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ELECTRICAL ENERGY PLANNING FOR ECONOMIC DEVELOPMENT IN WEST AFRICA

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# ELECTRICAL ENERGY PLANNING FOR ECONOMIC DEVELOPMENT IN WEST AFRICA

Emmanuel Kobla Glakpe

A Dissertation Submitted to the Faculty of the

DEPARTMENT OF NUCLEAR ENGINEERING

In Partial Fulfillment of the Requirements
For the Degree

DOCTOR OF PHILOSOPHY

In the Graduate College

THE UNIVERSITY OF ARIZONA

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THE UNIVERSITY OF ARIZONA
GRADUATE COLLEGE

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Dada
Papa
Kofi
Fuya
Mercy kple ameyinugbe Akuvi

.....esia nye miatɔ

Akos

.....eyi nso ye wode

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## ABSTRACT

In terms of economic development, internal availability of energy in a region means the capability to produce essential goods and services for the improvement in the quality of life of all the economic agents. Economic development consists in large part of harnessing increasing amounts of energy for productive purposes or by making more efficient use of available energy resources.

In this dissertation, the future electricity supply and demand interactions are examined for seven countries in West Africa: Benin, Ghana, Ivory Coast, Niger, Nigeria, Togo, and Upper Volta. A description of the primary energy resources (coal, hydro, natural gas, and oil) available in each country is presented. The future demands for electricity in the medium term (1980-1989) are projected through econometric models developed in the study. Two sectorial models for each country's economy, the residential sector, and the commercial and industrial sector, are presented. Multiple regression analysis is applied in the estimation of all demand equations.

Major determinants for electricity demand used in the estimation for the residential sector were average price of electricity, real personal income, and the number of households with access to electricity. Data on these

variables were obtained from international organisations such as the United Nations and from government publications for the period 1960-1977. Each of these determinants was found to be significant for most countries; however, their relative importance differ across countries. Similarly, average price of electricity, real output, and employment were major determinants used and found to be significant in the demand for electricity in the commercial and industrial sector of all countries. Price and income elasticities were obtained from the estimated equations.

A general multi-region supply model was developed to structure the future electricity supply possibilities in the countries involved. The objective of this model, using linear programming, was to seek the least-cost combination of resources (primary energy, capital, and technology) for the production of electricity. The impacts of various levels of resource availability on average cost of electricity were examined for each country, and for joint development efforts using a non-integer, deterministic, linear version of the general model.

The application of the supply and demand models to West Africa over the decade to 1989 reveals that except for Nigeria, all countries in the region will require fossil fueled systems to supply additional demands for electricity, because all hydro resources would have to be exploited by the mid-1980s. This will lead to higher costs in producing electricity. However, Nigeria is expected to have excess electrical energy if plans initiated in its third development plan are completed. The extension of transmission lines between Nigeria and Benin could effectively distribute the relatively cheaper energy from Nigeria to other countries, since adequate transmission network already exists between most of the countries.

# CHAPTER 1

## INTRODUCTION

In terms of economic development, energy availability in a region means the ability to produce shelter, clothing, communication, health care, education, transportation, leisure, and so forth. In fact, economic development consists in large part of harnessing increasing amounts of energy for productive purposes. This can occur either by tapping increased amounts of energy resources or by making more efficient use of available energy resources through use of appropriate tools and machines or conservation techniques. The relationship between energy and economic development is a dynamic one in which the amount, type, and speed of economic growth are mutually dependent variables of the quantity, kind, and price of the energy available.

For the developing nations, the present international predicament is ominous; they are unlikely to ever again have access to energy fuels priced at less than $3 a barrel of crude oil equivalent as the world did before 1974. This constitutes a tremendous constraint in the struggle for economic advancement.

In this dissertation, the future demand and supply interactions of electrical energy, or electricity, are examined for seven West African countries. Demand is modelled through causal economic factors and an optimization model seeking the least-cost combination of technology and resources programmed to structure the medium-term supply paths in these countries. Various levels of resource availability and cooperation between countries are analysed using these models as guiding tools.

## West Africa

This region of the continent of Africa is made up of 14 countries[1] (Figure 1) with a total land area of 7.5 million $km^2$. It runs between latitudes 4.5° and 22° N and longitudes 17.5° west and 14.5° east. It had an estimated 1977 population of 137 million, with the smallest country being Gambia and the largest, Nigeria. The climatic conditions vary from the arid in the north to tropical in the south close to the Atlantic Ocean.

The development of the economies of most of the countries of the region can be described as still at the traditional society stage of development with only a handful that could be considered as being in the take-off stage. For definitions of traditional society and take-off stages see for example Rostow (1960). Even with the difficulties in measuring the economic welfare of a country, Table 1

---

[1] These are Ghana, Ivory Coast, Benin, Togo, Upper Volta, Nigeria, Niger, Sierra Leone, Gambia, Mauritania, Senegal, Mali, and Guinea.

