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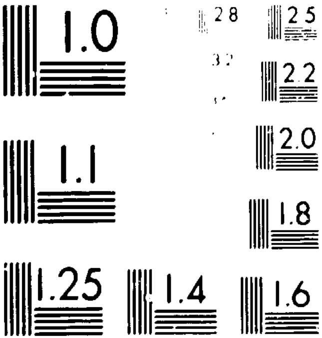
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INVESTMENT REQUIREMENTS OF DEVELOPING POWER INDUSTRIES FOR THE INDUSTRIALIZATION OF DEVELOPING COUNTRIES*

Prepared by the

Global and Conceptual Studies Branch

Division for Industrial Studies

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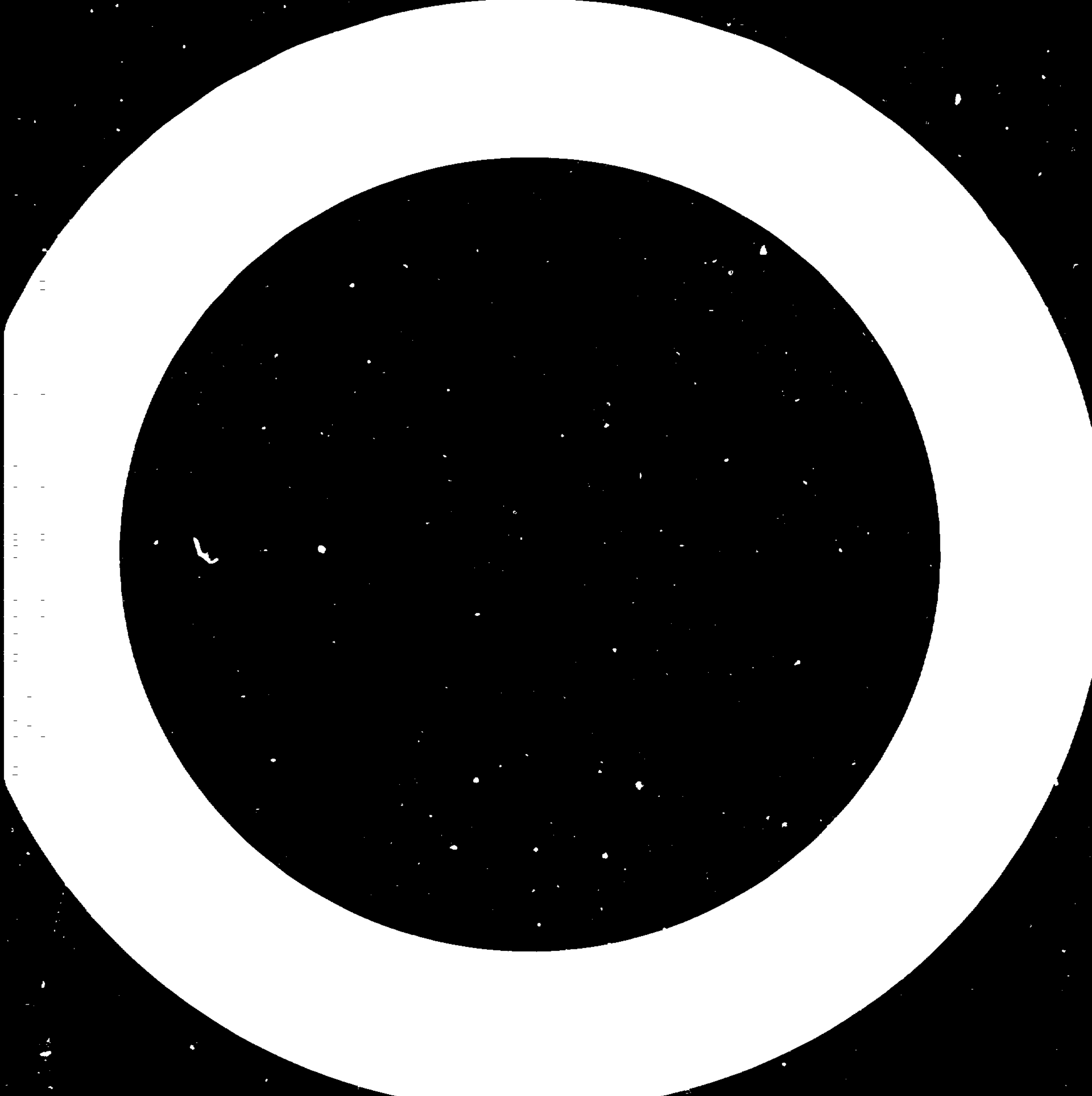

TABLE OF CONTENTS

Page

1. INTRODUCTION

Electricity is a vital element for development. Average electricity consumption growth rates for the developing world regions, even after 1973, range around 8% to 10%. The power sector claims one of the largest shares (18% to 20%) of public investment in most developing countries. It also claims the largest component of aid provided to developing countries. According to a World Bank estimate, nearly 34 billion dollars were invested in power industries in 1980.

Thus, power industries are one of the largest claimants of investment, aid and capital goods imports in the developing countries. Strangely enough, in spite of its importance, one rarely sees an overview of this sector. Although individual country studies are available, mostly carried out on an ad hoc basis (by IAEA, lending agencies and national governments), an integrated analytical study is necessary to deduce common features, to establish a framework for cross-country comparisons in order to guide policies for future developments, and to identify the scope of fruitful cooperation among developing and developed countries.

Today a large number of contracts are being signed every year between developing and developed countries without a clear perspective of objectives, and future directions. Even a reasonably self-reliant country like India has accumulated power plants from more than 19 countries each having different specifications, inventory of spares, maintenance schedules and requiring different training for personnel. Countries like Tanzania and Bangladesh are setting up rural electriciation programmes with the help of more than 4 countries, again each with its own characteristics.

Problems of standardization, the nature of contracts, regional cooperation, etc., can be discussed meaningfully only within a context of a systematic and analytical study that integrates the economical and technological aspects of power industry development in a number of developing countries.

In spite of the oil price increase, or for some countries because of it, the electricity demand will continue to increase due to the possibility of substituting electricity for oil for many end uses. Since electricity could be generated from hydro, coal, gas, nuclear energy, wind and other locally available options, its growth need not be as constrained as the growth of oil consumption.

Power industries offer one of the most important opportunities for cooperation between developed and developing countries. As can be seen later, the shares of developing countries in the world market for imports of power related equipment are very high. For example, in 1978, they imported 47% of the gas turbines, 37% of the switch gears, 56% of the insulated wires and cables and 65% of the steam boilers. In all, they imported nearly 12 billion dollars worth of power equipment.

In Section 2 the role of the power sector in the economy is described in terms of oil-substitution possibilities it offers for various sectors in the economy, viz. agriculture, household, industry and transport. The income elasticities and the share of the power sector in developing countries (DC) of investment and of world trade in power equipment are also briefly discussed.

In Section 3, the past and present trends of power* capacity (hydro and total), electricity production, capacity utilization and electricity conservation are reviewed.

In Section 4, a critique of three different methods of electricity projection is given first, followed by the use of each of these methods for projection with a discussion on the results.

Having established electricity demand up to the year 2000, investments for the power sector are estimated in Section 5. For this purpose discussions on T and D losses[1/], improvements in capacity utilization, cost coefficients for hydro, fossil and nuclear plants and their mix were necessary. The gestation periods and phasing were also discussed.

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* Power is the rate at which electricity is delivered; electricity is measured in energy terms (kilo-watt-hours - kWh) and power in terms of kilo-watt (kW). 1000 kW = 1 MW, 1000 MW = GW, 1000 MWh = GWh = 10^6 kWh, TWh = 10^9 kWh.

1/ Transmission and Distribution

Section 6 has been devoted to the least developed countries (LDCs) where past and present trends and special difficulties of the LDCs in the power sector, viz. economies of sale, unoptimal hydro-thermal mix, and high cost coefficients are explored using the Sahel region as an example. The nature of required cooperation is examined. Finally, Section 7 provides highlights and recommendations.

2. POWER INDUSTRIES: THEIR SALIENT FEATURES AND THEIR ROLE IN THE ECONOMY

2.1 Salient Features of Power Industries

Although regarded as part of the infrastructure, the power industry is a sizeable industry in its own right. However, unlike other industries, it is unique in several ways.

(a) The supply of electricity has to match the demand which fluctuates hourly, daily and seasonally. Moreover, it is expensive to store electricity and after its generation it requires its own grid system to transmit the electricity to the user. This is unlike other industries which can share transport systems among each other -- such as railways, trucks, ships, etc.;

(b) The components of power industries are power generation, transmission and distribution (TD). Each of these components require different hardware and management. Grid systems, i.e. TD for example, could require as much investment and manpower as the power generation. This is why power industries have very high incremental capital/output ratios (ICOR);

(c) There are a variety of ways of generating power -- coal, hydro, gas, oil, nuclear, etc. Although the user does not see the difference each one has different load characteristics and load fluctuations, i.e. base load and peak load. Thus, the grid system has to satisfy the fluctuating load demand by taking different mixes of hydro and thermal electricity, so that the costs are minimized for a given criterion of reliability. While fossil or nuclear based plants could be run without seasonal fluctuations, their operating costs are high; whereas the hydro-power, which has seasonal fluctuations, has very small operating costs.

2.2 Substitution of Electricity for Human and Animal Labour

In the formal and informal sectors of industry, in household activities done mostly by women and children, and in farming, electricity is gradually relieving humans and animals from backbreaking drudgery. In the formal and informal sectors of commerce, electricity is not only required to make routine tasks easier but also to improve the quality of products by increasing precision and uniformity. In animal labour used for irrigation, electric pumps are not only more efficient but also make land (needed to maintain and feed the animals) available for growing more food. (Animal labour vs. tractors is still a debatable issue for many developing countries depending on wage rates, diesel prices, capital costs, unemployment levels etc., but animal power vs. irrigation pumps is far less moot due to the nature of work and costs involved).

This does not necessarily mean that electricity reduces employment. On the contrary, it generates employment that previously did not exist and at the same time increases productivity. The surge in rural and urban industrial development would not be possible without electricity.

Unfortunately, the issue of substituting electricity for labour cannot be easily quantified for all the end-uses. However, it appears that this factor does contribute to high growth rates of electricity consumption.

2.3 Possibilities of Substituting Electricity for Oil

At the outset it must be stressed that using electricity in place of oil is not necessarily desirable if the electricity is produced from the oil itself. However, in some cases it is possible that the power industry uses fuel oil -- a residual product -- with high conversion efficiency saving more refined products, such as diesel oil or kerosene, used less efficiently in a number of scattered individual equipment.

The following countries that import oil have local resources to generate electricity, such as coal, hydro, gas, and geothermal resources which could be used to substitute imported oil.

- Coal resources (India, Pakistan, Afghanistan, Botswana, Tanzania);
- Gas resources (Afghanistan, Burma, Bangladesh, Pakistan, Thailand, Tanzania);
- Hydro resources: A number of countries, including many least developed countries;

-- Geothermal energy: Kenya, Pakistan;

-- Wind energy and Mini Hydro: Islands, mountain and coastal areas where oil is difficult to transport.

In developing countries, oil is used for many purposes for which electricity offers an efficient substitute. Thus, this diversifies their options and may reduce the bill of oil imports. These end uses in different sectors are discussed below.

(a) Household Sector: Developing countries do not have their rural areas electrified. Thus, rural and even poor households in the urban areas use kerosene lamps for lighting. This is the most inefficient use of oil (3% to 10% efficiency) and yet Bangladesh uses 90% of its imported kerosene for this purpose while its abundant natural gas reserves remain unutilized. For some countries, electricity used for cooking may be a better alternative than kerosene. Thus, electricity could be substituted for kerosene used for lighting and cooking;

(b) Agriculture Sector: Irrigation is essential for agricultural development and ground water irrigation offers the least capital intensive option which can be made available in a short time as opposed to some irrigation projects which require years of preparation. For such lift irrigation, diesel pumps, electric pumps and shallow and deep tube wells could be used. Diesel pumps are inefficient, and difficult to maintain and yet developing countries have to continue to use them in the absence of electricity. In some cases, electricity could be used for food processing instead of diesel oil or fuel oil;

(c) Industrial Sector: In the industrial sector, many processes which consume oil could be changed preferably to direct use of coal or locally available gas -- particularly in boilers and process-heat requirements. However, in some cases there are alternative processes which consume electricity, e.g., cement from wet processes vs. cement from dry processes which consumes more electricity instead of oil;

(d) Transport Sector: Oil could be substituted by electricity in two ways:

- Electrification of railways when the traffic densities are high, especially for freight transport. Diesel locomotives are less efficient than electric ones, and the additional investment for electric traction is well worth it for high traffic densities, especially for goods transport.

- Electric cars: For short distances within urban areas or towns, electric cars which are noiseless, pollution-free and cheaper to run and maintain for places where electricity could be cheaply generated. These vehicles are limited by the fact that they have low speeds and need frequent charging but are therefore suitable for vehicles such as police and postal vans, and other service vehicles going short distances. This could save considerable amounts of diesel oil.

(e) Commercial and Service Sector: In developing countries, there is a sizeable service sector which uses petromac and diesel generators for lighting and the latter also for running appliances. They consume kerosene, diesel oil or fuel oil. These uses of oil are also inefficient compared to the use of electricity.

Needless to say, some of the substitutions of oil by electricity would require rural electrification where there are doubts in some countries as they do not give adequate return on investment in the short run.

