, the Philippines, and Mexico, while gas is important (>25%) in Thailand, Pakistan, and Argentina. In all cases except the Philippines, the fuels come from domestic production. Hydropower is important in many of the countries, and is the main source in Brazil and Venezuela. Nuclear power is very prominant in South Korea and Taiwan, and is a minor source in Argentina, India, Mexico, and Pakistan. Geothermal power is significant in the Philippines and also plays a role in Indonesia and Mexico. If self-production were broken out by source, the share of oil would be larger, since most self-production relies on oil products (mainly diesel).

Table 4-3
Shares of Electricity Generation in 1990 by Power Source (%)

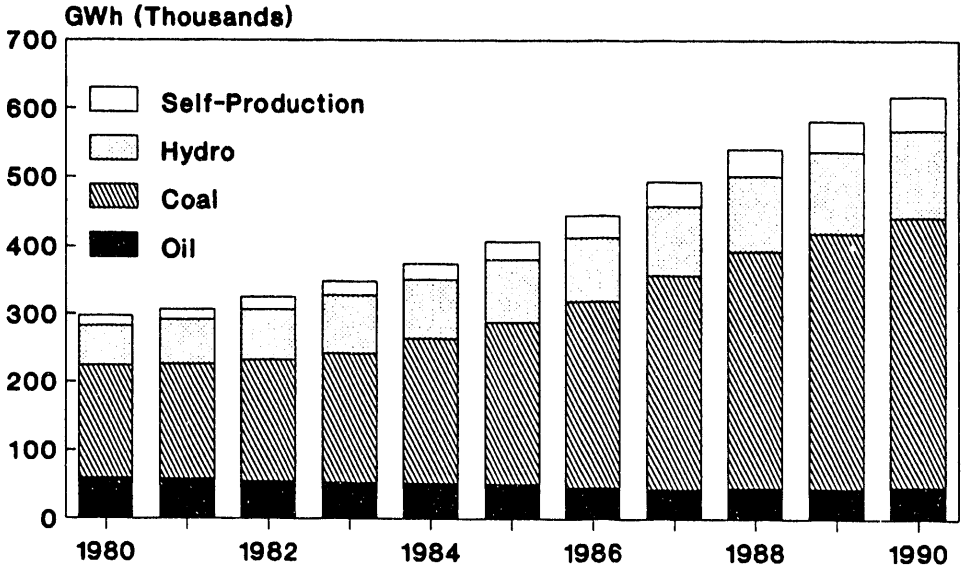
	Oil	Gas	Coal	Hydro	Nuclear	Geo.	Self-Prod.*
ASIA							
China	8	0	64	20	0	0	8
India	1	1	62	25	2	0	8
Indonesia	35	3	20	12	0	2	29
Malaysia	45	21	12	17	0	0	5
Pakistan	20	32	0	42	1	0	5
Philippines	41	0	6	21	0	19	12
South Korea	16	8	17	6	46	0	6
Taiwan	24	1	14	9	36	0	5
Thailand	22	38	24	12	0	0	3
LATIN AMERICA							
Argentina**	14	28	1	36	14	0	7
Brazil	1	0	1	93	0	0	4
Mexico	51	11	6	19	2	4	7
Venezuela	10	22	0	60	0	0	8

* Mainly from oil products.

** The split of thermal generation into oil, gas, and coal is an estimate.

Figure 4-1

Electricity Generation by Source
China



Electricity Generation by Source
India

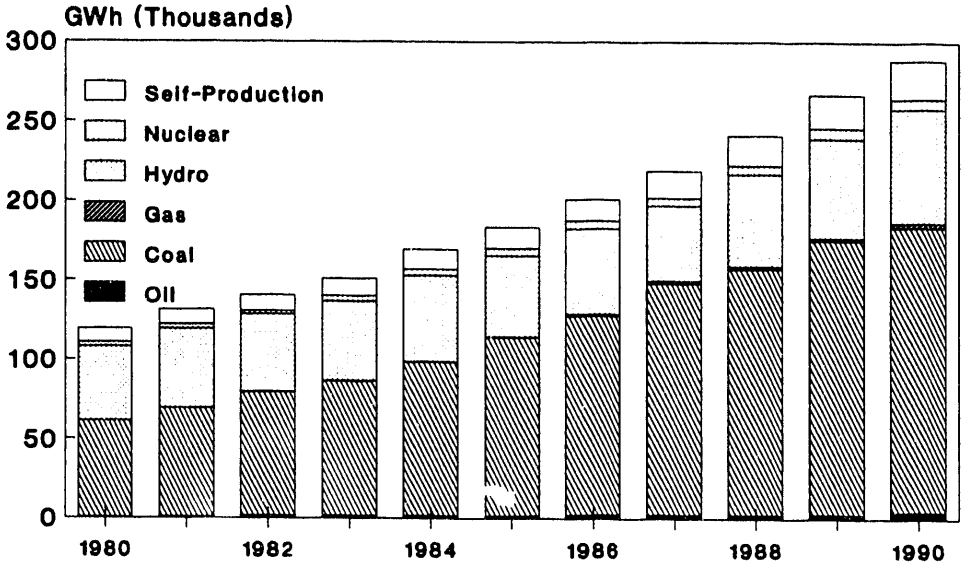
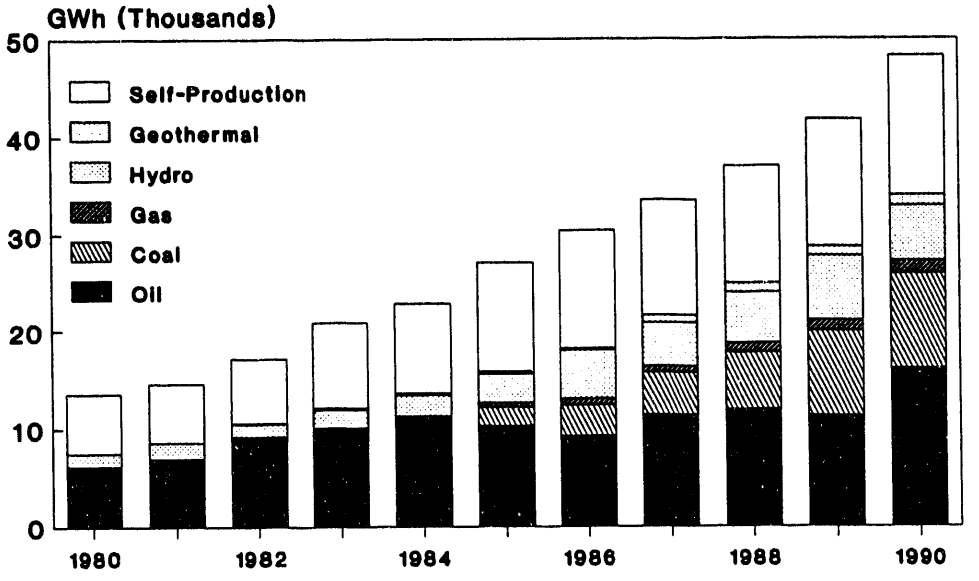