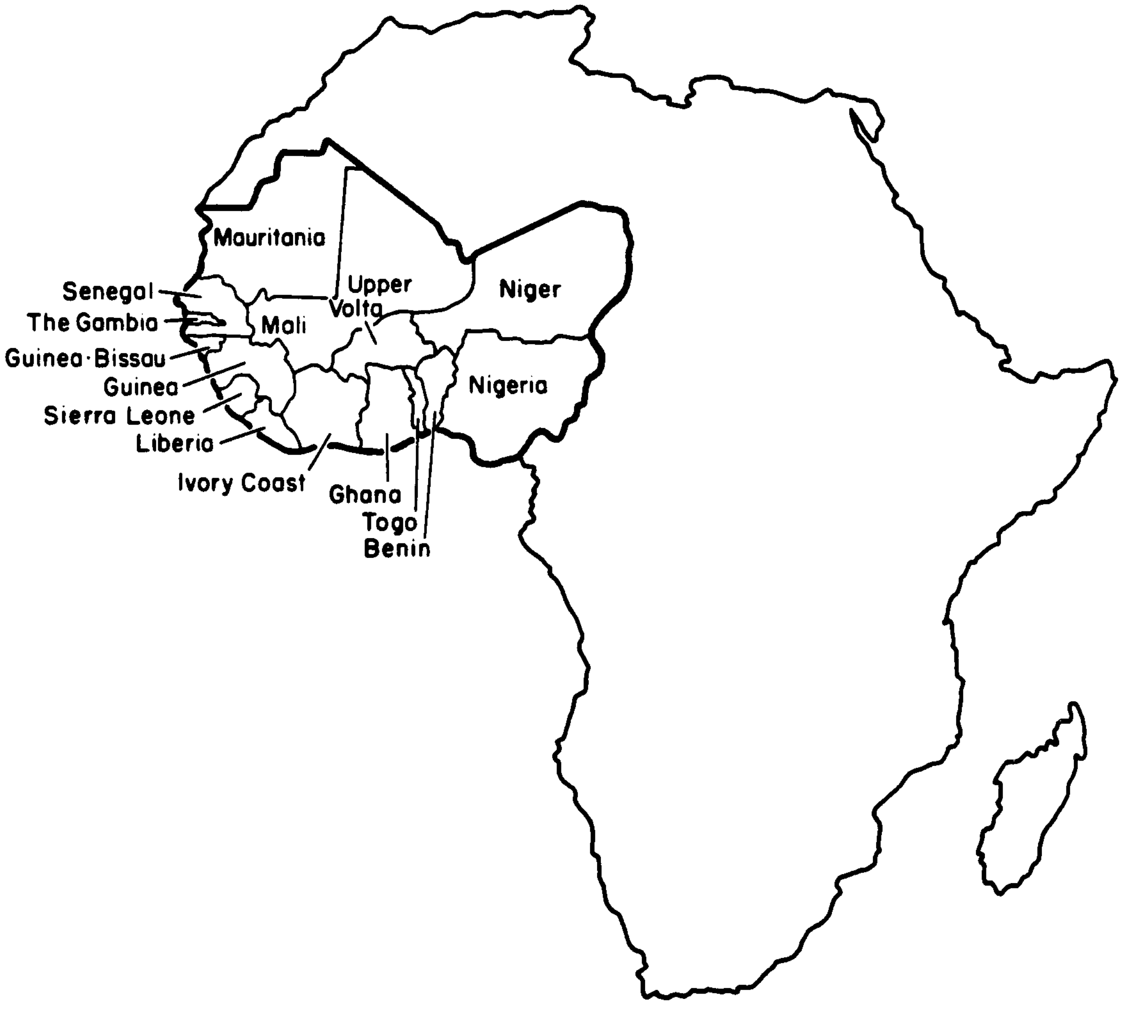


Figure 1. Map of Africa showing the countries of West Africa

Table 1. GNP per capita statistics of various countries

| Country | GNP per Capita (U.S. $) 1976 | GNP per Capita (U.S. $) 1977 | Average Annual Growth Rates (%): GNP per Capita (Real) 1970-76 | Average Annual Growth Rates (%): Population 1970-76 |
|---|---|---|---|---|
| West African Countries | | | | |
| Ghana | 370 | 380 | -0.7 | 2.9 |
| Nigeria | 400 | 420 | 5.4 | 2.6 |
| Niger | 150 | 160 | -2.4 | 2.8 |
| Benin | 180 | 200 | 1.0 | 1.5 |
| Togo | 270 | 300 | 1.1 | 2.6 |
| Upper Volta | 100 | 110 | 0.4 | 2.3 |
| Ivory Coast | 650 | 720 | 1.9 | 4.3 |
| Other Countries | | | | |
| United States | 7,880 | 8,640 | 1.7 | 0.8 |
| Brazil | 1,300 | 1,390 | 7.4 | 2.8 |
| Israel | 2,810 | 2,920 | 3.3 | 3.0 |
| Mexico | 1,060 | 1,110 | 1.7 | 3.5 |

Source: World Bank (1978)

presents the Gross National Product (GNP) per capita statistics on seven countries of the region and some other countries of the world either "fully" or "moderately" developed.

The low GNP per capita ratios of the developing economies reflect the retarding effects of such factors as high population growth rates, low revenues from export production, little or non-existent industrial activities and agricultural stagnation, which characterize these economies. Most importantly, gains in national product hardly exceed the rate of population growth, and thus the economies are unable to generate surplus resources for the diversification of their economies.

A goal in economic development for these contries is therefore to attempt to make locally available some of the factors of production as cheaply and reliably as possible, in order to remove the discontinuities that are predominant today in the utilization of capacities of production (Ghana News, 1978).

## Electrical Energy

Electrical energy has been selected as a prime target for this study for the following reasons: With technological advancement, electricity can hardly be substituted for in efficient production processes such as manufacturing, mining, commercial operations, and general comfort. Its cheap and reliable availability can provide a stimulus to economic development, therefore enhancing the quality of life of the economic participants. The uptrend in world prices for primary energy resources, principally oil, promises to further retard the process of economic development in the countries of the region. As an example of the vulnerability of some of these countries to oil price increases, Table 2 shows the oil imports bill for the Republic of Niger during the period 1968 to 1976 for the production of electricity enjoyed by not more than 10 percent of the population. It is important to note that in the last column of the table, the costs of oil for the production of electricity has been relatively steady between 1968 and 1976 due to earnings in uranium exports which contributed on the average 60 percent to the export earnings of the economy. Without any doubt, world oil prices will continue to rise and the dependence of an economy on one depletable (finite) resource to finance oil imports is bound to frustrate efforts at economic development. Furthermore, heavy future expenditures on oil imports will divert hard-earned external earnings from other development activities that could potentially impact most of the population.