2.4 Interdependence of Electricity and Economy

Since electricity is a part of the infrastructure, it is difficult to quantify its role in terms of the gross-domestic product it generates. It may be quantified in terms of income elasticities, the proportion of investment it requires and the trade it generates in developing economies.

2.4.1. Income Elasticities for Electricity Consumption

If we compare the growth rates of GDP with electricity (from the world development report of the World Bank 1981) we observe that in general, the electricity/GDP ratio varies from 1 to 2.5 or as much as 3 in special cases. The latter is especially the case for more industrialized developing countries. In most countries, the electricity/GDP ratio is higher than the energy/GDP ratio which varies from 0.8 to 2. This gives evidence of the importance of electricity for the DC.

2.4.2. Share of the Power Sector in Public Investment

According to the World Bank (1981), the DC invested $34 billion in the power sector in 1980. Between 1980-85 Bangladesh plans to spend 14.5% of their development expenditure on energy, of which 69% will go for power. In Kenya, 10.5% of its capital formation in 1983 will be in the energy sector, most of which will go to the power sector. In India, according to the 1980-85 plan, 27% of the sixth plan expenditure will go to the energy sector, and of that 70% will go into the power sector. Such predominance of the power sector in the energy plan has been questioned recently and the DC have been encouraged to invest in new and renewable energy resources. This will no doubt be a welcome change if the projects with feasibility studies are prepared urgently. However, the predominance of the power sector in the plans are due to three major reasons:

(i) The power sector is in its early stages of development. This can be seen from the low per capita electricity generation that one finds in the DC;

(ii) As the payments for oil come from annual expenditures the power sector remains a major item in the investment plan unless a country has major indigenous resource development programmes for coal, oil, or gas. This is why in Kenya the share of power in the energy plan is nearly 100%;

(iii) Power plants have high capital output ratios and even countries like India which have plans to develop coal mines and oil wells, spend 70% of their energy investment in the power sector.

2.4.3. Shares of Developing Countries in the World Market for Power Equipment

Power sectors generate considerable trade between developing and developed countries. In 1978, $12 billion worth of power-related equipment was imported by developing countries. Table 2.1 shows that their share in the world market in 1978 was 65% for steam boilers, 47% for gas turbines, 50% for power machinery, 56% for insulated wires, etc. If the demand is sufficient at home, if enough technological capabilities are found to make precision equipment and unless barriers are created for imports from existing industries then the DCs may not find it worthwhile to develop this industry.

Thus, only countries like Brazil, India, Mexico, etc., could hope to be self-reliant. The rest of them could develop partial manufacturing capabilities. Even so, it is clear that this would remain an area for cooperation between developing and developed countries for a long time to come.

3.1. Review of Recent Trends in Power Generation

3.1.1. Capacity for Power Generation

As shown in Table 3.1, of the 1914 GW capacity of electricity generation in the world in 1979, the developed countries created roughly 69% of the total (see tables). Another 21% was created by the centrally planned countries.

Table 2.1. Shares of developing countries in the world market for imports of power-related equipment* (1978).

	SITC No.	Total in US-$M	Dvlpg. Countr. %	Africa Dvlpg. %	America Dvlpg. %	Mid East %	Far East %
Steam boilers*	7111	665	64.7	10.1	11.6	27.0	15.8
Steam turbines*	7113	346	34.5	1.5	9.1	16.5	7.3
Gas turbines*	7116	438	46.6	11.7	11.9	21.2	5.6
Eelc.power machinery	7221	4205	50.4	10.7	10.8	18.6	10.2
Switch gears	7222	3358	36.7	7.3	6.9	13.2	9.2
Insulated wires	7231	1805	56.1	12.7	4.2	29.1	10.0
Elec.measrg. control eq.	7295	930	19.4	3.4	5.9	5.7	4.4
Elec. condensers	72995	271	22.3	0.6	5.2	2.1	14.4
		12018					

Source: Yearbook of International trade statistics, United Nations.

*Major fractions of the equipment is likely to be used by power industries but some of it could be also used by other industries. On the other hand, the list given does not include all possible items required by power industries.

The remaining 10% or so was created by all other developing countries put together. The developing countries raised the proportion of their power generation capacity to 10.7% by 1979 from 8.6% in 1970. Out of the 204 GW capacity in 1979, Africa*, America*, and the Far East* had 21, 92, and 68 GW capacity respectively. Within the developing countries, African regions came last consistently on the ladder. In fact, the proportion of their power generation capacity within the developing countries, including countries of the Mid-East, fell to 10.3% in 1979 from 13.4% in 1970. Compared with the world situation, the African region had only 1.1% of the total capacity.

Within the developing countries, the Latin American countries could raise the proportion of their power generation capacity to 45.1% by 1979 from 43.3% in 1970. Compared with the overall world situation, the countries had only 4.8% of total capacity. However, the share of capacity build-up by the Far East regions was around 33% within the developing regions and had only 3.5% of the total capacity in the world.

Hydro-Power: Overall in the world, the share of the capacity created in hydro-electric plants decreased from 26% to 23% during 1970-1979, the corresponding figures for the developed part of the world being 26% to 21.6% (see Table 3.2). The share of hydro remained the same (around 19%) during 1970-1979 in the centrally planned countries. In the developing countries the share of hydro power was around 39%.

However, within the developing countries there had been a striking difference from one region to another regarding the pattern of creation of additional hydro-capacity. In both the African and American parts of the developing world, the share of hydro-electric generation capacity increased over time, while the reverse had been the case with the Far Eastern part of the developing world.

3.1.2. Electricity Production

Table 3.1 gives details on the levels of production of electricity. The world situation shows a growth rate of 5.42% between 1970 and 1979.

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*Throughout this paper we consider developing countries within these world regions, i.e. excluding South Africa, North America, Japan, etc.

Table 3.1. Power Capacity and Electricity Production for Different World Regions.

World Regions*	Total Capacity of Electricity Generating Plants GW 1970	1979	Electricity Production (in 1000 million kWh) 1970	1979	1970–1979 Growth Rate
World	1125	1914	4954	7966	5.42
Developed Economies	783	1312	3489	5219	4.58
Centrally Planned Economies	244	397	1114	1968	6.53
Developing Economies	97	204	350	778	9.28
Africa, Dvlpg.	13	21	39	79	8.16
America, Dvlpg.	42	92	160	343	8.84
Far-East, Dvlpg.	32	68	124	276	9.30

GW = Gigawatts = 10^9W = 1000 MW = 10^6kW

TWh = Terawatt hours = 10^9kWh

Source: Yearbook of World Energy Statistics (1980), UN, New York.

*For definitions see the reference above.

Table 3.2. Hydro-electric Capacity and Production.

World Regions	Power Capacity in million kW 1970	1979	Elec. Production TWh 1970	1979	1970–79 Growth Rate
World	290	440	1175	1721	4.33
Developed Economies	205	283	843	1090	2.90
Centrally Planned Economies	47	77	176	298	6.03
Developing Economies	38	79	156	333	8.79
Africa, Dvlpg.	7	12	28	53	7.35
America, Dvlpg.	18	45	81	190	9.94
Far East, Dvlpg.	10	17	41	72	6.46

Source: Yearbook of World Energy Statistics (1980), UN, New York.

The growth rate of production in the developed economies is less than that of the world's growth rate. While the centrally planned economies showed a growth rate of 6.5% over this period, the developing world's corresponding figure was 9.28%.

Within the developing countries; the African region had been lowest on the ladder with an 8.16% growth rate, and the Far East had been highest with a 9.30% growth rate.

Pattern of electricity production: Table 3.2 gives details on the levels of electricity production through hydro-plants. It can be seen from Tables 3.1 and 3.2 that except in the Latin American countries, in the rest of the regions the growth rates shown in Table 3.2 (hydro) are less than the growth rates shown in Table 3.1. This implies that in most of the world, the hydro-plants contributed at a relatively less rate than compared to non-hydro plants (thermal, etc.) towards the overall increase in production of electricity in the 1970s. This is particularly less in the developed part of the world.

3.2 Trends in Electricity Consumption

In general, according to UN statistics the difference between electricity production and consumption is small, if any, and is only due to exports or imports from neighbouring countries. With present technology and unit sizes in the developing countries, electricity could be transported up to 400 to 600 kilometers at most. The transmission and distribution losses in DCs may vary from 15% to 35%. Thus, actual consumption could be much less, but such statistics are not available from the UN. They would be available within individual countries, however. Thus, the discussion below concerning "consumption" includes TD losses and auxiliary consumption (TDA).

3.2.1. Per Capita Electricity Consumption

The necessity for the high growth of electricity lies in the very low level of per capita consumption in the developing countries. Although some possibilities for conservation do exist, the levels of electricity consumption are far below those reached by the developed world. Table 3.3 gives a summary of the consumption index in 1979 with respect to 1970 of the developed and developing world regions. It can be seen that the developing regions have a higher index in total as well as in per capita terms. But their consumption of 360 kWh/cap in 1979 was much lower than to the 6673 kWh/cap of developed countries.

The growth rates in the developed world have substantially decreased during the seventies, especially when comparing them to the sixties, but those of the developing countries still remain high. Per capita consumption in Africa, America, and Far East in 1979 was 164, 968 and 225 kWh respectively.

Many of the rural areas are still dark at night and even urban-poor do not have access to electricity. Thus, it is not only the rise of existing consumers' consumption, but also the fact that many more people are entering into the system which calls for high growth of electricity in the developing countries.

Table 3.3 Electricity Consumption Index in 1979 with respect to 1970 and in kWh/cap.

World Regions	Consumption Index 1970 = 100		Consumption in kWh/cap.	
	Total	Per Cap.	1970	1979
World	122	113	1355	1849
Developed Economies	120	117	4805	6673
Centrally Planned Economies	124	115	915	1418
Developing Economies	140	127	204	360
Africa, Dvlpg.	129	115	119	164
America, Dvlpg.	214	168	576	968
Far East, Dvlpg.	223	184	122	225

Source: Yearbook of World Energy Statistics (1980), UN, New York.

3.3. Trends in Capacity Utilization

In principle, if a kW of capacity were to run for 24 hours for 365 days, the full capacity utilization could be 8760 kWh/kW. However, because of the demand curve and the maintenance requirements it is not possible to achieve 100% utilization.

Table 3.4 shows the aggregate levels of capacity utilization in 1970 and 1979. The production per capacity measured as kWh/kW on the world scale went down with regard to all electric power as well as power produced by hydro-plants. A closer look at the figures of individual region levels reveals that in fact the opposite is true with respect to centrally planned countries, African developing countries and Far Eastern developing countries. In the developed part of the world and the Latin American developing countries, the production per capacity went down in the 1970s. The total capacity utilization changed from 2896, 3758 and 3756 kWh/kW in 1970 to 3679, 3693 and 4061 kWh/kW in 1979 in Africa, Latin America and the Far East, respectively.

Table 3.4. Capacity Utilization in kWh/kW.

Regions	Production per kW capacity			
	Total		Hydro	
	1970	1979	1970	1979
World	4404	4161	4042	3908
Developed Economies	4453	3976	4107	3853
Centrally Planned Economies	4560	4954	3733	3822
Developing Economies	3608	3812	4072	4186
Africa, Dvlpg.	2896	3679	3712	4314
Latin America, Dvlpg.	3758	3693	4364	4214
Far East, Dvlpg.	3756	4061	3862	4017

Source: Yearbook of World Energy Statistics (1980), UN, New York

The developing countries as a whole have increased their capacity utilization between 1970 to 1979 from 3608 to 3812 kWh/kW. However, the question remains, to what extent is it possible to increase capacity utilization? What factors are involved and what are the solutions?

Apart from shut-downs and unexpected break-downs the following factors contribute to the decrease in capacity utilization (the first three do not apply yet to most of the developing countries but may apply to some of them in future).

- Excess capacity is built to have a higher reliability;
- In a cold climate and in order to meet the heating needs of winter and longer lighting additional capacity has to be built;
- When more and more hydro power plants are built only to meet the peaking load requirements. (In the developing countries, hydro-power is used to meet the base-load also);
- When the growth in the new capacity is large, there are teething problems for two years or so before full capacity utilization occurs;
- When the old capacity is not retired for want of new capacity;
- Recently, the existing oil-based plants have been utilized sparingly to reduce oil consumption and only using them if the situation demanded. This reason has contributed a great deal to the reduction of thermal capacity utilization of the developed countries after 1973.

The above mentioned reasons indicate that low capacity utilization does not always mean "low efficiency" in a strict sense. Moreover, they also show that since the first two reasons (and also the third to some extent) do not apply to developing countries, it is, in principal, possible for them to have higher capacity utilization than for the developed countries. In fact, in 1979, Korea, Malaysia and Ghana have reported capacity utilization as high as 6600, 5450 and 5000 KWh/kW compared to the average of 3976 kWh/kW for the developed countries.

3.4. Conservation of Electricity

What is the success of developing countries in the area of conservation? Indeed, one has to consider that DCs are undergoing transitions of several kinds and therefore require a high growth of electricity. As already mentioned, the three factos which call for increased consumption are:

(i) Consumption of electricity is initially low;

(ii) They are in a transition stage of changing over from human and animal labour to mechanization;

(iii) Many end uses call for substitution of electricity for oil, which could be more efficient and even energy saving as a whole.