Figure 4-2

Electricity Generation by Source
Indonesia



Electricity Generation by Source
Malaysia

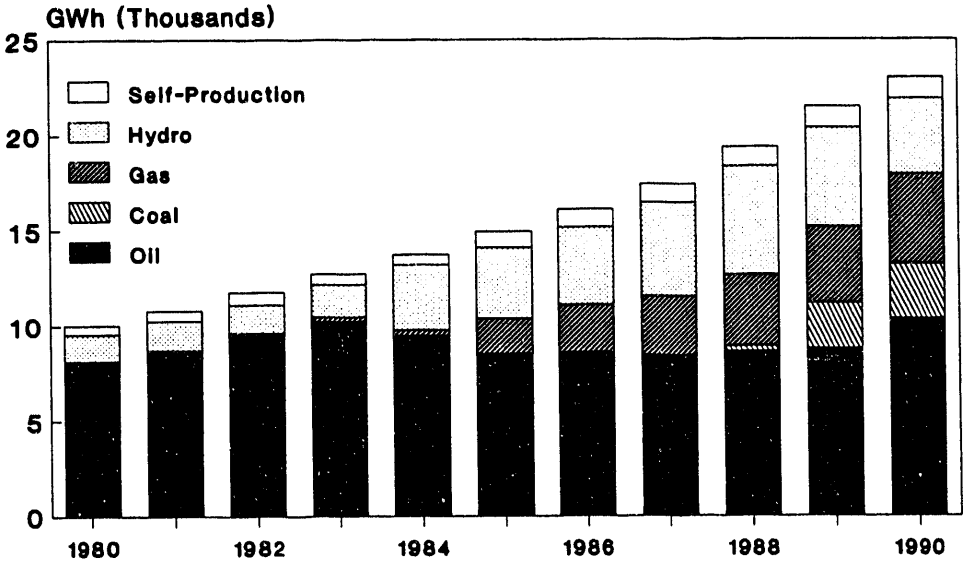
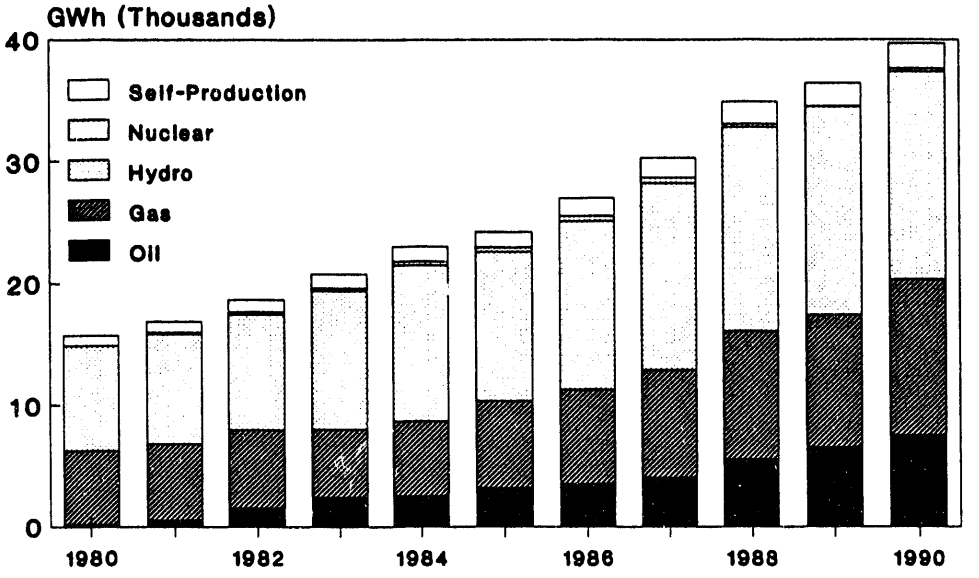


Figure 4-3

Electricity Generation by Source
Pakistan



Electricity Generation by Source
Philippines

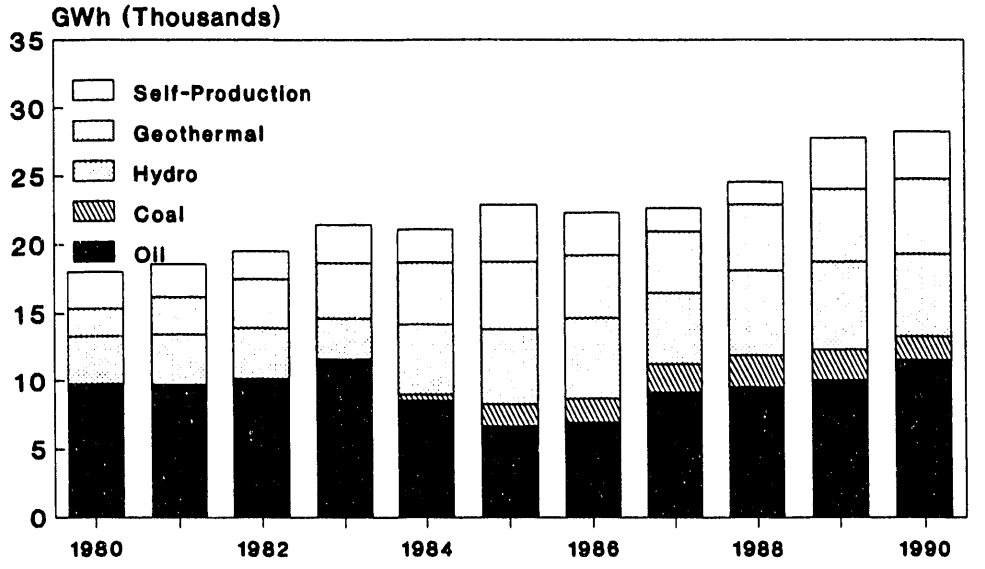
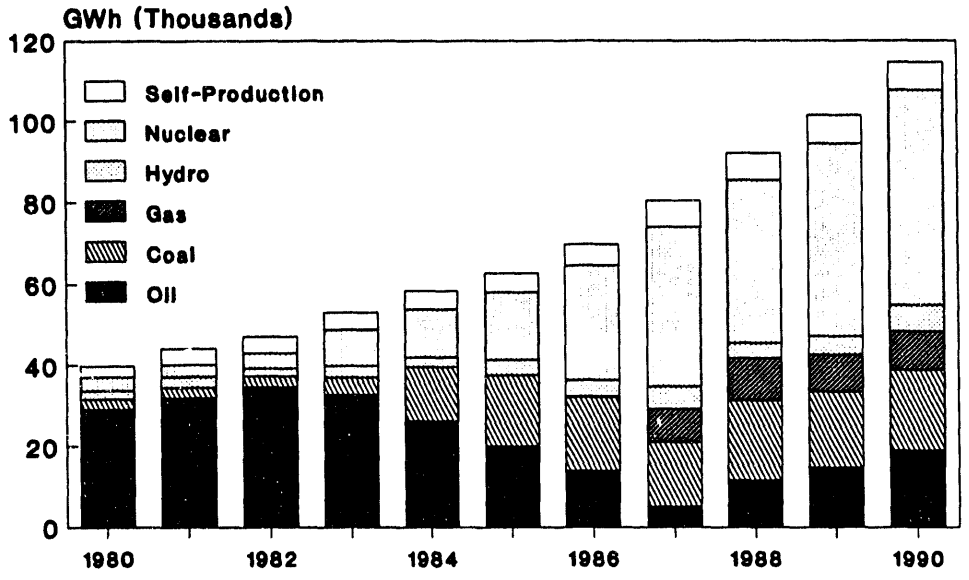