For the moderately richer countries of the region (such as Nigeria), plans to ensure supply and demand equilibrium are very welcome in their current exercise of using

Table 2. Fuel oil imports for electricity production in Niger (1968-1976)

| Year | Fuel Imports (tonnes) | Expenditure on Fuel Imports (billion CFA) | Percentage Change in Unit Prices | Fuel Costs as Percentage of Export Earnings |
|---|---|---|---|---|
| 1968 | 31,482 | 0.342 | --- | 4.80 |
| 1969 | 28,732 | 0.352 | 12.9 | 5.64 |
| 1970 | 36,797 | 0.430 | 4.6 | 4.90 |
| 1971 | 27,346 | 0.404 | 26.3 | 3.79 |
| 1972 | 29,812 | 0.561 | 27.3 | 4.09 |
| 1973 | 29,065 | 0.584 | 6.7 | 4.23 |
| 1974 | 30,809 | 0.654 | 5.6 | 5.18 |
| 1975 | 45,990 | 0.990 | 1.4 | 5.06 |
| 1976 | 44,754 | 1.464 | 52.0 | 4.58 |

Source: Banque Centrale des etats de l'Afrique de l'Ouest (BCEAO) (1968-1977) their petro-dollars for the development of the country. This is particularly so due to the recent electricity shortages and equipment failures that have plagued the economy (Central Bank of Nigeria, 1977). The Central Bank of Nigeria (CBN) (1977, p. 20) is quoted as saying "the perennial problem of interruptions in electric power supply assumed greater dimension during the year. The deteriorating situation was attributed largely to the low level of water in the Kainji Dam following the Sahelian drought."

In the other extreme case, Ghana, where excess capacity for electricity production has existed for a long time, an agreement (or joint development) with its neighbors on buying excess power will ensure (1) near-full utilization of capacity, (2) the improvement in the balance-of-payments position of the countries involved, and (3) better returns on capital expenditures.

## Research Objectives and Organization

Having enumerated the motivative forces behind this study, it is expected that a study of this nature will provide a better understanding of the factors contributing to the demand for electricity in each of the selected countries of the region. It will also aid in the planning of the electrical energy supply sector for future general development efforts with the recognition of associated uncertainties initiating and operating productive capacities in this important sector of any economy. The provision of an inexpensive tool for examining supply strategies in individual countries and joint development efforts and for directing experimentation on alternative sources of energy such as solar and biomass are the prime objectives of this study.

Specifically, the objectives of this research are threefold:

1, To establish quantitative relationships between electricity consumption and economic development in seven of the countries of West Africa, viz. Ghana, Nigeria, Upper Volta, Togo, Benin, Ivory Coast, and the Republic of Niger.

2. Assuming that the identified relationships will hold into the near future, to project the demand for electricity by various economic agents based on the assumptions of certain changes in the determinants of electricity consumption.

3. To match existing resources and proven technology with projected demands, taking into account existing supply systems, in order to satisfy an economic criterion over a defined planning horizon.

Policy questions addressed include the mix of supply plants during each planning period, the scale of such plants, the location of plants in the joint development case, operating policy, fuel requirements and expenditures, interchange of electrical energy between countries, and above all the economic gains realized by each country by comparing individual country results with those of certain levels of joint-supply efforts.

The relationship between energy and economic development is explored in Chapter 2 followed by an inventory of primary energy resources and existing electricity supply systems in each country. This is accomplished in Chapter 3.

Chapter 4 examines the links between electricity consumption and economic development through empirical analyses of demand in the residential and industrial and commercial sectors of each economy. Projections of future consumption are made with these identified relationships. A general mathematical programming model incorporating various characteristics of the developing countries is developed in Chapter 5, and in Chapter 6 a simpler version of this programming model is solved for the West African countries in the examination of the policy questions raised earlier.

Chapter 7 summarizes the research accomplishments, discusses possible areas of applications and further refinements of the models used, and recommends potential paths for the countries concerned in the quest of a supply of cheap, reliable electricity.

# CHAPTER 2

## ENERGY AND ECONOMIC DEVELOPMENT

Just as the problems of economic advance and the policies suggested as solutions are multi-dimensional, so too are the definitions of economic development. However, according to Kindleberger and Herrick (1977), students of the subject generally define it to include improvements in material welfare, especially for persons with the lowest incomes; the eradication of mass poverty with its correlates of illiteracy, disease and early death; changes in the composition of inputs and outputs that generally include shifts in the underlying structure of production away from agricultural toward industrial activities; the organization of the economy in such a way that productive employment is general among the working-age population rather than the situation of a privileged minority; and the correspondingly greater participation of broadly based groups in making decisions about the directions, economic and otherwise, in which they should move to improve their welfare.

Developing countries are generally characterized in various ways:

1. Economic system is agrarian rather than industrial.

2. Bulk of the people live in rural areas, and a large part of the national income is generated in agriculture.
3. Workers are largely self-employed and are not equipped with much physical or human capital.
4. In international transactions, the bulk of exports include only one or two products rather than a diversified range.
5. Export production may be foreign owned or controlled; government revenues depend largely on these exports whose prices in the world market fluctuate considerably rather than on income, property, or sales taxes.
6. Industrial activities are small or non-existent, so that most manufactured products are imported; demand for them grows more rapidly than revenues from exports, hence balance-of-payments problems accompany development.
7. Rapid population growth and agricultural stagnation may mean additional pressures on balance of payments, because food has to be imported.

There are lessons to be learned and, in fact, to be followed by the developing economies from developed ones on economic development that are identified with the structural transformation of the economy from a predominantly subsistence agricultural economy to an industrial and service economy. Development means, therefore, resource transformation (mainly labor) from the agricultural sector, where productivity is low, to the manufacturing and service sectors, where productivity is high. Furthermore, technological advances and urbanization in developed countries were partly instrumental in increasing production and lowering birth rates, helping these countries to pass through the demographic transition.

## Economic Development Potentials in West Africa

Various inputs are required for a region or country to succeed in the process of economic development even though the converse may not be true. In other words, the mere availability of adequate natural resources does not guarantee a successful economic development path. Amongst these factors are natural resources, physical capital, human capital, and land. The substitutability of one factor for another by some countries of the world, for example Japan, in their efforts at development have been successful so far.

It is generally acknowledged that the developing countries, in general, and therefore West Africa, in this case, are exporters of primary commodities from coffee in tropical zones to uranium in the arid zone of the Republic of Niger. Problems faced with the utilization of their natural resources for domestic production are best described under the general sections on industry and agriculture.