Yet, in spite of the above factors, DCs are responding slowly to the need for technological change for more efficient use of electricity (Parikh J. and Chaitanya A. 1980 and Jankowski J. 1981).

In order to understand what measures will save electricity, it is necessary to know how much of it is consumed by which sector. Since electricity bills are metered separately for each user, such categorization is available for many countries. Globally, out of 624 GWyr/yr electricity consumption in 1975, 359 (57%) were consumed in the industrial sector, 249 in household and service sectors, and 16 in the transportation sector. GWyr/yr were losses due to transmission and distribution (W. Häfele, 1981, IIASA). This and related works from the same Institute will be referred to as IIASA study).

The IIASA study aggregates the household, service and agriculture sectors (3 to 13%), and the manufacturing, mining and constructions sectors (1 to 3%). In Africa and South Asia in 1975 the distribution of electricity consumption in the transportation, household and manufacturing sectors was 2%, 17% and 81% respectively. For Latin America the distribution in the same sectors was 1%, 29% and 70%, respectively. Thus, invariably, the industrial sector is the largest user of electricity. It is for this reason as well for the following that maximum conservation could be expected to come from the industrial sector.

- Many of the conservation measures are known and document;
- These measures need to be conveyed to those relatively few users controlling a large fraction of total use;
- Relatively more skilled manpower and mobile resources are available to them. Therefore, it is easier for them to execute conservation measures if reasonable incentives are given;
- Industries by nature are profit-oriented. Thus, they are likely to respond to measures like pricing, taxes, subsidies, etc.

Thus, the efforts of DCs to conserve electricity are more clearly seen in the disaggregated data for the industial sectors of several countries.

Table 3.5 shows that indeed, in spite of the overall electricity consumption growth rate of more than 8-12%, the rise seen in the ratio of indexes of electricity consumption and industrial production during 1963-1973 slowed down after 1973. In fact, in some cases there was actually a decline in some of the Latin American countries. This was unlike India where electricity consumption/value added increased in kWh/Rs1000 in 1970 prices from 370 in 1960 to 690 in 1975. The reasons for this are varied and are given in Figure 3.1 quoted from Parikh J. (1981).

4. FUTURE DEMAND FOR ELECTRICITY

In order to estimate the investment requirements for the power sector, the following steps are necessary.

(a) Estimation of demand for electricity depending upon the economic growth scenarios and alternative paths of development;

(b) Estimation of required additional capacity to meet the future requirements for electricity, assuming T and D losses and capacity utilization coefficients;

(c) Determination of cost-coefficients and mix of hydro, thermal and nuclear plants;

(d) Calculation of additional investment by including the above three factors by considering construction periods, phasing of investment and depreciation of the old capacities.

The procedure is graphically illustrated in Figure 4.1.

It is necessary to discuss each of the above separately in detail. The first step, which is most crucial and can be done by several methods is discussed in the present section and the rest of the steps will be discussed in the following section. In general, literature on energy demand for the developed countries is abundant such as Pindyck R. (1980), Chateau B. and Lapiollane B. (1982), Leach G. (1980) and others. However, the discussions below refer only to the work on developing countries.

Table 3.5. Ratios[a] of electricity consumption index/production index for various manufacturing sectors (1970 = 100).

	1963	1967/68	1973	1974	1975	1976	1977
Brazil							
Food	—	116	104	108	113	112	118
Textiles	—	98	97	[illegible]	105	105	101
Paper	—	95	103	110	130	121	119
Chemicals	—	97	104	108	115	114	116
Iron and steel	—	102	115	126	118	129	130
All manufacturing	—	104	101	104	104	106	114
Colombia							
Food	96	72	75	80	71	74	—
Textiles	95	90	85	98	99	96	—
Paper	122	108	83	108	99	114	—
Chemicals	162	167	246	163	225	265	—
Petroleum refining	102	95	142	114	123	139	—
Iron and steel	56	102	118	145	156	147	—
All manufacturing	97	110	106	110	111	111	—
Dominican Republic							
Food		101	122	120	127	115	122
Textiles	149	131	146	149	115	103	149
Paper	46	129	81	147	200	164	107
Chemicals	109	121	79	78	58	52	51
All manufacturing	112	94	109	111	106	101	109
Ecuador							
Food	94	83	105	101	109	146	—
Textiles	103	95	89	103	96	103	—
Petroleum refining	104	89	89	77	71	63	—
All manufacturing	96	94	105	101	105	113	—
El Salvador							
Food	—	—	147	134	142	—	—
Textiles	—	—	108	127	130	—	—
All manufacturing	—	—	114	128	120	—	—
Korea[b]							
Food	—	—	108	122	123	107	97
Textiles	—	—	107	122	125	113	123
Paper	—	—	95	100	103	100	94
Chemicals	—	—	98	96	91	78	74
Iron and steel	—	—	87	68	72	68	67
All manufacturing	—	—	97	88	86	76	78

Table 3.5 continued.

	1963	1967/68	1973	1974	1975	1976	1977
Mexico							
Food	—	97	94	101	95	108	—
Textiles	—	—	86	87	85	91	—
Paper	—	97	100	92	98	91	—
Chemicals	—	—	94	107	111	117	—
Iron and steel	—	93	99	97	101	106	—
Philippines							
Food	—	82	164	146	—	—	—
Textiles	—	92	93	124	—	—	—
Paper	—	80	265	251	—	—	—
Chemicals	—	161	106	60	—	—	—
All manufacturing	—	87	135	145	—	—	—
Portugal							
Food	—	81	122	116	113	112	114
Textiles	87	102	90	89	91	93	102
Paper	86	100	105	88	77	91	85
Chemicals	—	138	255	313	335	247	274
Iron and steel	85	87	101	116	141	119	132
All manufacturing	86	111	121	127	129	126	141
Tunisia							
Textiles	—	125	12[illegible]	184	224	267	—
Paper	—	—	419	557	313	326	—
Chemicals	—	26	101	138	107	146	—
All manufacturing	—	53	129	157	148	160	—

Source: United Nations, Growth of the World Industry, vol. 1 (New York, UN) (various issues) and Yearbook of Industrial Statistics, 1977 Edition, vol. 1 (New York, UN, 1979).

[a]Index of electricity consumed in each sector divided by the index of industrial production for each sector where the base is 1970 and the resulting index ratio for 1970 = 100. The ratios measure the change of electricity consumption per unit of industrial production relative to the consumption/output relationships in 1970.

[b]Base year is 1972 = 100.

Source: Jankowski J. (1981)

Figure 3.1.

Why did the energy consumption norms and energy intensities increase in India compared to the past and compared to the other countries.

Increase compared to the past in India+	Energy/Output (Consumption Norms) (A) a) Improvements in quality of products b) Substitution of human and animal energy c) Substitution of non-commercial energy	Energy/Value Added* (D) a) Wage increase is slow b) Controled prices for some of the outputs c) Increase in consumption norms
Increase relative to other developed countries	(B) a) Technology of production not improving fast enough b) Scale of production c) Capacity utilization not good due to interruptions in production, for a variety of reasons d) Problems of measurement and comparison of energy use between countries e) Increased use of coal instead of gas or oil and decreasing quality of coal	(E) a) Wage - increase in other developed countries is higher b) Corrections for purchasing power of a rupee is necessary
Increase relative to other developing countries	(C) a) Increased use of coal b) Sometimes better quality product	(F) a) Comparatively large production base of energy-intensive industries such as iron and steel, chemicals, fertilizers and metals

*Energy/Value Added = $\frac{\text{Energy/Output}}{\text{Output/Value Added}}$. Therefore, the numerator is the same as in the (A), (B) and (C) blocks given on the left-hand side.

+This is not true of all products.

Source: Jyoti Parikh, "Energy: A Resource for Industrial Development in India", Working Paper WP-81-13, International Institute for Applied Systems Analysis, February 1981.

4.1. Critique of Methods of Demand Projections

In general, there are three methods for electricity projection:

(i) Econometric methods: Here the past electricity consumption is correlated with socio-economic variables, such as GDP, urbanization, industrial production, etc. This can be done using time series data of a given country (e.g., SIMA model by Parikh J. and Parikh K. 1979), or cross-country data, as is done in SIMCRED model (Parikh J. 1980);

(ii) Input-output models: Here electricity consumption coefficients for production in each sector of the economy are estimated and output levels of each sector are determined by final demand projections from the input-output model. This can be done using electricity consumption in physical terms (Parikh J. 1981) or in value terms. (UNITAD, 1982);

(iii) End-use methods: This is a short-cut to input-output models which do not exist for many of the developing countries. Here, only major activities using electricity are considered -- each one independently -- and the coefficients of electricity used for each are worked out based on engineering or other considerations (Häfele W. 1981). If done in more detail, it could also use the econometric method for each end-use activity and therefore combine the above two methods. (Parikh J. 1981).

However, each one of these methods has shortcomings. A critique of these methods is given below.

To begin with, one should note that all projection methods depend partly on existing information. This information may relate to data of the past and present energy consumption or to the status of existing technology and the manner in which technology has evolved over the past. Even when one speculates about future technologies, these speculations are conditioned by the experience and data of the past and the knowledge of present expectations. Reliance on past data and existing information, is unavoidable in any systematic approach. However, various methods do differ in the way they make use of these data. In the following, the places of "analysis of the past" and "scenario specification" in projecting energy demand are discussed.

4.1.1. Econometric Methods

Econometric analysis is a way to estimate a function that correlates changes in a given variable such as electricity consumption, with another set

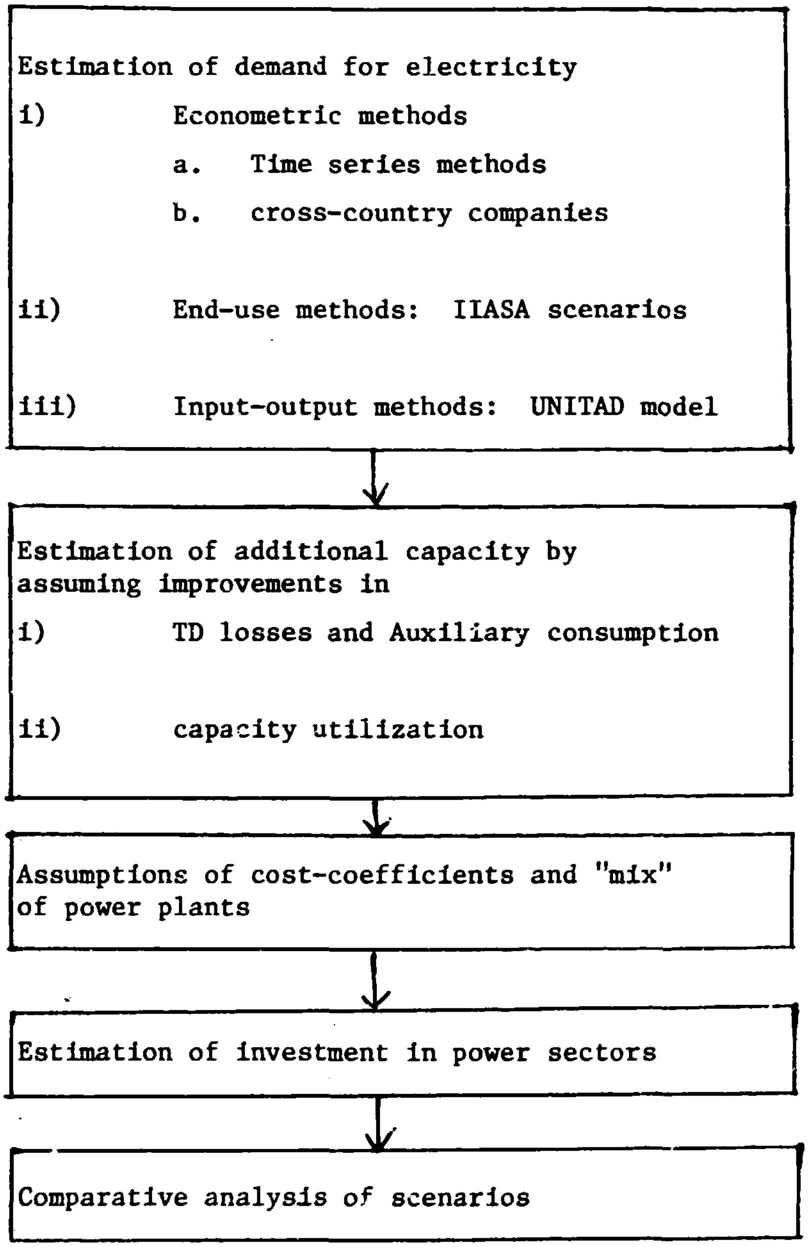


Figure 4.1. Procedure for estimating investment in the power sector.

of variables such as economic growth rates, population growth etc., based on past data and indicates the evolution of energy consumption over time.

The assumption behind the analysis is that the relationship estimated from the past data would continue to hold over the period of projection and that one has the freedom to specify the independent variable such as the economic growth rate. This transfers the problems of projecting energy demand to projecting the gross national product (GNP), for which projections may be availanle or easier to make. A simple method of energy/GNP ratio could be considered as a special case of an econometric method where only one data point is considered.

If disaggregated data for sectoral electricity consumption is available, then one can also relate electricity requirements to the structure of GNP. This may be particularly useful if the sectoral breakup of energy requirements are to be projected, since each sector may behave differently.

Regression can be based on two types of data: Time series data which refers to the data over different past periods for a given country or unit, or cross-section data which refers to data for different countries at one or more time periods.