Figure 4-4

Electricity Generation by Source
South Korea



Electricity Generation by Source
Taiwan

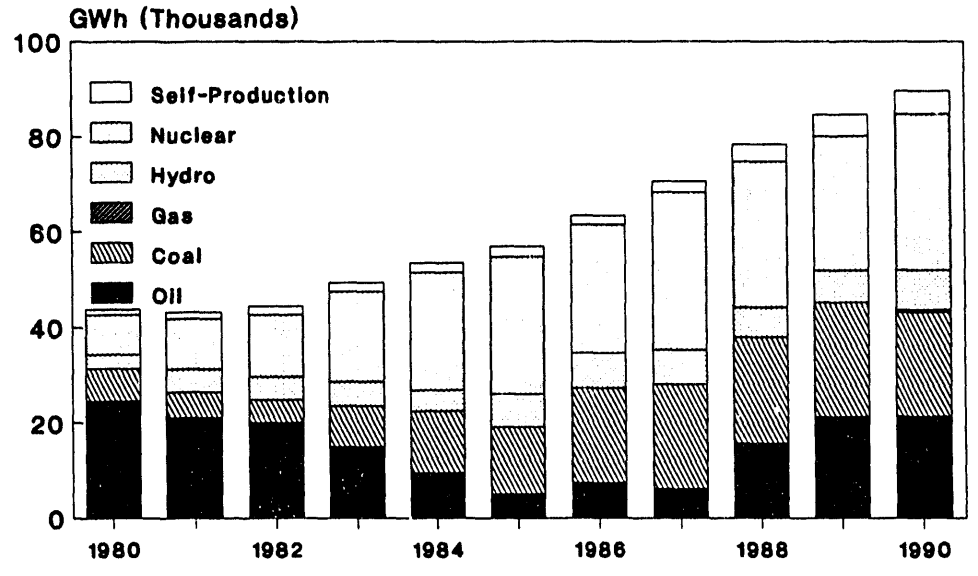


Figure 4-5

Electricity Generation by Source
Thailand

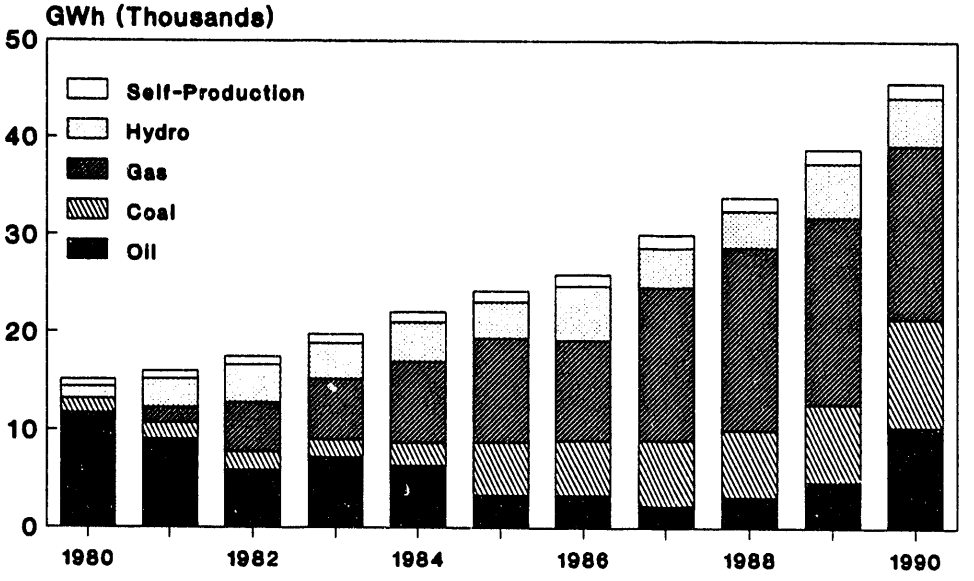
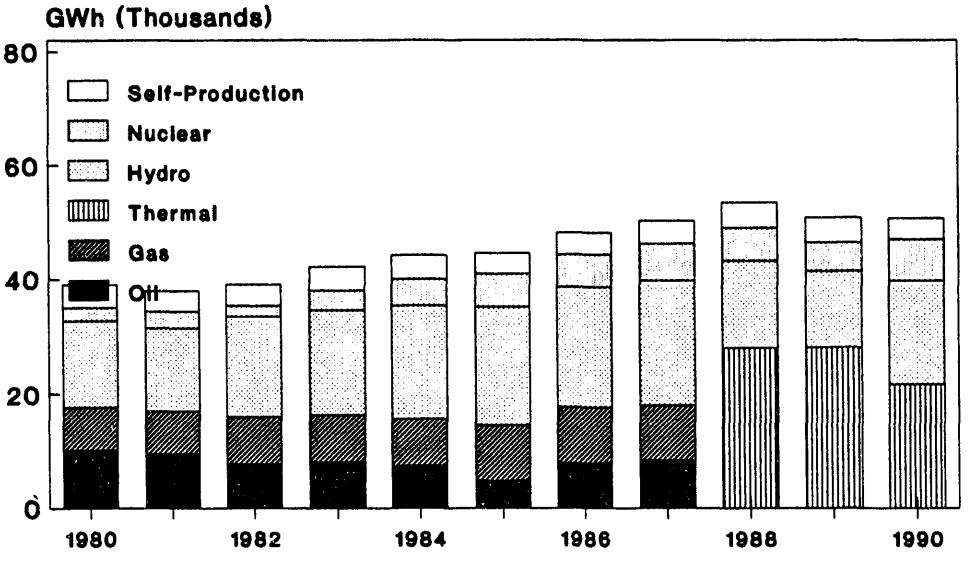