Industrial Sector

The process of modernization and development of natural resources is reflected in a wide range of construction activities such as industrial and public buildings, dams, roads, bridges, and harbors undertaken by individual countries of the region soon after independence. Despite such efforts, in most countries today, industrialization is still based to a large extent on import substitution, primarily goods for final use. Even that has met with some retarding forces primarily due to the unavailability of raw materials from external sources to be exchanged for exports of agricultural products. The result of this is that a large number of productive enterprises are operating at only an average of 30 percent capacity, thus locking up valuable assets that would otherwise be productively utilized (Ghana News, 1978).

The smallness of the domestic markets, due in part to the smallness of the countries themselves but even more so to the low levels of per capita income, prevents industry from taking full advantage of the economies of scale productivity and costs that exist in the economies of modern industry. Because economies of scale are especially important in heavy and intermediate industries these sectors are weak in all of these countries so that the industrial structure is generally unbalanced and industries depend heavily on imports of equipment and intermediate products.

Furthermore, basic inherent weaknesses in the form of shortages of managerial and technical cadres and skilled labor also exist as well as inadequate government machinery and a lack of the supporting institutions required for efficient operation of modern industry in such fields as credit and financing, marketing, training in industrial skills, engineering, and consulting services.

However, all is not lost yet. The recent establishment of the Economic Community of the West African States (ECOWAS), which embraces 14 countries of the region, promises to remove some (if not all) of the barriers to economic development mentioned in the preceding discussion.

## Agricultural Sector

Despite pockets of industry, the economies of the countries of the region are overwhelmingly agricultural. Employment in this sector ranged from 54 percent in Ghana in 1976 to 90 percent in Niger in 1976 of the economically active population, with large numbers living at subsistence levels. Expansion of the agricultural sector, particularly in terms of higher output per head, through mechanization is vital and will naturally raise national incomes and purchasing power but will do little to solve the employment problem.

Compared with the industrial sector, the following arguments are often made. The marginal product of labor is lower in agriculture than in industry. The transfer of a worker from agriculture to industry raises national output. Industrialization has associated economies, whereas agriculture does not. Rural society tends to be stagnant; urban society dynamic. The improvement of agriculture waits on the availability of manufactured inputs such as fertilizer and farm machinery. In order to increase efficiency on the farm, one must start in the factory.

However, the sheer size of the agricultural sector in the developing economies draws attention. If the bulk of a country's people is to be affected by development without long waits for spread or trickle-down effects, then development must act directly in the agricultural sector itself. Disillusion with outcomes of earlier policies that emphasized industrial growth is widespread, because industrial growth has occurred more slowly than expected by its optimistic advocates. It has also been surprisingly costly in terms of both imports and other scarce resources. This is due largely to the saturation of world markets with primary agricultural products, which generate insufficient incomes to pay for the increasing costs of imported manufactured goods, raw materials and the equipment required in the industrial sector.

Without any doubt, a balance between the agricultural and industrial sectors is desirable. Heavy emphasis on agriculture will not solve the developing countries' problems, and the industrial sector cannot develop if incomes are not generated by the agricultural sector to provide machinery and raw materials needed in the industrial sector.

## The Role of Energy in Economic Development

The physicist's definition of energy is the "ability to do work." However, different sources of energy have different capabilities of doing work, hence it is not surprising that scientists continue to search for new forms of energy sources. Historically, energy has played a significant role in the development of all societies. The forms of energy used have changed from purely manpower to the steam engine and presently to fission reactions from nuclear sources. Today we have moved from the qualitative description of the role of energy in societal development by Cottrell (1955) to a quantitative concern with the long-range relationship between energy consumption as measured by the Gross National Product (GNP) or Gross Domestic Product (GDP).

Using 1961 data for all 153 of the existing countries of the world, Felix (1964) showed the close relationship between national per capita income and total per capita commercial energy consumption. In a later work, Darmstadter, Teitelbaum and Polach (1971) presented some statistical analyses of historical and cross-sectional energy consumption and national income data of various countries. One of their basic conclusions was that,

> A prominent characteristic of per capita consumption of commercial energy forms is its systematic and quantitatively close association with indicators of general economic development, measured here by per capita GNP --that is, an area's production of all goods and services per person. This relationship between energy and GNP holds both cross-sectionally and historically: the higher a nation's income or output, on the current international scale, the higher, in general, its level of energy consumption; as its GNP rises over time, so does its energy consumption--in close, even if not proportional, conformity (p. 32)

The authors (p. 32) also recognized that

> Although the connection between energy consumption and GNP may be more or less evident, the chain of causation between these two factors is less distinct, for there are clearly two-directional forces at work: some amount of electric generating capacity is obviously required in order to support a modern industtrialized economy or one on the move toward it.

Felix (1964, p. 89) also had something to say about the causal relationship between energy consumption and the GNP.

> Although the consumption of energy per se is not necessarily productive of additional country wealth, the achievement of higher levels of national income does require the application of industrial, transportation and other mechanisms to productive uses, plus the services identified with these--all of which are energy consuming.

Today, the investigation of the relationship between economic growth and energy consumption has been proceeding along various lines. In addition to the methods of Felix and Darmstadter et al., one approach is based on micro-economic demand theory in which emphasis is put on the response of energy consumption to relative price, per capita income, industrial production, and other economic factors. The other approach is the investigation of the differences in use of energy in useful production between countries or political divisons of countries.

Starr and Field (1977) have investigated the differences between the states of the United States as an aid in explaining the differences between the developed countries. Darmstadter et al.(1977) have quantitatively depicted the comparative patterns of energy consumption for nine developed countries: United States, Canada, France, West Germany, Italy, The Netherlands, United Kingdom, Sweden, and Japan; Desai (1978) in his analysis attempted to disprove the notion that for the same economic growth rate a developed country would require less energy than a developing country by including non-commercial energy forms that are predominantly used in the developing countries in total energy consumption.

In terms of functional relationships, the analyses of Darmstadter et al. (1971, 1977), Ukpong (1976), and Tyner (1978), among others, have shown that there exists for any economy a significantly high correlation between energy consumption and national income. Thus, a plan to increase the national income and industrial output must necessarily include provisions to increase energy supply in all of its forms.