(a) Time Series Data

The time series data referring to a particular country embodies many features specific to the country. These features may refer to the physical as well as the social and political environment. Projections based on such data may be, therefore, conditional on continuation of some of these features.

Since the energy consuming capital stock -- transport network, industries, houses -- have long lifetimes, it is generally difficult to bring about drastic changes in the energy consumption pattern in a short period of a few years or even a decade in case of DC. Therefore, time series analysis may be especially relevant for a short term analysis of energy consumption in a country or a world region.

(b) Cross-country Data

However, for certain purposes, e.g. for medium or long-term analysis (25 to 30 years), it may be better to look at other countries which are at different stages of economic development. When a comparison is made from the data of a number of countries for a given year the assumption in such a cross-country comparison (regression) is that countries at similar stages of development have similar economic structure. It may, however, be pointed out that one can introduce variables in such regressions which account for differences in annual endowments of countries so that countries with the same level of development may show differences in structure. This method is suitable for projecting long-term energy demand of world regions (especially developing world regions) because it reflects the structural changes that occur due to development.

(c) Problems of Projection and Scenario Specifications

In using the equations estimated either from time series or from cross-section data for making projections, one needs to specify the future values of the independent variables.

The shorter the time horizon in which one is interested, the fewer the scenario specifications are required as well as more econometric estimations.

The various scenarios, such as price of oil, extent of available oil resources, life-style parameters, such as fraction of passenger kilometers travelled by cars and buses etc., are used in the literature to arrive at the probable future magnitude which may be expected under specific circumstances. In some cases, scenarios are constructed to analyse the implications of various alternative policies. The purpose of scenario construction is to get an insight into the behaviour of the energy system under varying assumptions.

It should be kept in mind that scenario specifications make the model subjective. Moreover, very often there is a lack of consistency between various scenario specifications used in the same run of a model, particularly when the level of complexities in the model is high, involving detailed treatment at sectoral levels. It is therefore desirable that, in a bigger model, as far as possible, some of the scenario variables should come from sub-models so that they are consistent with each other. For example, the set of economic assumptions, GNP growth rate, share of agriculture GNP, consumption, investment, etc. should be consistent. If they come from a macro-economic sub-model they could be made so. This is done in Parikh J. 1981 where macro-economic model SIMA model drives the energy demand model).

4.1.2. Use of Input-Output Coefficients for Projection

Input-output tables are available for many countries. With these tables one can project the detailed sectoral structure of the economy for some desired or expected future growth of the economy. The projection for end uses of energy may also be made without use of a formal input-output model (I/O). It may be also based on econometric regressions.

However, the assumption behind this method should also be noted. In input-output projection, the technology of production is assumed to be known in advance and is usually assumed to be constant. Studies show wide variations across firms in efficiencies of use of resources, including that of energy. Thus engineering norms should also be compared with real life performance and if this is not done the estimates may be usually too optimistic.

One should guard against the tendency to consider input-output coefficients as somehow more reliable. Unfortunately, there is no tradition among builders of input-output tables to attached standard deviations or t-statistics to the individual coefficients of the table.

4.1.3. End-use Method

To some extent, the end-use method can be regarded as a judicious mix of concepts of I/O and econometric methods. It uses a different basis however for disaggregation and using engineering norms such as energy per passenger km. etc. It is not a fundamentally different method, although it could be a useful one.

Nevertheless, this method facilitates detailed projections which are useful in considering alternative supply strategies which may include substitution of both the energy source as well as the final end-use product or process by another end-use product or process.

4.1.4. Concluding Observations Concerning Methodology

Future projections unavoidably involve assumptions regarding the future and knowledge of present and past data. The attempt should be to reduce the number of assumptions and also to be consistent about them. Instead of being committed to one method of projection, a variety of ways may be used in an eclectic manner to produce a range of estimates of energy requirements.

Further difficulties arise in incorporating technological changes as in any other methods. This is a subject of discussion at theoretical levels (Park S. 1982) but *ad hoc* attempts are made in practice. Moreover, often tables are constructed in monetary terms -- and not physical terms -- and prices may have to be used to convert them in physical units for planning purposes.

Having discussed three major approaches, the application of each is discussed below.

4.2. The Results of Econometric Methods

4.2.1. Time Series Method

Time series trends show that the growth rates of electricity consumption decreased from the sixties to the seventies from 10% to 8% in Africa, from 14.3% to 8.8% in Latin America and from 12.7% in the Far East. Unfortunately, GDP and urban population time series data aggregated at the regional level are not available so as to use them as independent variables.

Table 4.1 summarizes past and future developments. It can be seen that if projected at the past growth rates, the DC of Africa, America and the Far East would require 191, 867 and 748 TWh of electricity respectively in 1990. Compared to the results of 1979, this amounts to an increase of 2.5 times. This method is not suitable for extending up to 2000.

Table 4.1 Past and Future Growth in Electricity Production in TWh for Developing Countries* by time series method

World Regions	Growth 1960-70 %	Growth 1970-79 %	1979 Actual*	Consumption 1985 Projected	1990 Projected
Dvlpg. Countries+	10.4	9.3	778	1326	2069
Africa, Dvlpg.	10.0	8.2	80	129	191
America, Dvlpg.	14.3	8.8	343	569	867
Far East, Dvlpg.	12.7	9.5	276	475	748

* TDA losses are included.

\+ Includes Mid-East

4.2.2. Cross-Country Regression Method

Here we look at the results of SIMCRED model described by Parikh J. (1980) where using the data for 70 countries the following equation is estimated:

$$\log (EEL/N) = -0.896 + 1.1581 \log (Y/N) + 0.499 \log (NU/N)$$

t values (14.27) (3.30)

$R^2 = 0.96$

EEL = Electricity consumption in kWh

N = Population in 10^6

Y/N = per capita GDP US-$ of 1973

NU/N = Fraction of urban population in total population

Error terms for each region (departures from the above equation for individual region) are 0.238, 0.718 and -0.160 for Africa, the Far East and Latin America, respectively.

Table 4.2 shows the results of the model for "Reference scenarios" (GDP growths are slightly better than actual trends) and the modified international development strategy (IDS II) scenario proposed in the UNITAD model.

The growth values for electricity become 7% and 6.2% for 1985-2000 for the three regions respectively under "trend scenarios". They are 7% and 8.9% under the IDS II scenario. The differences between the two scenarios become substantial in 1990 for the Far East and Latin America and are mainly due to differences in GDP growth rate assumptions.

4.3. IIASA Energy Models

The global modelling exercise of the International Institute for Applied Systems Analysis (IIASA) is described by W. Häfele (1980), J. Anderer et al. (1980) and P. Basile (1981). The globe comprises seven world regions -- three developed and four developing regions. Latin America (Region IV) and South and East Asia + Africa (Region V) are of interest here.

Basically, as shown in Figure 4.2, the modelling exercise begins from macro-aggregates and demographic projections. These are used as inputs to the MEDEE model which is a demand model. The two main advantages of the IIASA models are:

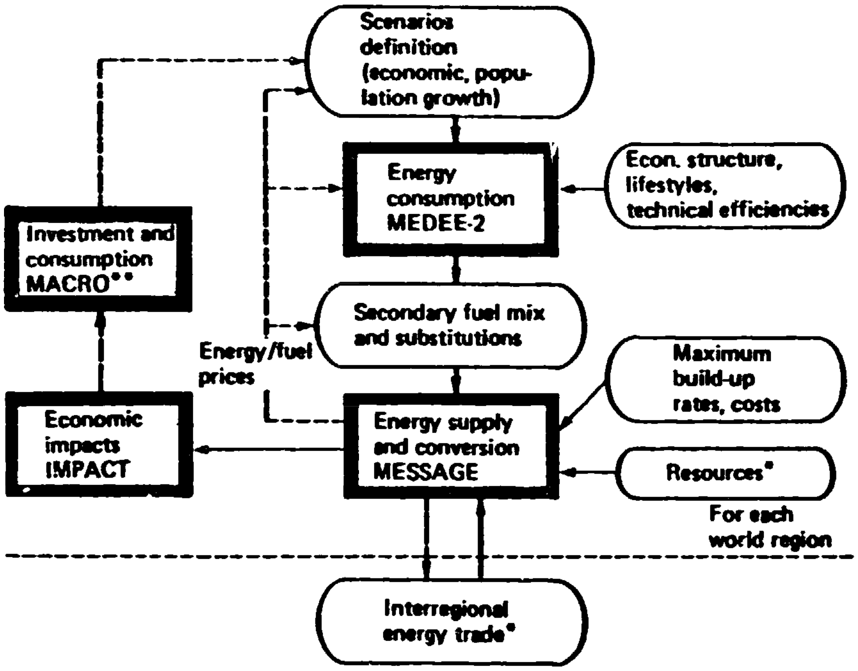
(i) Disaggregation of the end-use activities in three sectors: Transport, households (including commercial and agriculture) and manufacturing (including mining). The energy demand obtained here is disaggregated in energy forms such as motor fuels, electricity, district heat, solar, renewables etc;

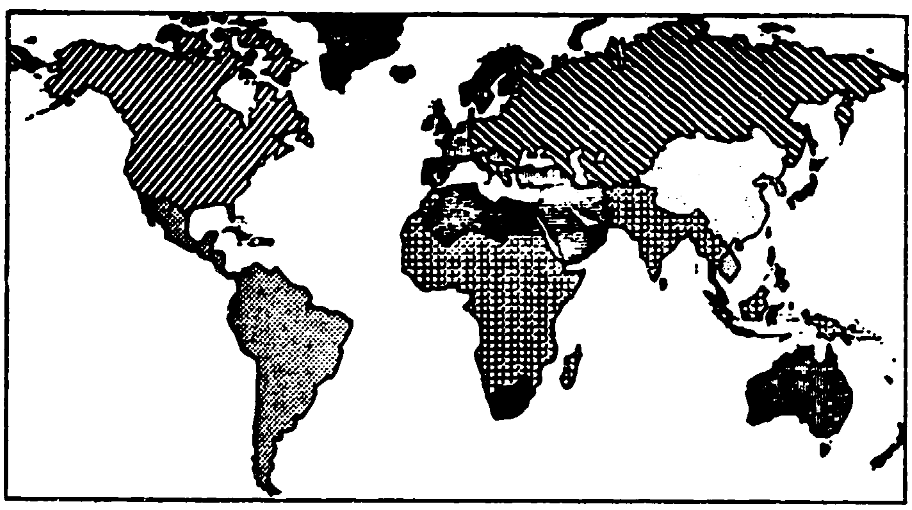
(ii) The final energy demand obtained thus provides inputs to the MESSAGE model, which gives optimized supply strategies for a mix of energy resources depending upon cost categories of various fossil fuels, conversion technologies, resource availabilities and demand structure. IIASA models, therefore, give disaggregated demand in terms of sectors and energy resources and give disaggregated and optimised supply alternatives.

The results of the MEDEE model are extracted for electricity demand and are given in Table 4.3.

It can be seen that in region V which consists of the Far East and Africa, major sectoral shifts in electricity consumption do not occur. However, in Latin America, (region IV) the shares of transport and household services increase considerably while reducing the shares of industrial electricity consumption. These results are not comparable with other studies because IIASA models aggregate different countries, use different GDP growth rates, and exclude TDA losses.

Fig. 4.2. IIASA Set of Energy Models and World Regions





Region I	(NA) North America	
Region II	(SU/EE) The Soviet Union and Eastern Europe	
Region III	(WE/JANZ) Western Europe, Japan, Australia, New Zealand, South Africa, and Israel	
Region IV	(LA) Latin America	
Region V	(Af/SEA) Africa (except Northern Africa and South Africa), South and Southeast Asia	
Region VI	(ME/NAf) Middle East and Northern Africa	
Region VII	(C/CPA) China and Centrally-Planned Asian Economies	

Source: Energy systems programme group of IIASA (1981)

Table 4.2. Results of the cross-country method (SIMCRED model)

	Africa			Far East			Latin America		
	1985	1990	2000	1985	1990	2000	1985	1990	2000
Population 10^6	498	576	763	1502	1710	2134	426	486	620
Urban population 10^6	148	187	288	409	506	747	285	339	464
Electricity 10^9 KWh									
Reference	120	165	311	393	515	1154	436	586	1034
IDS II	122	171	335	410	555	1478	486	747	1730
Growth 1985-2000		7.0%			8.9%			8.8%	

Source: Parikh J. (1980) (SIMCRED - Simulation by Cross-Country Model of Energy Demand) (reference) scenario taken refers to growth rates of 5.4, 5.0 and 6.0 for 1973-1985 and 5.5, 4.7 and 5.7 for the period 1985-2000 for the three regions respectively.

GDP-IDS II scenario refers to growth rates of 6.2, 6.0 and 8.0 for the three regions respectively for the period 1980-2000 (adapted to these regions from UNITAD model).

Table 4.3 Electricity projections by IIASA models and sectoral distributions

	Region V: Africa and Far East 1975	1985	2000	Region IV: Latin America 1975	1985	2000
Electricity 10^9 KWh						
Low	192	386	832	214	381	748
High	192	444	1167	214	442	1045
Percentages*						
Transport	1.8	1.6	1.8	0.7	0.8	1.5
Households Service	17.0	16.7	18.5	28.6	19.7	32.4
Manufacturing + Agric.	81.2	81.7	79.7	70.6	69.5	66.1

* The percentages are given for low scenarios but high scenarios have similar sectoral distribution. The growth rates for the period 1985-2000 for the low and high scenarios amount to 5.2% and 6.6% for Region V and 4.6% and 5.9% for Region IV.