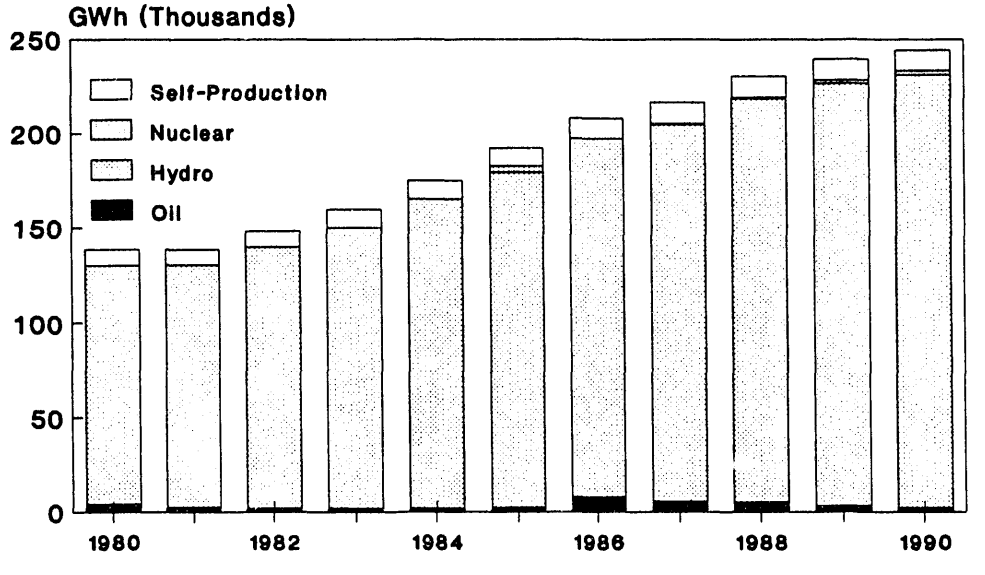
Figure 4-6

Electricity Generation by Source
Argentina



Note: 1988-90 thermal breakdown not available.

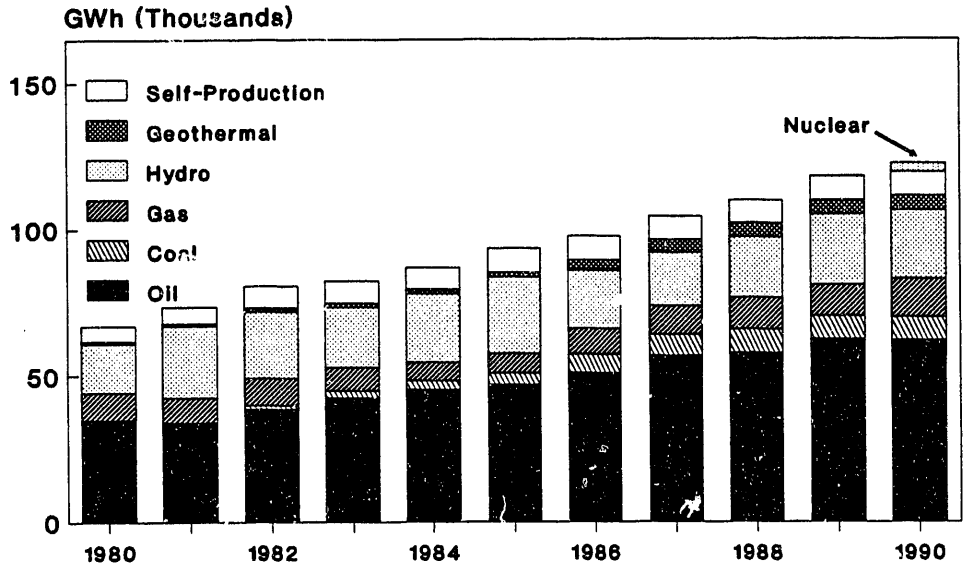
Electricity Generation by Source
Brazil



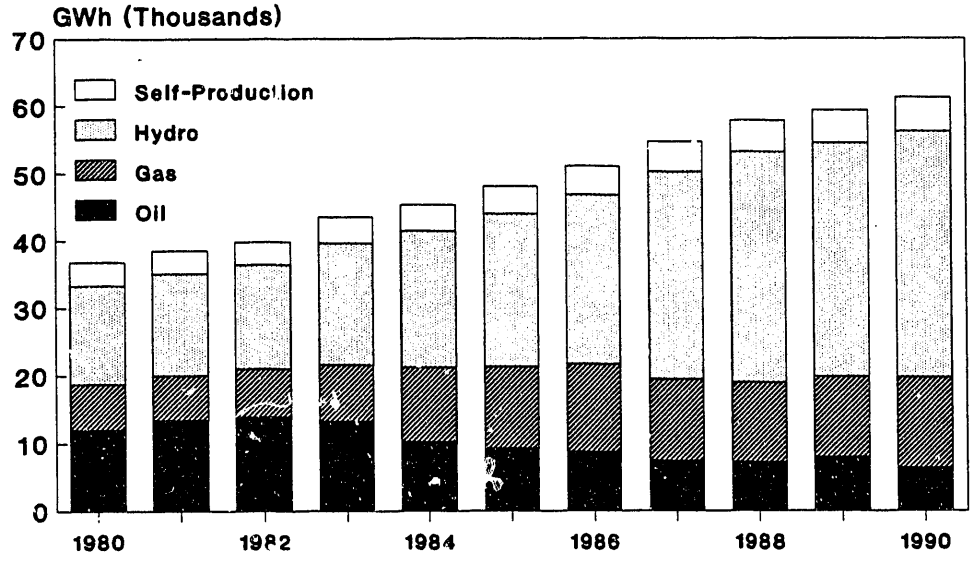
Note: Hydro includes electricity imports

Figure 4-7

Electricity Generation by Source
Mexico



Electricity Generation by Source
Venezuela



5. EFFICIENCY OF ELECTRICITY SUPPLY

A relatively small part of the energy that goes into electricity generation reaches end users. Energy is lost in conversion to electricity; a portion of gross generation is used at power plants; and a part of the electricity that leaves power stations is lost in transmission and distribution (T&D). In this chapter we describe what the data show in each of these areas, and discuss some of the key issues.