# CHAPTER 3

## PRIMARY ENERGY RESOURCE ENDOWMENTS OF THE REGION

The previous chapters have attempted to define the role of energy in the development of a country or region. It has been concluded that its availability cheaply coupled with a favorable political climate can induce both internal and external entrepreneurs into investing in private enterprises and thus alleviate the capital deficiency problem that the developing economies face after independence. A case in point is the Volta River Project in Ghana in which an agreement between Kaiser Engineers of Oakland (USA) and the government enabled the country to obtain international financing to build the first giant hydro-electric dam on the Volta River, thus providing cheap electricity (approximately 2.5 cents/kwh) to Kaiser's aluminum smelter, the Volta Aluminum Company (VALCO) at Tema. Most importantly, this dam also provides electricity to residential users and other industrial enterprises. All indications are that revenue from sale of electricity to VALCO pays for the annual loan payments, which is remarkable since the government does not have to divert scarce foreign exchange earnings from other sources to meet its loan obligations.

In what follows, the existing technological and institutional infrastructure connected with electric power production and distribution, the primary energy resources for electrical energy production, and current energy consumption are reviewed for each country to provide the basis for later chapters. There, the resource endowments described in this chapter will be used in conjunction with planning practices for an examination of future electrical energy production strategies as a result of changing demand patterns of electricity consumption.

## Nigeria

The largest country in the region, Nigeria, is endowed with diverse sources of primary energy, notably coal, hydrocarbons (petroleum and natural gas), water power, and traces of the radioactive minerals, uranium and thorium.

Coal is mainly consumed internally. Only a small portion is exported to Ghana for their railway system. Estimates of exploitable coal reserves in the country are given as 359 million tonnes and 90 million tonnes of lignite or brownish-black coal (U.S. National Committee of the World Energy Conference, 1974). Despite these abundant reserves of coal, consumption by the railway system has remained approximately steady (Table 3), and thus its share in total national energy consumption has declined in the years 1977 and 1978.

Table 3. Coal production and consumption in Nigeria (1969-1978)

| Year | Production (tonnes) | Consumption (tonnes) | Percentage Share of Total Energy Consumption |
|---|---|---|---|
| 1969 | 17,000 | 21,500 | 3.0 |
| 1970 | 59,000 | 53,000 | 2.0 |
| 1971 | 194,000 | 137,306 | 4.0 |
| 1972 | 341,000 | 271,489 | 6.0 |
| 1973 | 326,000 | 274,463 | 5.0 |
| 1974 | 304,000 | 240,643 | 4.0 |
| 1975 | 245,000 | 182,705 | 2.0 |
| 1976 | 310,000 | 218,226 | 2.2 |
| 1977 | 264,616 | 221,896 | 1.9 |
| 1978 | 229,834 | 192,970 | 1.6 |

Source: Central Bank of Nigeria (1970-1979).

The declining trend in coal consumption is accounted for by the shift in consumption by the former principal consumers (the Nigerian Railway Corporation, the Electricity industry, Nigerian Ports Authority, and the Government) to petroleum products, which are relatively cheaper in price and easier to transport, and environmentally cleaner to use. Before the discovery of petroleum and gas, most of the steam electricity generating stations were coal fired. Coal is used minimally today for electricity generation. However, there are plans to revive the coal industry through the Federal and State Governments' development and export promotion programs. The 3rd National Development Plan projected the internal consumption of coal to reach 950,000 tonnes while the projected export volume is expected to reach 1,500,000 tonnes by 1980. Consumption will be mainly in the following industries: Railways, electricity, cement, iron and steel, other small industries and domestic consumers. Most importantly, coal consumption in electricity generation is to be about 250,000 tonnes by 1980 (MacLean and Arnold, 1978).

Petroleum

Nigeria is the sixth largest crude-oil producer outside the non-communist world and North America. The exploitable reserves of crude oil are estimated at 20-billion barrels (Business International, 1979) and all indications are that most exploration efforts are resulting in the discovery of new, economically viable oil fields (Wall Street Journal, 1980, p. 26). Production has gone from 275,000 barrels per day in 1965 to about 2 million barrels per day in 1977 (Table 4). Oil now accounts for 45 percent of the $24 billion gross domestic product, 80 percent of the $10 billion the government collects in revenue and represents 90 percent of all export earnings.

Internal consumption of petroleum products in the form of gasoline for automobiles, kerosene for lighting and cooking, diesel and residual fuel oils for industry and electricity production, etc. have increased from 2.970 million tonnes in 1972 to 9.805 million tonnes in 1978, an average rate of growth of 38.3 percent annually. Gas associated with oil production is another source of energy for electricity production. In Nigeria only 2 percent of this gas is used; the rest is burned off (Business International, 1979). Some of the existing gas-fired power systems of the Afam, Ughelli, and Sapele are all located in the oil fields. There are plans in the recent National Development Plan to increase the capacities of these thermal plants in an effort to utilize more of this resource.

## Natural Gas

Proven reserves of natural gas in Nigeria totalled 1,456 billion cubic meters in 1976 (United Nations, 1977). Natural-gas consumption accounted for 11.9 percent of all

Table 4. Historical production of crude oil and consumption of petroleum products in Nigeria (1972-1977)

| Year | Crude Oil Production (Million Tonnes)[a] | Consumption of Petroleum Products (Million Tonnes) | Percentage Share of Total Energy Consumption |
|---|---|---|---|
| 1972 | 89.25 | 2.97 | 67 |
| 1973 | 101.77 | 3.57 | 71 |
| 1974 | 111.56 | 4.12 | 69 |
| 1975 | 88.44 | 4.91 | 70 |
| 1976 | 103.45 | 7.32 | 74 |
| 1977 | 102.22 | 8.53 | 75 |

Source: Central Bank of Nigeria, 1973-1978

[a]1 tonne = 7.4348 barrels.

primary energy consumed in 1978 (Table 5). Production is envisaged to increase in the 3rd National Plan, with plans to establish gas liquefaction plants, gas associated industries and large capacity gas-fired electric power stations. This is a result of a 20-year plan between the government and a group of international oil companies to export about 1.6 billion cubic feet of natural gas a day to the United States and Europe (Arizona Daily Star, 1980).