4.4. Input-Output Method Used in UNITAD Model

The UNITAD model is an input-output (IO)type model for 11 world regions. The IO tables for each region are constructed from a number of country IO models. Ten producing sectors are considered, one of which is energy and 12 utilizing sectors, one of which is utilities, i.e. includes electricity, water, and gas. Thus, it would be difficult to separate the electricity component from "energy" and "utility". Moreover, the discussion is in monetary units and not physical units, the conversion of which may introduce additional assumptions and perhaps ambiguities. The model is static but reduction factors for conservation are introduced and capital labour co-efficients are changed, although in a somewhat ad hoc manner. However, the strength of the model over other models is that it has a trade component (mainly for oil) to it which ensures global balances by giving trade matrices. The growth rates for energy for 1975-1990 for Tropical Africa, the Indian sub-continent, East Asia and Latin America in the IDS II scenario are 7.3%, 6.5%, 6.5% and 5.3% respectively.

4.5. Comparative Analysis of all the Methods:

A summary of the results of all the methods are given in Table 4.4.

a) The time series method is unsuitable for long-term projections but may be reasonable for a short-term projection. Table 4.1 demonstrates that the growth rates in the seventies are less than those of the sixties. Keeping this in mind, therefore, the use of the growth rates of the seventies for the eighties may also over-estimate electricity demand.

b) Cross-country methods are lower growth rates because the more developed countries have lower electricity/GDP ratios than the less developed ones. The SIMCRED model is based on this approach where price elasticities are also incorporated in an ad hoc manner.

IIASA/MEDEE models which use end-use methods show even lower growth rates than the previous two, partly because conservation in each sector is taken into account and partly because the GDP growth rates used are lower to those used in the IDS (II) sceanrios. The absolute levels of electricity

Table 4.4 Comparison of results of electricity demand and growth rates using different methods.

	Africa			Far East			Latin America			Comments
	1985	1990	2000	1985	1990	2000	1985	1990	2000	
Econometric Methods										
a. Time series	129	191	-	475	748	-	569	867	-	Unsuitable for extending up to 2000
Electricity consumption growth rates										No disaggregation
1979-1990		8.2%			9.5%			8.8%		
b. Cross-country method (IDS II)	122	171	335	410	555	1053	486	747	1730	Aggregated demand
Electricity consumption growth rates										Growth rates reduce with development
1979-1990		7.1%			6.5%			7.3%		Flexible GDP growth
1985-2000		7%			6.5%			8.8%		
End-use Method IIASA/MEDEE*	444	-	1167				442	-	1045	Disaggregated demand, reducing growth rates subjective scenarios
Electricity consumption growth rates 1985-2000		6.6%						5.9%		low GDP growth rates
Input-Output UNITAD Growth rates for all energy 1975-1990		7.3%			6.6%			5.3%		Disaggregated but physical outputs not available Global balances and Trade flows

* In IIASA world regions some countries of Africa and Far East are aggregated and it excludes TDA losses. Therefore only growth rates are relevant. GDP growth rates are also low.

consumption are difficult to compare because the regional aggregation is different, and TDA losses are excluded. The UNITAD world economy model which has 10 sector input-output models has an energy component (but does not have electricity separately) in value added terms and not in physical quantities. While, in general, it is possible to develop an energy sector within this modelling framework, only the growth rates in value-added could be obtained from this model. The energy growth rates for Latin America are very low in spite of the high GDP growth rate assumptions.

5. ESTIMATION OF INVESTMENT FOR POWER SECTOR

In the preceding section various methods of deriving electricity demand were discussed. The next three stepts, described in the beginning of Section 4, will be carried out here, viz:

(i) Estimation of additional capacity considering improvements in T and D losses and capacity utilization;

(ii) Determining cost coefficients from literature survey and assuming a mix of power plants (i.e., hydro, coal, nuclear, oil-gas);

(iii) Discussions concerning the required investment.

This procedure requires sound judgment concerning improvements in reducing losses, increasing capacity utilization, cost coefficients and supply-mix. Each of this is discussed below.

5.1. Estimation of Additional Capacity Requirements

In order to derive the additional capacity from future demand, assumptions concerning capacity utilization and reductions in T and D losses have to be made.

5.1.1. Capacity Utilization

In Section 3, the trends of capacity utilization in different regions, the reasons for the present state and why they could be expected to increase are discussed. Based on this analysis, capacity utilization for each region is assumed and given in Table 5.1.

Table 5.1. Actual and Assumed Capacity Utilization in kWh/kW.

	1970	1979	1935	1990	2000
Dvlpg. Countries	3608	3812	4000	4300	4500
Africa, Dvlpg.	2896	3679	3800	4100	4400
America, Dvlpg.	3758	3693	3800	4100	4400
Far East, Dvlpg.	3756	4061	4100	4300	4400

Data source: Yearbook of World Eenergy Statistics (1980) U.N.
The values for future are assumed values

In principle, for a short-term forecast, capacity utilizations for each type of plant should be determined separately. However, as an approximation for a long-term forecast, average capacity utilization numbers are used to arrive at capacity requirements.

5.1.2. Reduction in T and D Losses

As much 28% to 38% of electricity is lost in the developing countries in the TDA system itself, before reaching the consumer. It sh-ıld be possible to bring them down to 18% to 25% by 2000, if appropriate parts are used, scheduling is planned properly, pilferage is reduced, and the load is increased. Of course, in the early stages of rural electriciation, the losses are bound to be high but as the load is increased and the network strengthened, the losses should decrease. It is assumed that such improvements would lead to reductions in demand (which includes TDA losses) for Africa, Far East amd Latin America by 0.95, 0.90 and 0.90 respectively by 1990.

5.2. Cost Coefficients for Power Capacity

For estimating investments, cost coefficients of various types of power plants need to be estimated. The cost coefficients adapted from "typical bank projects" as taken as reference points by the World Bank (1981) are indicated below along with other estimates on the same subjects. Unfortunately, neither IIASA, nor the World Bank cost estimates are region-specific. Wide variations exist, especially for hydroprojects and to generalize from these estimates for a certain country is not possible.

Cost coefficients for hydroprojects in the late seventies differ considerably, as can be seen in Table 5.2.

Table 5.2. Investment costs in hydroelectric power stations

	MW	10^6US-$[1]	US-$/kW[1]
1975 Nigeria (Bakolari)	500	485	970
USA (Auburn)	750	1,095	1,460
Brazil (R. Iguazu)	1,333	885	664
1976 New Guinea (Wibo)	3,500	4,835	1,381
Brazil (Embarcacao	1,000	970	870
Sri Lanka (Canyon)	30	45	1,500
Turkey (Aslentas)	140	177[2]	1,264
Brazil-Paraguay (Itaipu)	12,600	7,900	627
1977 Zaire (Ruzizi)			
1978 Colombia (Urro)	1,390	480	345
1980 India	-	-	750
1978 Pakistan	-	-	800

[1]Value 30.6.1978

[2]including irrigation

The following are difficulties in generalizing cost coefficients of hydro power plants:

(i) Hydro projects are site-specific and some sites are easier and others difficult;

(ii) Labour costs are different and change with time. They form sizeable components of the construction costs;

(iii) Clearing the site may require compensation costs to the local residents, which require different laws in each country;

(iv) Often the projects are multi-purpose and it is difficult to separate the costs for the power components;

(v) The transmission and distribution costs are site-dependent because often the sites are away from the demand centres. This also applies to the transport costs of the materials and manpower to the site of construction;

(vi) It may take more than 8 years to build it and final costs vary so much from the projected ones, that it is difficult to distinguish the costs due to delay from what it would have been otherwise.

Costs of fossil fuel plants are also different from one plant to another, but the variations are comparatively smaller than in the case of hydro plants. A summary of first figures made from several studies and five year plans are given in Table 5.3. Reference figures selected in terms of US-$ (1980) are indicated in the bottom line.

5.3. Gestation Periods, Phasing of Investment and Depreciation

5.3.1. Gestation Periods and Phasing

It should be realised that investments for power are not only large but they have long construction periods over which they are phased out. The DC thermal power plants take 3 to 5 years, oil and gas power plants 2 to 4 years, hydro-power plants 5 to 10 years and nuclear from 6 to 10 years. Moreover, even after construction, it may take a couple of years before satisfactory levels of capacity utilization are reached. Therefore, to meet the demand by 1990 one has to invest in the early eighties. Thus, if this factor is not recognised, and all the investment is shown in the year when the demand has to be met, one may get an underestimation of GDP required for power investment.

On the other hand, if one simply puts all the investment in the initial stage, a misleading conclusion may emerge where large investments are required several years before the demand. This is because the investments are phased over several years as shown in one example of thermal plants in Annex 1. The correct procedure is described there to consider gestation periods and the phasing so as to obtain streams of investment. For simplicity, it is assumed that during 19811990 the investments would be made for meeting the demand for mid 1983 to mid 1993. Thus in region V 103 GW and region IV 115 GW of additional capacity would have to be built for which investments would be required during the eighties.

Table 5.3. A summary of capital cost coefficients per kW capacity in US-$ in literature* and selection of the reference figures

	Hydro	Oil	Coal	Gas	G.Turb.	LWR
IIASA[1]	620	350	550	325	170	700
World Bank[2]	815	580	580	580	580	580
India[3]	750		700			900
Pakistan[4] a	800-1600		600	500		1000
b	600	328	450	310		800
Sahel[5]	2500	680	-	-	-	-
Reference for this study	800	500	700	500		1000
Ref. incl.T.D.	1600	1000	1400	1000		1500

[1]Source: W. Häfele (1980). The coefficients are not adapted to DC but are suited for relative magnitude. (US$1975)

[2]Source: World Bank (1980). Here T&D costs (assumed to be 50%) are subtracted from the original estimates. (US$1980)

[3]Source: Parikh J. (1981). Exchange rate $ = Rs.8.

[4]Source: 4a Khan A. (1981). Figures in US-$ 1980.
4b Private communication Jameel A. and Strub M. at IIASA. Figures in $ 1975.

[5]Source: Club du Sahel (1978). Exchange rate $ = 220 CFA.

* All figures except the last line exclude TDA investment. The last line consists of the reference figures selected in terms of US$1980.

5.3.2. Depreciation Factors

The lifetime of fossil power plants are approximately 30 years, nuclear power plants 20 to 25 years and hydro-power from 50 to 100 years. In the developing countries the overall depreciation is small due to the low proportion of old capital stock.

Table 5.4. Hydro and Thermal Capacities in 1955 and 1960 in GW

	Total	Thermal	Hydro	Total	Thermal	Hydro
Africa	7.1	6.0	1.1	10.6	8.3	2.3
America	13.9	6.8	5.1	18.0	11.1	7.9
Far East	5.8	4.1	1.7	9.6	6.5	3.1

Source: World Energy Tables (1976)

Table 5.4 shows the capacity that existed in 1955 and 1960 for thermal and hydro power plants respectively. Thus, it assumed that 100% and 30% replacements of thermal and hydro power plants respectively built during 1950-1955 in the period 1985-1990 and those built during 1955-1960 to be replaced in 1990-1995, it is expected that 12 GW of additional capacity would have to be built prior to or during 1985-90 as a replacement of the old stock and another 10GW during 1990-1995. Thus, the additional capacity required for replacing old stocks region V and IV during 1980-1990 is approximated to be 7 GW and 5 GW respectively.

5.4. Final Estimate of the Investments Required

Putting together all the factors described in Table 5.5 and cost coefficients and optimal mix in Table 5.3 before, final estimates of investments are arrived at.

Table 5.5 Power Capacity Required in the Developing Regions

	Africa			Far East			Latin America		
	1985	1990	2000	1985	1990	2000	1985	1990	2000
1) Electricity demand 10^9 KWh	122	171	335	410	555	1078	486	747	1730
2) Factor for reduced TDA losses (compared to 1979)	0.98	0.95	0.9	0.98	0.95	0.9	C.98	0.95	0.9
3) Electricity to be generated (10^9 KWh)	120	162	301	402	511	970	476	710	1557
4) Assumed capacity utilization (KWh/KW)	3800	4100	4400	4100	4300	4400	3800	4100	4400
5) Capacity Required	31.6	39.6	68.5	98	119	220	125	173	354

1979 figures for (1) are 79, 276 and 343 respectively and for (4) 3679, 4061 and 3693 respectively and existing capacity 21, 68 and 92.

5.4.1. Additional Capacities Required

It can be seen in Table 5.5 that considering the improvements in TDA losses and capacity utilization, the capacity required could be to 40, 119 and 173. GW in 1990 for Africa, Far East and Latin America respectively. Considering that 21, 68 and 92 GW capacity existed in 1979 already, the requirements of additional capacity would be 19, 51 and 81 respectively for the same regions. Considering the time lag for construction periods and replacement required for old capacities, the capacity of power plants required during 1981-1990 in region V would be 110 GW and for 120 GW in region IV.