5.1. Efficiency of Electricity Generation

We estimated the average efficiency of utility thermal (fossil) electricity generation using data from national sources on fuel use by electric utilities.[1] As shown below, the values in 1990 ranged from around 25% in China and India to 37-38% in S. Korea, Taiwan, and Thailand. The low values in China and India reflect the age and deteriorated condition of much of the installed fossil capacity and the poor quality of the coal that dominates thermal generation. By contrast, the high values in S. Korea, Taiwan, and Thailand reflect the relative newness of much of the installed capacity, as well as good operational and maintenance practice.

Table 5-1
Efficiency of Utility Electricity Supply in 1990

	Thermal efficiency (% of fuel input)	Plant use (% of gross gen.)	T&D losses (% of net gen.)
ASIA			
China	26	8	16
India	24	9	23
Indonesia	33	5	16
Malaysia	33	5	11
Pakistan	30	3	22
Philippines	-	4	14
South Korea	38	7	6
Taiwan	37	7	7
Thailand	37	4	11
LATIN AMERICA			
Argentina	29	5*	18*
Brazil	-	2	14
Mexico	33	5	14
Venezuela	33	2	19

* Estimated based on 1988 data.

[1] We have not included data on the Philippines because the reported data appear to be in error.

Change in the average thermal power plant efficiency in 1980-90 is shown in Figure 5-1. (Large annual fluctuations are likely due to erroneous data.) The data show some improvement in average efficiency in a number of countries. The major reason is addition of new powerplants. In Asia in particular, a considerable share of the installed capacity in 1990 was built in the 1980s. In many cases, the average size of new plants has risen, and these larger plants operate with relatively high efficiency. This was the case in India, where the average efficiency rose from around 21% in 1980 to 24% in 1988. In China, by contrast, the slight decline in efficiency after 1987 may be partially due to the addition of many relatively small powerplants in rural areas.

The types of fuel and powerplants that are utilized shape the average thermal efficiency. For example, the improvement in Thailand in the first half of the 1980s and the increase in Malaysia since 1985 both reflect the installation of gas-fired combined-cycle power plants, which operate with high efficiency. On the other hand, the decline in Thailand after 1987 is probably due to the growing reliance on lignite-fired power plants. Installation of combined-cycle capacity was also a factor in Mexico, where the average efficiency rose modestly in the 1980s despite the financial difficulties of the national utility.

5.2. Power Station Use

Among the study countries with available data, power station use of electricity in 1990 ranged from 2% of gross generation in systems dominated by hydropower (Brazil and Venezuela) to 9% in India. As India and China illustrate, power station use is relatively high in systems that rely heavily on coal (due to conveyor belts, etc.). In general, auxiliary electricity use of coal-fired powerplants built over the past decade has risen due to application of air pollution control technologies. Modern electrostatic precipitators for particulate control have been routinely fitted to new coal-fired power plants financed by the World Bank over the past decade. Auxiliary use is also relatively high where nuclear power is significant (due to pumps and safety-related equipment), as South Korea and Taiwan illustrate.

The high use in India also results from the way in which power plants are dispatched on the integrated grids. The generally newer and more efficient plants operated by national companies (for thermal and hydro plants respectively) are usually given priority over the plants operated by the State-owned utilities. Many of the in-house demands for electricity in the latter (lighting, etc.) must still be met even if only a small fraction of the capacity is being used.

5.3. Losses in Electricity Delivery

The data on T&D losses include both technical losses in power supply and non-technical losses due to theft, illegal connections, and lack of metering and/or billing. For the study countries, T&D losses in 1990 ranged from only 6-7% of net generation (gross generation minus auxiliary use) in South Korea and Taiwan to over 20% in India and Pakistan. Differences in the level of losses are attributable to the length and voltage of transmission and distribution lines, other technical factors, and the extent of non-technical losses. Countries with extensive low-voltage rural electricity supply (such as India and China) tend to have high T&D losses. Losses in Brazil are higher than otherwise due to the long transmission distance from hydro stations inland to load centers on the coast.

Data from the World Bank for a group of 100 LDCs show that losses in 1988 were below 10% in only seven countries.[2] They were in the 10-15% range for 35 countries, in the 16-20% range for 29

[2] J. Escay, *Summary 1988 Power Data Sheets for 100 Developing Countries*, Washington, DC: World Bank, August 1991. Although these data are reportedly for T&D losses only, in a few cases they appear to also include power station use.

countries, in the 21-30% range for 22 countries, and were over 30% in seven countries.

In the industrial countries, T&D losses in the 6-9% range are regarded as good. Even with good equipment and maintenance, one would expect a somewhat higher level of technical losses in LDCs, since most of these systems have lower transmission voltages and distribution systems spread over wide areas. Nonetheless, there is clearly much room for improving technical performance. In many cases, a large share of technical losses are incurred at the end of the distribution system, especially in low-tension feeders and distribution transformers. Studies indicate that this area accounted for 35-43% of total technical losses in Bangladesh, Kenya, and Madagascar in recent years.[3] Substandard distribution systems that lead to losses are also responsible for voltage fluctuations and power outages.

The contribution of non-technical losses is difficult to measure (it requires a thorough calculation of the actual technical losses), but it is evidently considerable in many countries. For six countries, a World Bank study reported estimated non-technical losses that ranged from 4% to 22% of net generation.[4] Properly speaking, non-technical losses should be counted as electricity consumption (although it is a loss from the perspective of the utility). Although the potential pay-off for reducing non-technical losses is great, it has proven to be an elusive goal in many countries with high losses.

Changes in T&D losses for the study countries in 1980-90 are shown in Figure 5-2. Losses have increased somewhat in India, the Philippines, and Venezuela.[5] (The apparent increase in Malaysia may be due to data problems.) Losses declined in Pakistan (from 30% in 1980), but still remained very high. In other countries, the percentage has remained roughly the same. The increase in India reflects the expansion of rural electrification (with low-voltage distribution lines and other factors that contribute to losses) in the 1980s. In the Philippines, the rise in losses in the mid-1980s was partly due to increase in theft and problems in billing during the instability of that period; the situation improved thereafter.