## Hydro Energy

In addition to large fossil energy reserves, Nigeria is also endowed with abundant hydro-energy resources, which are most favoured due to their renewability. Total capacity of installed hydro plants operating in the country today is only 785 MW compared with a potential of 4,765 MW (United Nations Economic Commission for Africa, 1976) broken down by sites in Table 6. There are other sites suitable for hydro power, even though their capacities are not known. For example, there are plans to add generating turbines to the Tiga irrigation dam project in the north, and the Mada River project in Kwara State is also a candidate for a power-generating plant (Ukpong, 1976).

## Electricity Production and Consumption

The National Electric Power Authority (NEPA) is the government entity solely responsible for the production and distribution of electricity in Nigeria. The total installed

Table 5. Consumption of natural gas in Nigeria (1972-1978)

| Year | Consumption (tonnes) | Percent Share of Total Primary Energy Consumed |
|---|---|---|
| 1972 | 365,826 | 8.0 |
| 1973 | 328,548 | 6.0 |
| 1974 | 541,686 | 9.0 |
| 1975 | 618,216 | 9.0 |
| 1976 | 119,135 | 11.3 |
| 1977 | 1,160,705 | 10.1 |
| 1978 | 1,483,026 | 11.9 |

Source: Central Bank of Nigeria, 1979

Table 6. Hydro resources in Nigeria

| Site | Capacity (MW) |
|---|---|
| Operating Hydro Plants | |
| Kainji I | 320 |
| Jekko I & II | 11 |
| Kura | 7 |
| Other Nedeco | 7 |
| Kainji II | 440 |
| Total | 785 |
| Potential Hydro Resources | |
| Kainji III | 200 |
| Shiroro | 300 |
| Jebba | 500 |
| Gongola | 30 |
| Ikom | 400 |
| Makurdi | 600 |
| Lokoja | 1950 |
| Total | 3980 |

Source: United Nations Economic Commission for Africa (1976) generating capacity increased by 62.1 percent to 1,729 MW at the end of 1978 (Central Bank of Nigeria, 1979), in part due to new power stations at Sapele (120 MW), Ijora (62.5 MW), Oji (12.5 MW), and Sokoto (4.0 MW). Major extensions to existing power stations were also undertaken, principally in Kainji (240 MW), Ughelli (108 MW), Afam (102 MW), and Ijora (60.5MW).

Massive capital outlays have been budgeted for the construction and engineering feasibility studies of various potential sites in preparation for the projected increases in demand in the post-1980 period. Among these sites are the Jebba and Shiroro hydro sites, which West Africa (1979a) described as reducing power supply interruptions, once they are completed.

Sectorially, consumption of electricity has been shared between the industrial, commercial, and residential sectors of the economy. Total consumption in 1978 rose by 15 percent from 1977 to 4,306 million kilowatt-hours of which industrial and commercial consumption accounted for 2,044 million kilowatt-hours (47.5 percent of total compared with 59.7 and 61.4 percent in 1977 and 1976, respectively). Residential consumers accounted for 52.2 percent in 1978, as compared with 40.1 percent in 1977. Table 7 shows the historical share of electricity consumption between these two sectors of the economy. Average price of electricity is approximately 5.07 cents per kilowatt-hour.

Table 7. Nigeria: Historical consumption of electricity by sectors of the economy $10^8$ kW-hrs (1970-1977)

| Year | Industrial and Commercial Sector | Residential Sector |
|---|---|---|
| 1970 | 7.60 | 4.36 |
| 1971 | 10.00 | 5.11 |
| 1972 | 11.46 | 6.05 |
| 1973 | 13.23 | 7.67 |
| 1974 | 13.81 | 8.71 |
| 1975 | 16.56 | 9.96 |
| 1976 | 18.22 | 11.37 |
| 1977 | 22.36 | 15.02 |

Source: Central Bank of Nigeria (1971-1978)

It is an acceptable fact that electricity supply in Nigeria has not kept pace with the increasing demand for the commodity; hence there exists an increasing competition between the industrial, commercial, and residential consumers. The shortage in supply capacities in the face of increasing demand has led to overloading of the facilities and consequently abnormal rate of plant breakdowns. The economic loss to the economy resulting from such power shortages has been found to be considerable (Ukpong, 1973).

However, the government in conjunction with NEPA has recently readdressed the electricity supply question. In its 3rd National Development Plan, massive capital expenditures totalling about 1.7 billion dollars has been budgeted for extensions to existing plants, new generating plants, transmission and distribution systems, and rural electrification (U.S. Commerce Department, 1976). A summary of existing plants and planned construction activities is presented in Tables 8 and 9.

It is interesting to note that all the planned new plants and extensions to existing plants in the 1975-80 National Development Plan were meant to meet increasing demand up till the end of 1980. However, due to various uncertainties, many of these plants will not be completed in time, hence the economic benefits will not be realized within the planned time framework.

Table 8. Existing power plants operated by NEPA

| Location | | Plant and Fuel Type |
|---|---|---|
| Kainji | 780 | Hydro |
| Sapele | 240 | Steam turbine, gas fired |
| Afam | 200 | Gas turbine |
| Delta #2 (Ughelli) | 240 | Gas turbine |
| Ijora I | 85 | Steam turbine, gas fired |
| Calabar | 6 | Thermal, fuel oil |
| Oji | 30 | Steam turbine, coal fired |
| Ijora II | 96 | Gas turbine |
| Kaduna | 12 | Thermal, fuel oil |

Sources:
1. Ukpong I.I. (1976)
2. Central Bank of Nigeria (1978)
3. Federal Ministry of Economic Development (1975)

Table 9. Planned power plant installations

| Location | | Plant and Fuel Type |
|---|---|---|
| Sapele | 360 | Steam turbine, gas fired |
| Oji River | 20 | Thermal, coal fired |
| Sokoto | 3 | Thermal, fuel oil |
| Mobile Emergency | 0.944 | Thermal, fuel oil |
| Kaduna | >348 | Thermal, fuel oil |
| Shiroro | 300 | Hydro |
| Jebba | 500 | Hydro |
| Gongola | 30 | Hydro |

Source: Federal Ministry of Economic Development (1975)

It is obvious from the preceding that Nigeria is endowed with adequate primary energy resources and with enough capital resources should be able to meet its electrical energy demand requirements in the post-1980 era. For a country endowed with such resources, past energy consumption has been extremely low, a result of slow growth in industrial and agricultural activities resulting in low per capita incomes.