Table 5.6 Investment required in DC during eighties considering the mix of hydro-thermal plants*

	Reg.V	Reg. IV
Additional capacity to be created during eighties (GW)	110	120
Percentages of each type from IIASA and optimisation model		
Nuclear	3.0	5.6
Coal	55.0	14.8
Hydro	22.0	31.1
oil-gas	20	48.5
TOTAL	100	100.0
Capacity addition in GW		
Nuclear	3.3	6.7
Coal	60.5	17.8
Hydro	24.2	37.3
Oil-gas	22.0	58.2
	110.0	120.0
Investment in $\$10^9$ (undiscounted in 1980 prices)		
Nuclear	4.9	10.1
Coal	84.7	24.9
Hydro	38.7	59.7
Oil-gas	22.0	58.2
TOTAL	150.3	152.9

*New and renewable energy resources could play an important role for heat energy but not for electricity during the eighties according to IIASA scenarios

5.4.2. Investments Required for Power in the Eighties

Having determined the total capacity required, the next step is to consider its break-up in nuclear, fossil and hydro plants.

Here, we consider scenarios obtained by IIASA energy models where the optimal mix is arrived at by considering the nature of demand for each world region, the existing resources and costs to develop them and the permissible build-up rates for building each capacity. The mix obtained by IIASA is slightly modified in this paper in order to consider slightly different structures of world regions and thus, the percentage shares of nuclear, coal, hydro and oil-gas in 1990 for region V is 3%, 55%, 22% and 20% respectively and 5.6%, 14.8%, 31.1% and 48.5% for region IV. New and renewable energy sources do not contribute significantly during the eighties to electricity generation (but do contribute to heat energy) according to IIASA scenarios.

The investments required for such a mix of power plants considering the reference cost-figures given in Table 5.3 for each type of power plant is $150 billion for region V and $153 billion for region IV, (in 1980 prices). Thus $303 billion (1980 prices) would have to be invested during the eighties for the development of the power sector in DCs of Africa, America and Far East. Note that this excludes the DC of the Mid-East, whose electricity growth rates are the largest.

5.5. World Bank Estimates of the Required Investments

The World Bank estimates that in 1980 $34,4 billion was spent in the power sector. Table 5.7 provides some estimates regarding investment requirements of commercial energy of the oil importing developing countries as projected by the World Bank (1980). Unfortunately, detailed documentation of how the figures are arrived at is not available. But it appears that 8% historical growth for demand is considered and no improvements in capacity utilization is foreseen. Additional remarks on the different results of this study with World Bank estimates are made at the end of the section.

It can be seen that the power sector alone (with generation, transmission and distribution) claims approximately 75% of the total investment requirements in the commercial energy sector. The investment is expected to grow at 9.1% for thermal power plants and 6.8% for hydro power plants.

Table 5.8 provides a summary of the investment requirements for the power sector by all the developing countries in the present decade. Around US$414 billion (1980 prices) are estimated to provide sufficient investment for generating a total additional power supply of 282 Gigawatts. If, the mid-East is excluded however, then the required capacity is approximately 240 GW requiring $358 billion. Of this amount, 70% goes towards generation and the rest is for transmission and distribution. The per KW investment requirement

Table 5.7 Oil Importing Developing Countries. Principal Investment Requirements in Commercial Energy, 1980-90 (Billion 1980 US-$).

	Estimate 1980	Annual Average 1981-85	Annual Average 1986-90	Average Annual % Growth Rate 1980-90
Electric Power	18.5	27.5	39.7	
Thermal	8.0	11.8	15.4	9.1
Hydro	9.2	13.5	15.1	6.8
Others	1.3	2.2	9.2	
Coal, Oil, Gas...	6.1	9.2	13.7	
Total Investment in Commercial Energy	24.6	36.7	53.4	10.9
Share of Power Sector (%)	75.2	74.9	74.3	
Total for all Dvlpg.Countries	34.4	54.4	82.2	12.3

Source: Energy in Developing Countries, World Bank (1980).

Table 5.8 Developing Countries: Power Generating Capacity and Power Production; Projections for 1980-90.

	1980		1985		1990	
	GW	TWh	GW	TWh	GW	TWh
Thermal	137.9	481	200.3	732	282	1005
Hydro	99.6	394	147.0	592	201.3	777
Others	3.8	17	11.6	61	40.4	240
Total	241.3	892	358.9	1385	523.7	2022

Source: Energy in Developing Countries, World Bank (1980).

for hydro-plants has been shown to be 1.5 times higher than that of thermal plants. (Of course, the operating costs are considerably less for the hydro-power plants). The summary considers "thermal plants" as an aggregation of nuclear, coal, oil and gas plants. Annex 2 and 3 show that during 1976-1980 the annual average lending to all developing countries by the World Bank for the power sector was barely around $1.2 billion.

Until recently OPEC aid to the energy sector was largely extended to electric power projects; Although lately aid has been extended to projects involving all forms of energy (e.g. oil, gas, coal).

Available data indicates that up to the end of 1980, lending for energy projects by 8 OPEC aid institutions amounted to US$2.324 billion. The OPEC fund is one of these institutions. Energy projects represent 44% of total project loans extended thus far to developing countries. These include hydro and thermal power projects in Burma, Ghana, Madagascar, Nepal, Pakistan, Sri Lanka, India, etc. This indicates the paucity of external ($3 billion) funds compared to the magnitudes of investments required ($34 billion). This gap will increase further in the eighties. Figure 4.1 and Tables 5.5 and 5.6 show more realistic investments, one also gets indications concerning how to reduce the investments.

The present procedure makes allowance for a number of factors not considered in World Bank or UNCTAD estimates such as:

(a) Starting points is the demand for electricity which is estimated using various methods and a reference figure is chosen after a discussion on all the methods; The projected growth rates in this paper are lower than the historic growth rates assumed by the above two;

(b) Possible reductions in TDA losses considered;

(c) Improvements in capacity utilization estimated;

(d) Optimised mix of hydro and thermal plants of various types is taken from IIASA models and their cost-coefficients taken from actual projects;

(e) Gestation periods, phasing and replacement of old stocks are considered.

Of course, a number of improvements in this present method could be made, such as:

- Estimate separate capacity utilization factors for different types of plants i.e. fossil, nuclear, hydro.
- Consider phasing of investment for each type of plant as shown in Annex 1 so that streams of investments are obtained.
- Include details of individual country-characteristics by splitting regions in smaller units etc.

However, the central message that "needs are greater than means" is unlikely to change despite these improvements. What is relevant are the policies for reducing investment which are discussed below.

5.6. Policy Measures for Reducing Investment

The measures for reducing investment, of which some have already been discussed, are listed below:

- Reducing the demand itself. (Reduction due to technological changes is discussed in Section 3. However, the question of pricing is discussed in this Section).
- Increasing capacity utilization of the existing plants and the additional ones and reducing TDA losses.
- Decreasing the per kilowatt costs by:
  - streamlining construction and reducing delays.
  - obtaining credit at low interest rates. (This is described at great length in the next section in the context of the least developing countries, but it is equally applicable to any developing country).
- Decreasing the foreign exchange requirements.
  - increasing technological capability.
  - selecting hydro-capacity where possible, where local labour could be used for civil construction.

Some of these issues are discussed below.

5.6.1. Pricing Policy for Electricity

The pricing policy is relevant on two counts:

(i) To promote price-induced conservation: although it is difficult to distinguish price-induced conservation from conservation due to technological change in the long term, in the short term one could define it to be that which is achieved using the existing technology;

(ii) To raise internal funds: quite often the pricing is such that the operating costs of the power plants are barely recovered. Thus, to add new power capacity, almost 100% funds have to be externally raised.

In order to encourage industrial development in the past developing countries have given low-cost electricity at subsidized rates. Some have even entered into long-term contracts for providing cheap electricity at a bulk rate, so that the more one would consume the less they would pay for a unit. This policy has not only resulted in wasteful electricity consumption but it has also burdened the utilities with huge financial losses and consequently there have been inadequate funds needed to expand the capacity or even to maintain the existing electricity supply. Even after the oil price rise of 1973, this policy was not changed until 1978 in some countries. The help needed for expanding the power industries should be given initially in the form of credit facilities and low interest rates. Once the power stations are in operation, they must be encouraged to be as self-sufficient as possible. Similarly, the help to the user industries should also be given to facilitate its initial development rather than offering long-term contracts for cheap electricity. Such a policy will encourage the user industry to plan and invest for more efficient use of electricity and the power supply industry to be self sufficient.

5.6.2. Reducing the Delay in Construction Periods

In developing countries, because of weak infrastructural facilities -- such as telephones, transport, telecommunication, and local manufacturing facilities -- and bureaucracy, the construction periods for power plants extend far beyond the expected dates. Often, the construction periods are longer by 40% to 100% compared to the developed countries. This increases investment costs in two ways:

(i) Interest costs: the power industries are capital-intensive and if the power plant takes 8 years instead of 5 years, interest costs could increase and mount up from 20% to 100% - and more - of the actual costs, depending upon the interest rate and whether the delay takes place at the beginning or towards the end.

(ii) Inflation: the delays in construction and erection and increase in capital costs are due to inflation because the basic prices which are considered at the time of preparation of projects change. In the countries of Latin America, where triple digit inflation occurs in some countries, it is difficult to even obtain increased funds halfway, in order to complete the projects.

In addition to organization and management skills, strengthening of industrial development and infrastructure could reduce the delay.

6. POWER INDUSTRIES AND THE LEAST DEVELOPED COUNTRIES

The LDCs are unprivileged even among the developing countries because they have considerably low per capita incomes and nutrition. (They are listed later in Table 6.1). In this paper, special attention is given to the problems concerning power for least developed countries (LDCs) to cover the following points:

(a) The overview of the past and present situation of electricity consumption, power capacity and comparison with other developing countries;

(b) Specific difficulties of the LDCs with regard to the power sector;

(c) Comparison of the investment requirements and the costs of electricity generation for hydro, steam and diesel plants under soft and hard loan conditions;

(d) Future prospects and possibilities for the LDCs, in particular through bilateral, multilateral or regional co-operation.

6.1. Overview of the Past and Present

P. Comoli (1982) gives consumption of all energy sources and also electricity by the least developed countries (LDC). In 1979, per capita electricity consumption of these countries ranged between 15 kilo watt-hours (kWh) for Nepal to 24 kWh for Bangladesh, 50 kWh for Sudan and 39 kWh for Tanzania. The LDC average in 1978 was 28 kWh per capita which was much le than even the average in the developing countries of 360 kWh. However, it could be seen that during the time period 1960-1979, most of the least developed countries have increased their production seven-fold, e.g. Afghanistan, Ethiopia, Malawi, Mali, Niger, Chad, etc. Of course, there are some who have increased it by much less or none at all (Benin, Burundi, Uganda) and there are others who have done better than seven-fold increase (Botswana, Nepal). The progress is not impressive when one considers the growth between 1970-1979 time period. Major accomplishments of three to four fold increase were made only during the sixties. There was only a two-fold increase at most during the seventies. In fact, the per capita average improved from 21 kWh in 1970 to only 29 kWh in 1979, whereas the corresponding increase for developing countries was from 204 kWh in 1970 to 360 kWh in 1979.

Table 6.1 gives data on total installed capacity in 1970 and 1979 and average capacity utilization in 1979. The total power plant capacity ranges from a few MW to 100 to 200 MW. Assuming that the total capacity consists of a network of smaller plants, the individual plants could range from less than a MW to 30 to 50 MW capacity. Many have no hydro-capacity at all and some have a predominantly hydro-capacity such as Rwanda, Uganda, Afghanistan.

In most cases, the capacity utilization of the LDCs in 1979 was much lower than the average developing countries which was 4200 kWh/KW. Only those countries with thermal power plants such as Botswana (coal based thermal plants), Sudan, Maldives and Uganda came close to this figure. The rest of them, in spite of having no hydro had very low utilization. Nearly 16 out of 23 countries have capacity utilization below 3200 kWh/KW. Since thermal plants do not depend upon fluctuations due to rainfall, this low utilization could be due to two reasons:

(i) The thermal plants of the LDC's are oil-based and they were unable to obtain oil for running the power plants;

(ii) There were frequent breakdowns and not enough skills and spare parts to repair them.

TABLE 6.1

TOTAL AND HYDRO-POWER CAPACITY IN LEAST DEVELOPED COUNTRIES AND CAPACITY UTILIZAITON

	1970 Total MW	1970 Hydro MW	1979 Total MW	1979 Hydro MW	Capacity Utilisation kWh/KW
Africa:					
1. Benin	10	0	15	0	333
2. Botswana	-	-	96	0	4375
3. Burundi	7	0	7	0	143
4. Cape Verde	5	0	5	0	1500
5. Chad	16	0	38	0	1658
6. Comores	1	0	1	0	4000
7. Ethiopia	170	91	330	206	2182
8. Gambia	9	0	10	0	3500
9. Guinea	100	25	175	50	2829
10. Malawi	49	26	110	70	3091
11. Mali	27	5	42	6	2381
12. Niger	15	0	20	0	2300
13. Rwanda	23	22	38	35	4211
14. Somalia	15	0	30	0	2400
15. Sudan	117	30	220	110	4091
16. Uganda	162	156	163	156	3988
17. Tanzania	143	49	258	188	2713
18. Uppor Volta	14	0	30	0	3000
Asia and the Pacific:					
1. Afghanistan	207	190	380	286	2316
2. Bangladesh	704	80	982	130	2398
3. Laos	19	2	70	50	-
3. Maldives	1	0	2	0	5450
4. Nepal	46	26	65	37	3000
Developing Countries	97000	38000	204000	79000	3812
Developed Countries	783000	205000	1312000	283000	3976

Source: Compiled by the author from various tables given in United Nations (1980) Yearbook of Statistics, New York, USA.