Data from the World Bank for a much larger set of LDCs shows that average system losses remained stable at just over 20% between 1973 and 1981, but rose during the 1980s.[6]

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[3] U.S. Congress, Office of Technology Assessment, *Fueling Development: Energy Technologies for Developing Countries,* Washington, DC: U.S. Government Printing Office, April 1992.

[4] M. Munasinghe, J. Gilling, M. Mason, *A Review of World Bank Lending for Electric Power,* Washington, DC: World Bank, 1988.

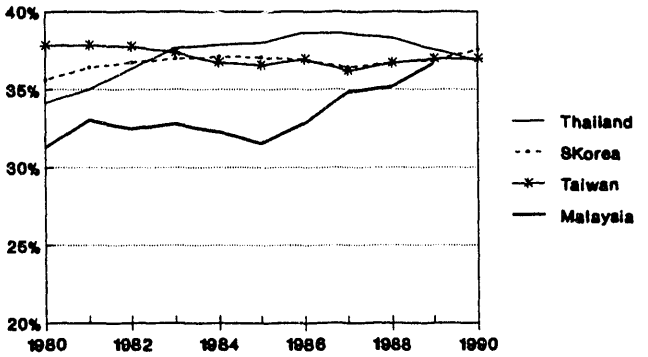
[5] Sharp year-to-year fluctuations may be due to inaccurate data. For example, sales that actually occured in 1980 may get counted in 1981 due to accounting problems.

[6] G. Schramm, "Electric Power in Developing Countries: Status, Problems, Prospects," *Annual Review of Energy* 15, 1990.

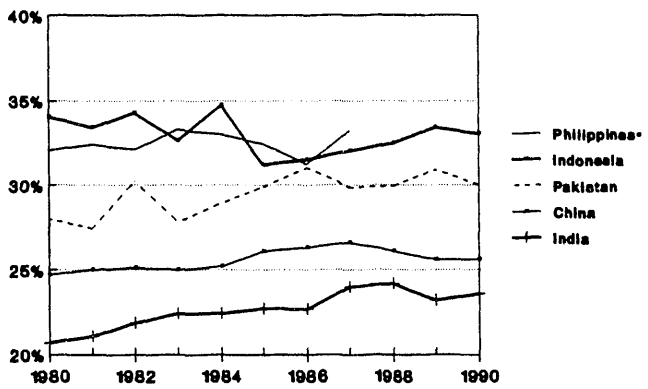
Figure 5-1

Thermal Power Plant Efficiency

Malaysia, SKorea, Taiwan, Thailand



China, India, Indonesia, Pakistan, Phil.



* Includes oil generation only.

Latin America

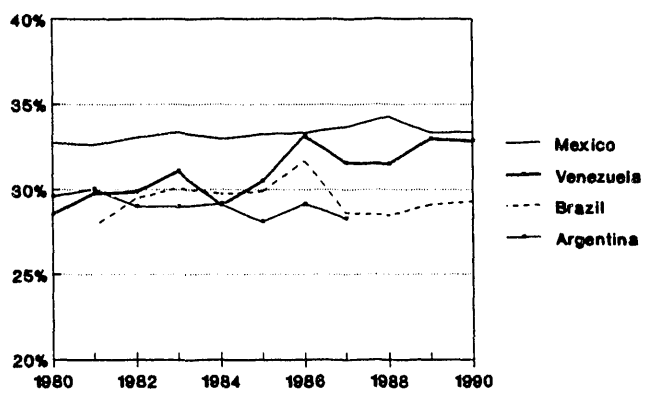
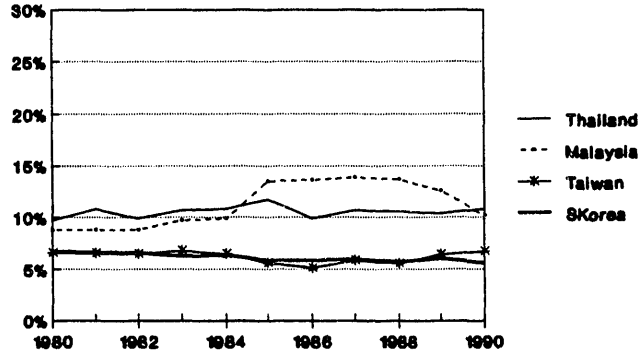


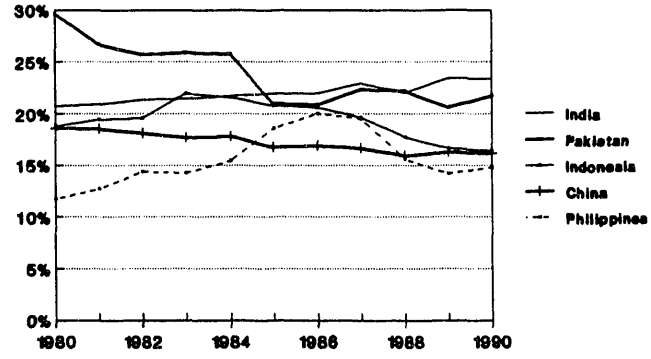
Figure 5-2

Electricity T & D Losses

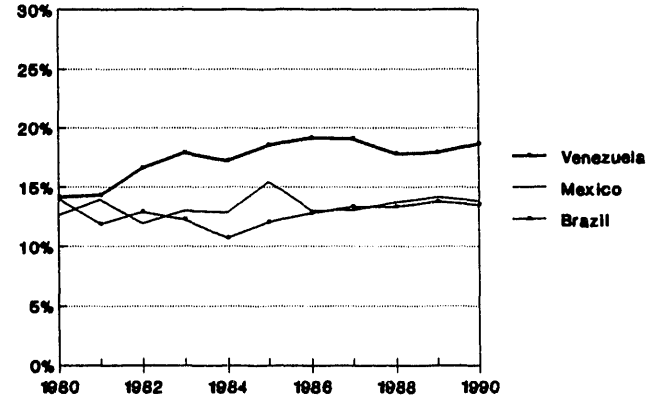
Malaysia, SKorea, Taiwan, Thailand



China, India, Indonesia, Pakistan, Phil.



Brazil, Mexico, Venezuela



6. CARBON DIOXIDE EMISSIONS FROM ELECTRICITY SUPPLY

We calculated carbon dioxide (CO_2) emissions by multiplying reported fuel use by utilities by carbon content factors.[1] This method somewhat understates total emissions from electricity supply since it does not include fuel use for industrial self-production.

Because of their large electricity generation and high degree of reliance on coal, China and India accounted for 52% and 24% of total CO_2 emissions from the 13 study countries in 1990. The other 11 countries together accounted for about as much as India alone. Total emissions have grown considerably in all cases, especially in China (Figure 6-1).