Technically, prior to the Kainji hydro-electric power station, the national electrical system was dominated by small generating units, as can be seen from Table 8. This structure did not lend itself to the economies of scale that generally characterize power generating systems, especially in steam-generating systems (Huettner, 1974).

Ukpong (1976 p. 253) summarizes the Nigerian problem this way:

> The preponderance of small generating units in the face of growing markets for electricity made it impossible for the scale effect to function and for the power industry to benefit by new technology (which is embodied in large units) in electricity generation. The net effect was the increasing generation cost.

## Ghana

Unlike Nigeria, Ghana is not endowed with long-term exploitable primary energy resources; however, it is better endowed than other West African countries. Amongst coastal West African countries, Ghana is a major consumer of oil, supplied entirely by imports, mainly in the form of crude oil, which is then refined at its port city, Tema. Oil is used chiefly as a source of fuel by the transport industry, and its supply is of particular importance to ensure the shipment of the largest export earning crop, cocoa. At current (1978) estimates, Ghana consumes about 35,000 barrels of oil each day with an import bill of about $300 million annually. This represents about 30 percent of total export earnings which depend largely on a single crop whose international market is at best only slightly stable. In 1972 (a pre-oil embargo year), consumption was 24,384 barrels per day and with oil at $3 a barrel, implied a total import bill of $26 million (International Monetary Fund, 1977). Ghana has therefore been seriously affected by the increases in the world price of crude oil. Because of the predominant use of oil to transport its principal export commodities to port, Ghana cannot afford to compress domestic demand for oil to any great extent, although it may be possible to reduce by a small degree gasoline consumption by private automobiles.

There is, however, some relief in sight. Due to the skyrocketing of crude oil prices, Ghana's first oil discovery in 1970, some 8 miles offshore at Saltpond, has become economically attractive, and production of 10,000 barrels per day was started at the end of 1978 (West Africa, 1979b). It is not known how much of this oil is available for internal consumption because the American oil consortium, Agri-Petco (Ghana) must be paid either with some of the oil discovery or with foreign earnings that would otherwise have been used to import oil. A second offshore discovery has been made at Tano on the Tano River by Phillips Petroleum in what may have been a result of joint exploration efforts between Ghana and the Ivory Coast because this river is close to their common border (West Africa, 1979b). The size of the discovery and the production date are still not known.

Apart from these latest developments in the Ghana energy picture, the only present technologically and economically exploitable primary energy resources available is hydro power, hence the next section is devoted to historical developments and future resources available for electricity production.

## Electricity Production and Consumption

The initial production of electricity for domestic consumers started in the 1940s during colonial times, when Ghana was then the Gold Coast. Electricity was then probably used essentially to supply the domestic requirements of the officials of the civil service. Industrial applications for electrical energy were also limited to large repair shops of the railway organization and also to the gold mining industry. Figures 2 and 3 show the historical data for power and electricity demand over a period of 25 years. It is significant to note that it was not until the potential

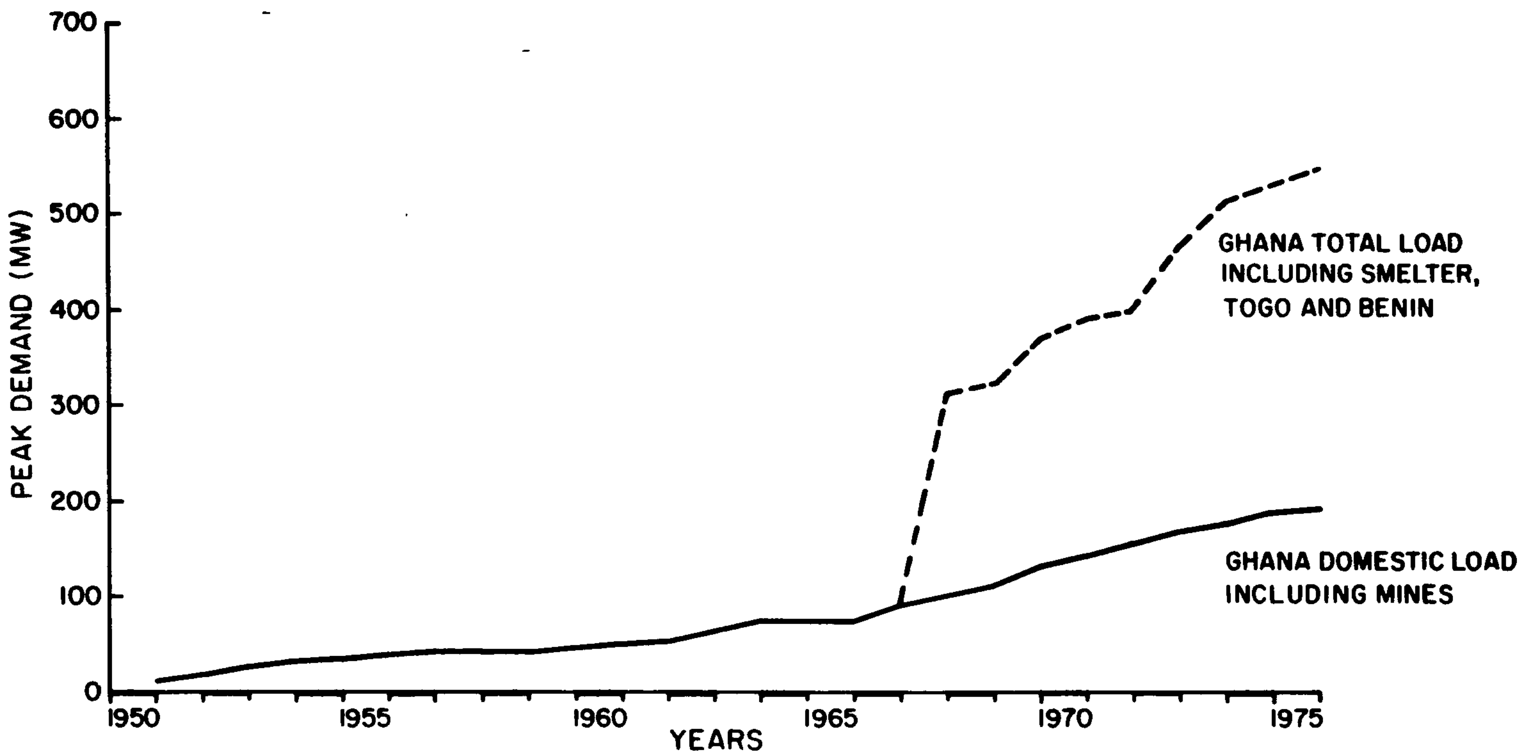


Figure 2. Historical load growth of demand for electrical power in Ghana (1950-1975)