6.2. Special Difficulties of the LDC for Power Sector

Even apart from the usual consideration of low electricity consumption per capita - which is the case for consumption of many other commodities and services by the LDCs - the power sector poses special problems for the least developed countries.

6.2.1. Economy of Scale

In addition to low GNP per capita, they are often small countries with small populations or small geographic areas, or they have geographic disadvantages of being landlocked or islands, etc. Thus, it is not possible for these LDCs to have large power plants and many of them could have at best 5 to 15 MW power plants losing out on economy of scale. In fact, it is quite likely that some have power plants of the order of magnitude of kilowatts. The developed countries consider 1000 MW as a standard sized - power plant.

The small unit size raises the costs of generation from diesel from 1.6 to 6.0 cents/kWh in the developing countries. For example, in Figure 6.1 the illustration given of economies of scale is based on the data given for power generation from diesel for Latin America (IAEA Bulletin, 1974) for small power plants ranging from 50 KW to 4 MW which is a relevant range for the least developed countries. The figure shows that the total cost per kilowatt hour for the electricity from diesel is nearly double for a power plant of 100 KW capacity compared to that of 4000 KW. However, after the rise in the price of diesel, the economy of scale has decreased as the increase in operating costs per kilowatt hour is now two to three times greater than the increase in capital charges per kilowatt hour. This raised the total costs from 2.1 to 3.9 cent/kWh for a 4000 KW power plant in 1974. In 1973, the capital and operation costs per kilowatt hour were approximately the same. When utilization increased from 2000 to 3500 kWh/KW the costs per kilowatt hour fell by 20 per cent.

The costs in power generation from steam produced from coal, on the other hand, have increased by only 50 per cent since 1973 and stand at 2.1 cents/kWh compared to 3.2 cents/kWh from an oil-based plant (Parikh J. 1980).

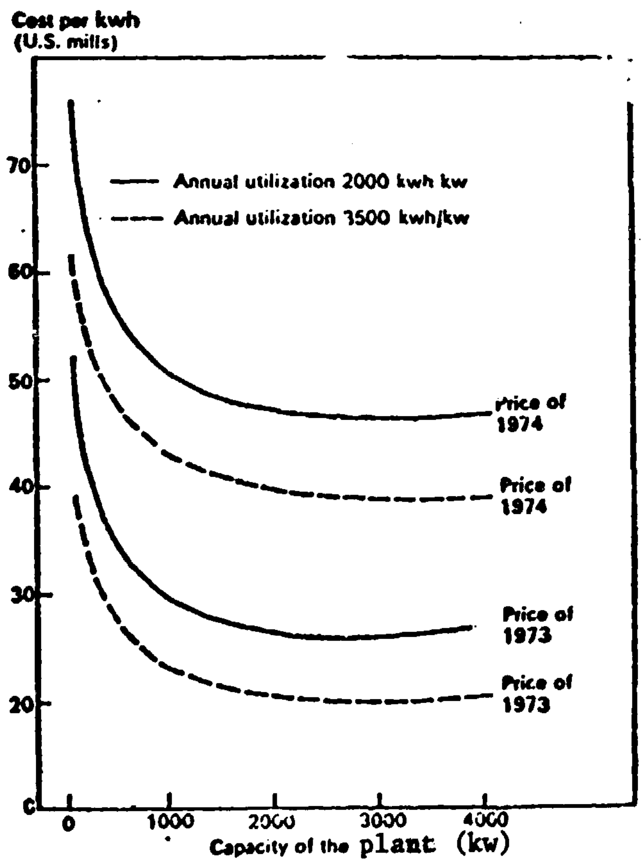
Thus a larger plant size, especially in steam generation - and higher utilization could bring down the costs of electricity. Unit sizes, however, cannot be increased in the least developing countries until the demand for electricity increases considerably and necessary transmission networks are established.

Moreover, a small demand does not make efforts for technological development and manpower training an economically viable proposition. The difficulties concerning low utilization possibly due to scarcity of skills and spare parts have already been highlighted.

A specific example of investment requirements in the Sahel region is discussed in the next section.

6.2.2. Optimal Mix of Hydro and Thermal Plants

As can be seen from Table 6.1, LDCs have either thermal power plants



Source: United Nations. Small Scale Power Generation IAEA Bulletin. 1/2. 1974

FIG. 6.1 Cost Estimate of Power Generation from Diesel (which are likely to be only oil-based plants making them susceptible to oil-price rise for which there may be no other option), or hydro power plants, from which output could fluctuate from season to season substantially making it less reliable for assured supply to crucial industries. Such polarization is seen for either hydro or thermal generation for nearly 18 countries out of 23, which is undesirable. In other words, many of the least developed countries are not in a position to plan a power system having a suitable hydro-thermal mix which is necessary if one wants to minimize operating costs due to oil-use as well as the fluctuations in the electricity supply associated with hydro-power plants.

These two difficulties - coupled with lower per capita income and dim prospects of high growth - make the prognosis discouraging for the least developing countries.

6.3. Investment Comparisons of Hydro and Thermal Plants

The purpose of this section is to illustrate the differences between hydro, steam and diesel plants regarding the following matters:

(a) Impacts of rising oil prices on costs per kWh in the future;

(b) The differences in unit* costs under soft and hard conditions of financing for each of the three types of plants;

(c) The effects of economy of scale for each of the three types of plants.

The illustration chosen is from a typical country in the Sahel region using the information from a study made by Club du Sahel in 1978.

For comparative putposes, it should be mentioned from the beginning that in these least developing countries, not only are the investments high compared to the developed countries but they are even higher when comparing them to the average taken for developing countries. As shown in Table 5.3, generation costs are \$3180 per KW for hydro and \$682 for thermal plants for a 30 MW plant which are higher than the World Bank average figures for developing countries of \$1730 and \$1130 for each respectively, including TDA investment. The generation cost alone is approximately 6 US cents per kWh even for 200 MW

*unit = 1 kWh

hydro plant. Thus, eventual costs to the consumer could be two to three times higher.

6.3.1. A Case of a 200 MW Hydro Plant vs. Thermal Plants in Sahel Region

Table 6.2 provides a comparison of costs per kWh produced by large hydro, steam and diesel power plants. A large hydro power plant of a capacity of 200 MW with an annual production of 1000 gWh is expected to last for 50 years, whereas a steam and diesel plant of the same capacity and production level are expected to last only for 25 years. However, a steam and diesel plant have low line investment costs (transmission distance is small for them).

For a proper comparison we need to consider them on an equal basis. Assuming that steam of a diesel plant is reset up at the end of 25 years and hence fresh investment costs towards this purpose would be incurred in the 20th year a comparison between hydro plants and steam and diesel plants can be made. From the table it is clear that, even if the discount rate is assumed to be less, the steam and diesel plants would incur less total investment costs compared to a hydro plant. The total investment costs incurred by a hydro plant are approximately 4 times that of a steam or a diesel plant whereas the plant life of the former is only twice that of the latter.

The costs involved in debt service would vary according to the method of financing. Table 6.2 provides these details also based on the terms of soft and commercial financing. The unit fixed costs for commercial (hard) financing terms are approximately 70 per cent higher than those with soft financing terms in the case of hydro plants. The corresponding increase in the unit investment is approximately 32 per cent in the case of steam plants and 20 per cent in the case of diesel plants.

The debt service component within the fixed costs is of course very high in all the cases. However, this is as high as 94 per cent in the case of hydro plants, financed by hard terms. This component, for hydro plants financed by soft terms, works out to be around 89 per cent which is higher than that for a diesel or steam plants financed by hard terms (around 85 per cent).

TABLE 6.2

COMPARISON OF COSTS PER KWh PRODUCED BY LARGE HYDROPOWER AND THERMAL PLANTS IN SAHEL REGION

	HYDROPOWER		STEAM PLANT (heavy fuel oil)		DIESEL PLANT (light fuel or diesel oil)	
Total (thermal) capacity: (in one or several units)	200 MW		200 MW		200 MW	
Annual production	1 000 GWh		1 000 GWh		1 000 GWh	
Transmission distance	700 km		-		-	
Technical lifespan of plant (line)	50 yeras (50 years)		25 years		25 years	
Investment costs of plant (1)	500 000 (700 000)CFA francs/KW		150 000 CFA francs/KW		150 000 CFA francs/KW	
Investment costs of line	25 000 million CFA francs/KW		-		-	
Plant investment 10^9 CFA francs	100 (140)		30		30	
Line investment 10^9 CFA francs	17,5		-		-	
Total investment 10^9 CFA francs	117,5 (157,5)		30		30	
Financing terms (interest rates, maturity) soft or commercial terms	4%, 30 years	8%, 20 years	8%, 15 years	10%, 10 years	8%, 10 years	10%, 8 years
Debt service 10^9CFA F.	6.8(9.1)	12.0(16.0)	3.5	4.9	4.5	5.6
Operation and Maintenance costs -plant 10^9CFA F.	0.5	0.5	0.9	0.9	0.9	0.9
Operation and Maintenance costs -line 10^9CFA F.	0.3	0.3	-	-	-	-
TOTAL FIXED COSTS/KWh	7.6(9.9)	12.8(16.8)	4.4	5.8	5.4	6.5
Fuel purchases CFA francs/KWh: 1978	-		7		19	
1990	-		10.5		23	
2000	-		14		27	
COST PER KWh in CFA francs	Soft terms	Commercial terms	Soft terms	Commercial terms	Soft terms	Commercial terms
1978	9.3(12.2)	12.8(16.8)	11.4	12.8	24.4	25.5
1990			14.9	16.3	28.4	29.5
2000			18.4	19.8	32.4	33.5

Note (1) - Two investment assumptions are examined.

Ref: Club du Sahel (1978) 220 CFA = 1 US$

Due to differences in debt service assumptions for steam and diesel plants, their unit fixed costs are different though their plant investment costs are the same. This is done in order to illustrate the fact that not only do the interest rates matter, but the maturity years also contribute differently in the eventual cost per kWh. Steam and diesel plants would, however, have additional costs over the investment costs towards fuel purchases which are almost nil for the hydro plants. Table 6.2 shows the estimated fuel costs per kWh in the years 1978, 1990 and 2000 in the case of these two types of plants. Due to this additional expenditure on fuels by these two types of plants, the unit total costs in the case of hydro plants turns out to be less than that of the diesel or steam plants. The expenditure on fuels is high particularly in the case of diesel plants, which leads to the following situation:

(a) The unit fixed costs in the case of hydro plants are around twice that of the diesel plants under commercial terms (i.e., 12.8 vs. 5.8 CFA/kWh in 1978);

(b) The unit total costs in the case of hydro plants are around only a half that of the diesel plants - both under commercial terms (i.e., 12.8 vs. 25.5 CFA/kWh in 1978 to 33 CFA/kWh in 2000);

(c) The most important point is that the debt service alone amounts to 94%, 84% and 86% of fixed costs of hydro, steam and diesel plants respectively under hard conditions and 89%, 79% and 83% under soft conditions - the rest being for operation and maintenance. Thus, reduction in investment during construction period due to efficient management and soft loans have a crucial role in reducing the cost of electricity.

6.3.2. Economy of Scale - A Case of 30 MW Plants

The above mentioned contrast in the relative cost structure is even more if economies of scale for hydro-power are taken into consideration. Table 6.3 provides details for comparison of costs per kWh produced in medium-size hydro-power plants (30 MW capacity and 150 gWh annual production). It can be seen from tables 2 and 3 that while there is absolutely no cost reduction per unit by shifting from a medium-size diesel plant to a large size diesel plant, there is quite a significant cost reduction per unit by shifting from a medium-size hydro plant to a large-size hydro plant. This reduction in the hydro plants come to about 40 per cent. However, even for medium-size plants the total costs per cent in the case of hydro plants is only about 83 per cent of that of diesel plants, in 1978; a figure that was estimated to be even lower (only 64 per cent) by the year 2000.

Table 6.3 shows that for a medium-size 30 MW power plant, there is no gain in going for a hydro power plant (over steam or diesel) under present conditions, unless it is financed under soft financing conditions. The cost per kWh works out to be approximately 22 CFA/kWh for all the alternatives under commercial terms but decreases to 12.7 CFA for hydro power if financed under soft conditions. However, as one approached the year 2000, even under commercial conditions, hydro-power gives electricity at 30 per cent less unit cost and at 60 per cent less unit cost if financed softly.

Thus, the economy of scale is especially relevant for hydro plants where the cost per kWh is 9.3 and 12.8 CFA for 200 MW and 30 MW plants respectively under soft conditions. Corresponding figures for hard conditions are as much as 12.8 and 21.4 respectively. However, oil based plants do not have pronounced effects of economy of scale.

6.4. Future Prospects for the LDCs

As mentioned earlier, there are special disadvantages for the LDCs arising from geographic problems, small demand and inability to balance hydro-thermal mix for power generation.

Thus, the LDCs should pay special attention not only to the terms of the financial aid but also to the terms of lending skilled manpower, equipment, spare parts etc. The most important contributions can come from bilateral, multilateral and regional co-operation.

Many difficulties could be avoided if LDC development is regarded as a part of larger framework comprising several countries. This point is illustrated again from the example of several countries.