Among the countries, the level of CO_2 emissions per kWh of *total* electricity generated by utilities in 1990 rises with the thermal (fossil) share of generation, as one would expect (Figure 6-2). China and India are relatively high due to the dominance of coal, while Thailand is relatively low because natural gas is a very significant source.

The trend in CO_2 emissions per kWh of electricity has varied among the 13 countries (Figure 6-3). Changes are the result of both long-run shifts in the mix of energy sources used for power generation and annual fluctuations in hydroelectric production (refer back to Section 4).

In both China and India, there has been a slight upward trend since the mid-1980s. (The decline in India in 1990 was due to favorable hydro conditions.) The most marked declines were in South Korea and Taiwan, where nuclear power came to play a major role. In both cases, however, the ratio rose in the late 1980s as demand growth required greater use of fossil fuels. There was also significant decline in Venezuela, where hydro and natural gas became more important. The ratio declined in the Philippines as well due to growth in generation from hydro and geothermal energy.

Thailand has seen an upward trend since 1986 as the role of lignite has increased. The ratio also rose gradually in Pakistan in the second half of the 1980s as hydro production failed to keep pace with demand growth. The trend in Indonesia has been roughly stable; the jump upward in 1990 was due to a sharp rise in oil use. In Mexico, the ratio rose in the 1981-87 period, but it declined slightly thereafter as generation from hydro, natural gas, and (in 1990) nuclear power each increased slightly.

[1] The factors used are coal: 23.8 kg/GJ; oil: 19.4 kg/GJ; gas: 13.9 kg/GJ. These are in kg of carbon in carbon dioxide.

Figure 6-1

Carbon Emissions in Thermal Generation
13 Developing Countries

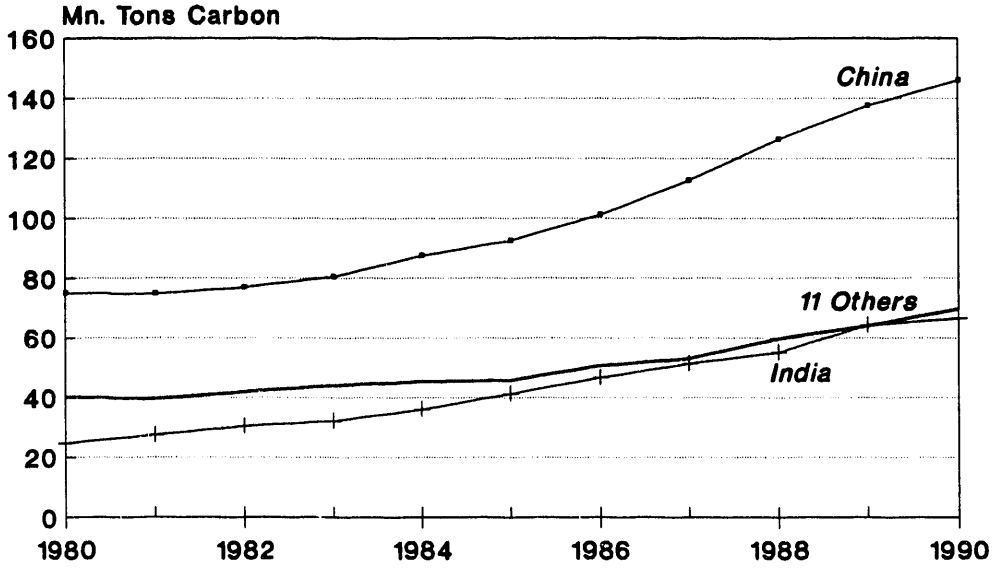


Figure 6-2

Carbon Emissions per GWh of
Utility Generation, 1990

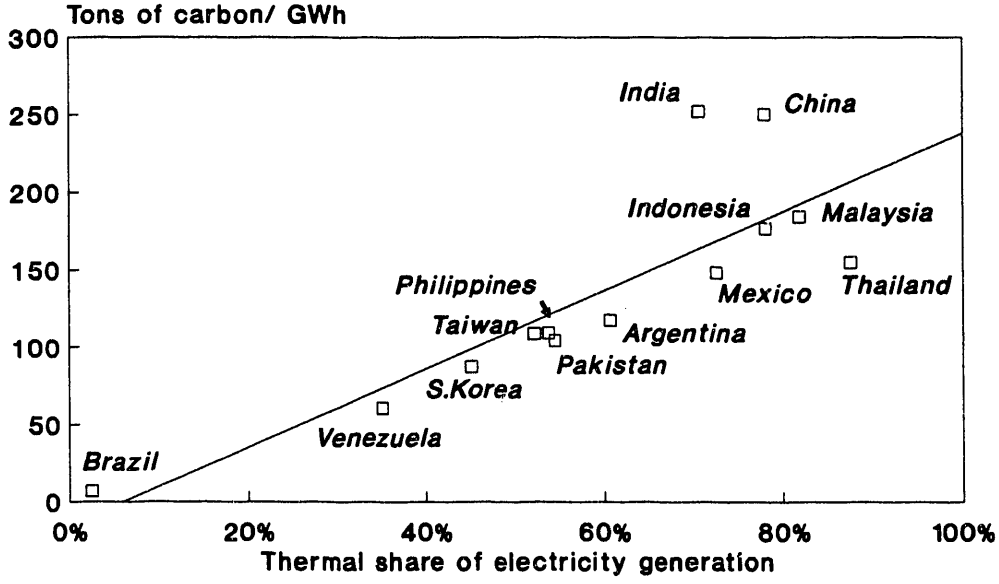
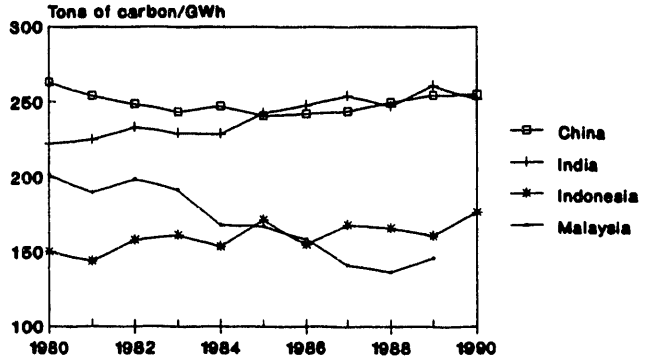


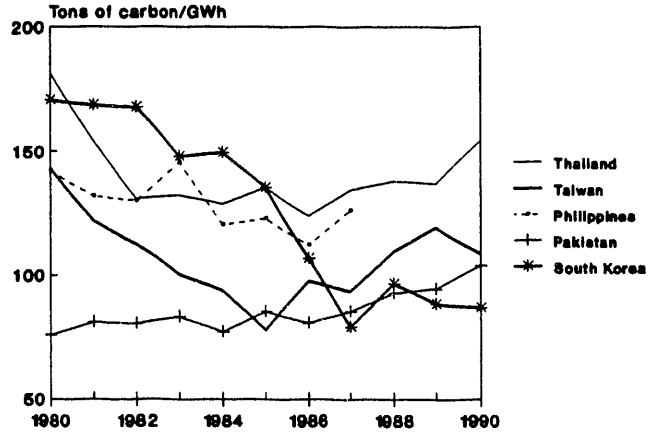
Figure 6-3

Carbon Emissions/GWh Utility Generation

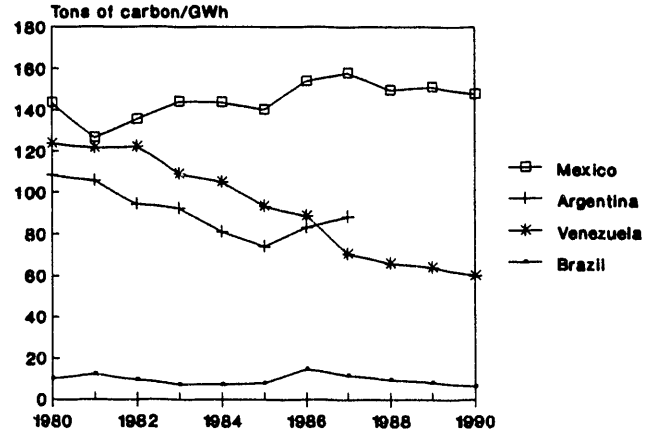
China, India, Indonesia, Malaysia



Pakistan, Phil, SKorea, Taiwan, Thailand



Argentina, Brazil, Mexico, Venezuela



7. SUMMARY AND CONCLUSION

Electricity production in the developing countries as a group averaged growth of nearly 7% per year in the 1980-90 period. This average obscures major differences among regions; generation grew much faster in China and the rest of Asia than in Latin America and Africa.

For 13 of the largest developing countries for which we assembled consistent data series, growth in electricity consumption ranged from only 4.2% per year in the Philippines to nearly 13% per year in Indonesia. In most cases, residential and commercial sector consumption grew faster than industrial use, although the latter still accounts for over half of total electricity consumption in most of the 13 countries.

The mix of power sources for electricity generation shifted strongly toward coal in the 1980s for the 13 countries as a whole. The share of coal in total generation rose from 28% in 1980 to 37% in 1990, while the share of oil fell from 24% to 12%. Most of the oil backout occurred in the first half of the decade; there was an increase in oil-fired generation in some countries in the late 1980s.

The importance of different sources varies considerably. Coal is the dominant source only in China and India, but these two countries together accounted for half of the total generation for the 13 countries. The share of coal rose in both China and India, and also increased in several other Asian countries. Natural gas became more important in Malaysia and Thailand, while oil continued to play a major role in Indonesia, Malaysia, the Philippines, and Mexico. For the 13 countries together, the share of hydropwer declined slightly, although it continued to play a dominant role in Pakistan, Venezuela, and especially Brazil.

The generating efficiency of thermal power plants increased in a number of the 13 countries in the 1980s as new powerplants came on line. The average efficiency varies considerably from only around 25% in China and India to over 35% in Malaysia, Thailand, South Korea, and Taiwan. T&D losses rose in some of the countries, but declined in others. Here too there is a wide range among the countries from only 6-7% in South Korea and Taiwan to over 20% in India and Pakistan.

Carbon dioxide emissions from electricity generation in the 13 countries rose considerably in the 1980s. Emission per total GWh generated are highest in China and India due to their heavy reliance on coal. The ratio rose in India in the 1980s, and also in Mexico, but declined in a number of the other countries as no- or low-CO_2 technologies came to play a greater role.

The future evolution of electricity demand and supply in the larger developing countries is the subject of a current project whose findings will be reported in 1993. The information presented in this report provides a background for consideration of future prospects. It shows that the evolution of the power sector in the 1980s was quite varied around the developing world. While some common trends are apparent, such as the relatively more rapid growth in residential and commercial consumption, in many areas countries have had differing experiences. Thus, generalizations across the the developing world must be made with care.

APPENDIX: DATA SOURCES

CHINA

State Statistical Bureau
Statistical Yearbook
Energy Statistical Yearbook

Metallurgical Industry Press
Energy in China

INDIA

Tata Energy Research Institute
TERI Energy Data Directory and Yearbook (TEDDY)

Ministry of Energy
Department of Coal Report
Department of Power Report

Ministry of Petroleum and Natural Gas
Statistical Report

INDONESIA

American Embassy, Indonesia
Indonesia's Petroleum Sector

MALAYSIA

Ministry of Energy, Telecommunications and Posts
National Energy Balances Malaysia

National Electricity Board
Statistical Bulletin

PAKISTAN

Ministry of Petroleum and Natural Resources
Energy Yearbook

PHILIPPINES

National Power Corp.
Annual Report

Bureau of Energy Utilization
Quarterly Review

National Economic and Developmental Authority
Philippine Statistical Yearbook

SOUTH KOREA

Ministry of Energy and Resources
Yearbook of Energy Statistics

DATA NOTES

China. The reported data on T&D losses from Chinese sources are known to be low as they only count transmission losses on large transmission systems. Thus, a portion of actual T&D losses are counted in Chinese statistics as part of sectoral consumption. Based on estimates from China that actual T&D losses are roughly twice those reported,[1] we assumed that the "uncounted" losses were in fact equal to reported losses. We then subtracted these "uncounted" losses from the sectors reported electricity use according to their shares of total reported electricity use in each year.

Philippines. Because consistent time-series data on national electricity consumption by sector are not available from country sources, the Philippines' consumption was derived in the following way: National Power Corporation generates electricity and sells to Meralco, (the main electricity distributor), to miscellaneous utilities, and directly to industry and some commercial operations. For each sector we totaled NPC sales, Meralco sales, and a share of the NPC sales to miscellaneous utilities (after deleting 15% for their transmission and distribution losses).

[1] F. Liu, W.B. Davis, M.D. Levine, *An Overview of Energy Supply and Demand in China,* LBL-32275, Berkeley, CA: Lawrence Berkeley Laboratory, May 1992.

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