6.4.1. Co-operation for Hydro-Power Plants in Africa

Out of a possible 75 GW hydro-plants in Africa, only 11 GW are operating, 4.6 GW under construction and another 11 GW are in the planning stage. The

TABLE 6.3

Comparison of costs per kWh for medium size (30 MW) hydro and thermal plants

	MEDIUM HYDROPOWER CAPACITY			
Total (thermal) capacity: (in one or several units)	30 MW		30 MW	
Annual production	120 GWh		150 GWh	
Transmission distance	150 km		-	
Technical lifespan of plant (line)	50 years (50 years)		25 years	
Investment costs of plant	700 000 CFA francs/KW		150 000 CFA francs/KW	
Investment costs of line	20 000 000 CFA francs/KW		-	
Plant investment 10^9 CFA francs	21.0		4.5	
Line investment 10^9 CFA francs	3.0		-	
Total investment 10^9 CFA francs	24.0		4.5	
Financing terms (interest rates, maturity) "preferential" or "close to market terms"	4%, 30 yrs	8%, 20 years	8%, 10 years	10%, 8 years
Debt service 10^9 CFA francs/yr	1.39	2.44	0.67	0.84
Operation and Maintenance costs - plant 10^9 CFA francs/yr	0.08	0.08	0.14	0.14
Operation and Maintenance costs - line 10^9 CFA francs/yr	0.05	0.05	-	-
TOTAL FIXED COSTS (CFA francs/KWh)	12.7	21.4	5.4	6.5
Fuel purchases CFA francs/KWh: 1978	-		19	
1990	-		23	
2000	-		27	
COST PER KWh in CFA francs	Soft terms	Commercial terms	Soft terms	Commercial terms
1978	12.7	21.4	24.4	25.5
1990	12.7	21.4	28.4	29.5
2000	12.7	21.4	32.4	33.5

Ref: Club du Sahel (1978). 220 CFA = 1 US$

rest of the 48 GW have yet to be considered. This consists of 9 GW in Angola, 5 GW in Mozambique and 32 GW in Zaire which could benefit a number of neighbouring countries, many of which are LDCs. A scheme connecting many countries of South-West Africa up to South Africa was proposed but never pursued.

Table 6.4 gives the hydro-power potential for six countries in the Sahel zone of Africa out of which five countries are LDC. A look at the location of the sites with respect to the demand zones shows that Mali, which has an 800 MW hydro-power potential expects demand to be 200 MW by the year 2000, whereas Senegal which has only a 250 MW hydro-potential expects the demand to reach 700 MW by 2000. Both the countries could benefit from mutual co-operation such that Mali's potential could be economically exploited and Senegal's development potential.

6.4.2. Co-operation in the Indian Sub-continent

Similarly an opposite example could be that of a large country exploits its own large potential to accommodate the needs for the neighbouring LDC with low demand and low hydro-potential. Examples of such collaboration could be:

(a) India and China could develop hydro-potential of Brahmuptra river to fulfill the need for power of their own and of Bangadesh to mutual advantage;

(b) India and Nepal could collaborate on hydro-power development of Ganga river to mutual advantage;

(c) Pakistan and Afghanistan could co-operate through exchange of equipment, manpower etc. on natural gas and coal development of both the countries.

Thus, the LDC development should be an integrated part of the larger neighbouring countries as far as possible. Moreover, they should be assisted with loan of skilled manpower and spare parts so as to obtain better utilization of their existing and future power plant capacity.

7. SUMMARY AND HIGHLIGHTS

7.1. Electricity fosters the development of industries, commercial and agricultural sectors and is necessary for household comfort as well. In the

TABLE 6.4

THE SAHEL COUNTRIES' HYDRO POTENTIAL

COUNTRY	Site	Power potential	Guaranteed power	Expected annual output
THE GAMBIA*	Yellitenda	14- 28 MW		
SENEGAL	Sambangalou dam	95-100 MW		800 GWh
	Kékréti dam	40 MW		250-300 GWh
	Gourbassi dam (Falémé River)	113 MW		
MALI*	Manantali dam	190 MW	100 MW	800 GWh
	Sélingué dam	45 MW		184 GWh
	Galougo dam	300 MW		
	Félou Falls	50 MW		
	Petit Gouina	70 MW		
	Koukoutamba	85 MW		
	Mako	?		
	Tossaye dam	?	30 MW	
	Labasan	80 MW		
	Kénie	25- 30 MW		
UPPER VOLTA*	Noumbiel dam (on the Black Volta)	70 MW		303 GWh
	Pama dam (on the Kompienga River)	?		33 GWh
	Bagré dam (on the White Volta)	?		
NIGER*	Kandadji dam (Niger river)	300 MW	1	800 GWh
	Hydro plants on the Mékrou	26 MW	13 MW	83 GWh
	W dam (2 stages)	84 MW		526 GWh
CHAD*	Ganthiot Falls on the Mayo Kebbi	?		
	TOTAL:	More than 1,700 MW		

* These countries come under the classification of the least developed countries.

Club du Sahel (1978)

developing countries, the power sector claims nearly 7% to 10% of capital formation, 17% to 20% of planned investment and 70% to 85% of the development aid and lending given to the energy sectors by various institutions. Moreover, in 1978 developing countries imported more than $12 billion in power equipment and invested $34 billion in the power sector. The GDP elasticities range from 1.3 to 3 in the DC. Thus the power sector plays a very important role in the economy.

7.2. The growth of the power sector has decreased from 10% to 14% in the sixties and from 8% to 10% in the seventies in the developing world. In spite of the high oil prices, high growths will continue in the eighties because of the following:

- Electricity substitutes human and animal labour reducing drudgery and increases efficiency in production and the quality of the products;
- Electricity, particularly when generated from locally available coal, gas or hydro, could be a substitute for oil in:
    - The household sector for kerosene used in lighting and cooking;
    - The agriculture sector for diesel used in irrigation pumps, tube-wells and food processing;
    - The industrial sector for fuel, oil and diesel oil;
    - The transport sector for diesel for railways and service vehicles;
    - The commercial sector for kerosene and diesel used for lighting, petromax or diesel generators for electricity.
- More than 60% of the electricity in the DC is consumed in the industrial sector, where there is considerable room for conservation. There are indications that some progress has been made.

7.3. Out of a 1914 GW capacity in the world in 1979, 181 GW was in the DC of Africa (21 GW), America (92) and Far East (68) of which 77 GW was hydro capacity. The growth rates in the seventies for the three regions were 8.2%, 8.8% and 9.3% respectively which are significantly less than those in the sixties.

- Average per capita electricity consumption of the developing countries in 1979 was 164, 968 and 225 for the developing countries in Africa, America and Far East respectively. This is much less than the consumption of 6673 kWh in the developed world for the same year.

Capacity utilization in DC could, in principle, be higher than in the developed countries who must have excess capacity to provide for winter needs and high stands of reliability. In 1979, capacity utilization was 3679, 3693 and 4061 kWh/KW for the three regions respectively and it is expected to improve up to 4400 kWh/KW by 2000.

7.4. The estimation of required investments has to be derived from projections for electricity demand. Three different methods in literature are examined for their relative merits viz:

(i) Econometric methods which use time-series or cross-country data of electricity consumption and other economic and demographic methods suitable for short or medium-term projects;

(ii) End-use methods which consider sectoral use of electricity and the expected changes in the future for each sector including possibilities of conservation, changes in population and lifestyle, etc. This is used by IIASA models for long-term projections;

(iii) Input-output models used by governments and UNITAD models consider utilities in value added rather than physical terms. They are suitable up to a decade or so.

All the methods rely on past and present data and use different approaches to incorporate "expected future changes" which could make the models subjective.

It is shown that for IDS II growth rates (6.2%, 6.0% and 8.0% respectively), one gets electricity demand of 171, 555 and 747 bkwh for Africa, Far East and Latin America respectively for 1990 using SIMCRED model (Parikh, 1980). The growth rates for 1985-2000 work out to be 7%, 6.5% and 8.8% respectively. The results of other models are described in the text.

7.5. Estimation of Investment

Having estimated electricity demand, required investment was estimated by considering:

- Reduction in TDA losses by 30%; (i.e. instead of 30% to 35% losses as of present to 2% to 25% in future);
- Improvements in capacity utilization by 10%;

- No further real increase in capital costs which are taken at $1600, 1200, 1500 and 800 per KW of hydro, coal, nuclear and oil-gas plants capacity in 1980 prices;
- Gestation periods of several years for (construction and achieving full scale production) all power plants such that investments for 1993 (allowing for phasing of investment) would have to be made in 1990;
- Replacement of 12 GW of capacity built during 1955-1960;
- Optimal mix of hydro-thermal plants from IIASA models and separate capital costs for each estimated additional capacity is 230 GW for Africa, Far East and America which would require $303 billion over this decade. As against this, the World Bank estimates are 240 GW requiring $358 billion. In either case the needs are much greater than means and the principle issue is how to reduce the investment. This could be done by:
    - Reducing the demand itself by price-induced and technology-induced conservation;
    - Increasing capacity utilization of the existing and the additional plants by streamlining organization and reducing the breakdowns of power plants;
    - Obtaining soft term loans as far as possible to reduce the interest during the construction period.

7.6. Least developed countries face special problems because even within the developing countries, their consumption is less than a tenth of the average developing countries. This means that they are restricted to small, uneconomic power plants with obsolete technology and therefore very expensive electricity. Moreover, they cannot choose optimal mix of hydro and thermal plants for a hedge against seasonal fluctuations and high operation costs of using fossil fuels. From the data of capacity utilization it appears that there must be frequent breakdowns of the power plants, which taken together with a small number of plants for the entire countries would imply serious disruptions in power supply. In addition, small demand does not make technological development and manpower training a viable proposition. The least developed countries, therefore, require special consideration such as soft loans and other forms of direct aid such as skilled manpower, machinery and spare parts, etc. In addition, mutual co-operation with neighbouring countries - examples of which are given in the text could benefit not only the LDCs but the neighbouring DCs as well. The UN agencies could play an important role in opening such dialogues for co-operation among developing countries where the interests of the LDC are incorporated in a regional approach.

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ANNEX 1

An example of investment calculations with phasing. Capital requirement for electricity generation:

$C_{generation}$

Five-year projected growth rate of electricity

$$gel(t) = [elec((t) + 5)/elec(t)]^{1/5}$$

Electricity requirements for in-between years

$$elec(t + 1) = [elec(t) \times (1 + gel(t))^{1+i}]$$

Additional electricity requirements each year

$$d\,el(t + 1) = elec(t + 1) - elec(t + i - 1)$$

Additional capacity requirements

$$d\,k\,w(t + 1) = del\ (t + 1) - del\ (t + i - 1)$$

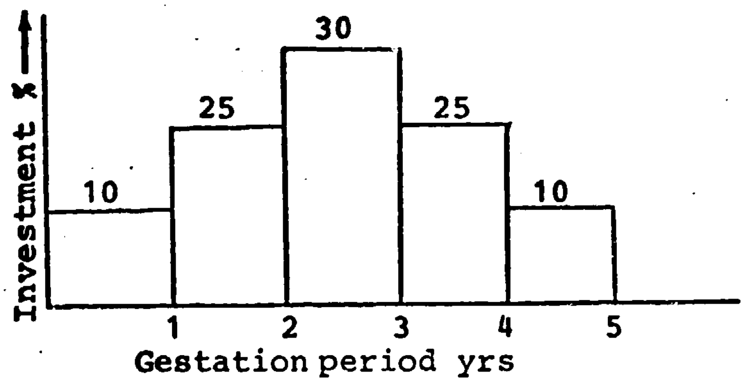
$$C_{generation(t)} =$$

$$\Big[.10 \times dkw(t + 5) + .25 \times dkw(t + 4)$$

$$+ .30 \times dkw(t + 3) + .25 \times dkw(t + 2)$$

$$+ .10 \times dkw(t)\Big] \times Cap\ kw$$

Cap - kw = Capital requirement per kw.



Phasing of investment in thermal plants

Similar phasing of investment transmission—distribution would have to be worked out.

Similarly, capital and import requirements for coal, oil, and gas as discussed on the preceding page would be considered.

Annex 2 World Bank Lending to Various Regions Towards Energy Projects (1980).

Region	Oil, gas and coal (US-$ millions)		Power (US-$ millions)	
	1971-75 Annual Average	1976-80 Annual Average	1971-75 Annual Average	1976-80 Annual Average
1. East Africa	4.	9.7	57.1	58.0
2. West AFrica	-	1.0	18.1	36.3
3. East Asia & Pacific	-	36.8	95.2	28[illegible].7
4. South Asia	12.	36.0	37.8	364.1
5. Europe, Middle East, North Africa	18.3	54.5	163.5	211.6
6. Latin America & Caribbean	-	15.7	152.4	404.2
		153.7	524.1	1358.9

Source: Annual Report of the World Bank (1980).

Annex 3. World Bank Lending to Various Regions Towards Energy Projects (1980).

Region	Oil, gas and coal (US-$ millions)		Power (US-$ millions)	
	1971-75 Annual Average	1976-80 Annual Average	1971-75 Annual Average	1976-80 Annual Average
1. East Africa	4.	9.7	57.1	58.0
2. West AFrica	-	1.0	18.1	36.3
3. East Asia & Pacific	-	36.8	95.2	284.7
4. South Asia	12.	36.0	37.8	364.1
5. Europe, Middle East, North Africa	18.3	54.5	163.5	211.6
6. Latin America & Caribbean	-	15.7	152.4	404.2
		153.7	524.1	1358.9

Source: Annual Report of the World Bank (1980).