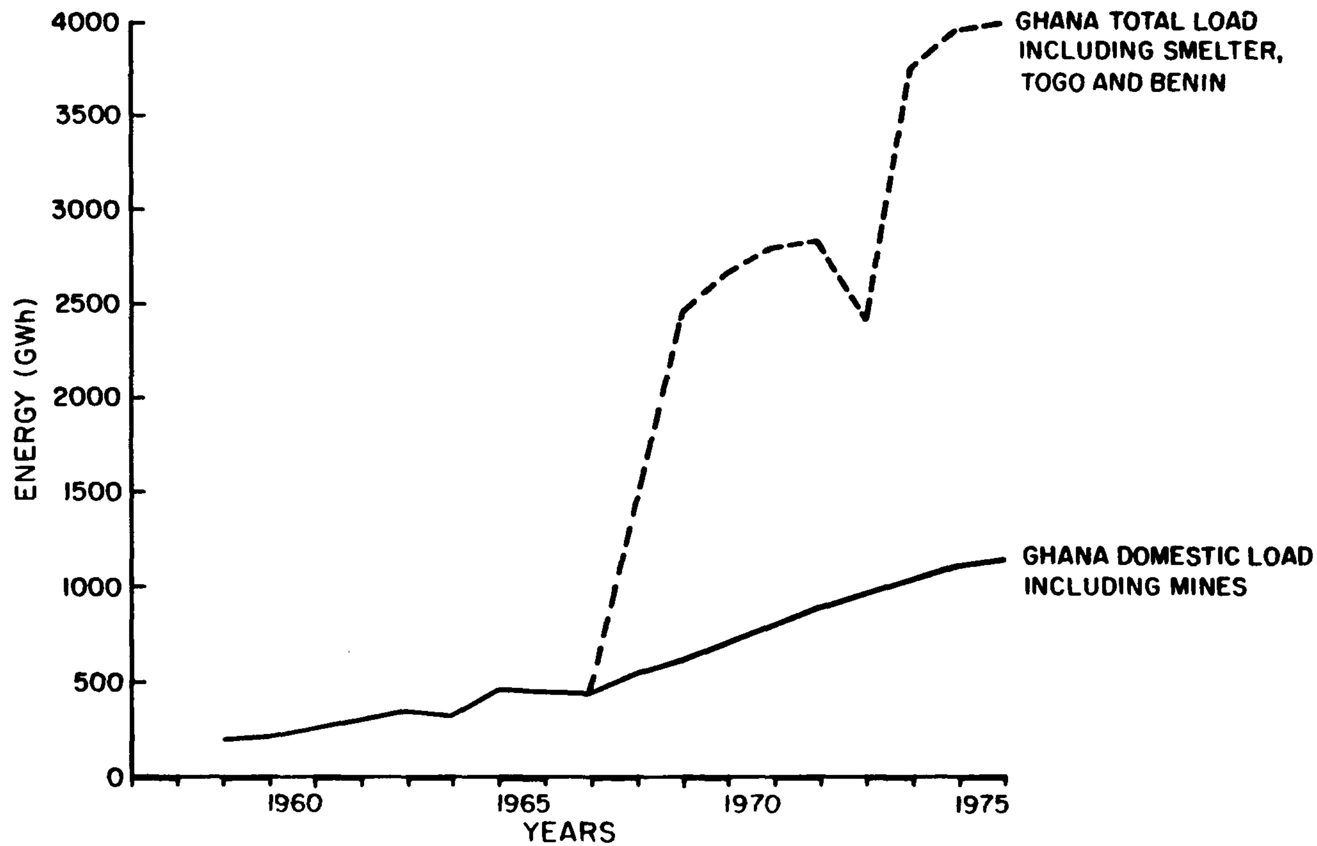


Figure 3. Historical growth of total energy demand for electrical power in Ghana (1957-1975)

development of the aluminum smelter in 1964, that the possibility of exploiting the huge potential of hydro-electric power became a reality. Hitherto, most of the equipment installed for power generation up to 1965 consisted of small diesel plants with total capacity of 147 MW (United Nations, 1976). These installations ranged in size from a diesel station of 20 MW capacity, down to individual units of less than 50 KW in size. Up until 1958, the total installed capacity of diesel oil-fueled plants totalled 82 MW made up as follows (Casely-Hayford, 1976).

| | | |
|---|---|---|
| 1. | Ghana Electricity Department (commercial and domestic customers only) | 31 MW |
| 2. | Mining Industry | 51 MW |

Load factors on the average were low, ranging from 10 to 40 percent, and distribution networks were not well developed. During this period (1950-1958) the demand for electrical energy was generally in excess of installed capacity. The limited ability to increase generating capacity had the effect of restraining to some extent the load growth, therefore resulting in relatively high cost energy from these installations as shown in Table 10.

Today, Ghana boasts of an adequate short-term supply of cheap electricity from its only hydro-electric dam completed in 1965 at Akosombo on the Volta River. The construction of this dam was the result of extensive discussions in 1959 between the government and a consortium of aluminum

Table 10. Cost of energy produced by diesel power plant installations

| | Cost (cents/kWh) |
|---|---|
| Location | |
| Accra | 5.66 |
| Koforidua | 9.58 |
| Estimated National Average | |
| Ghana Electricity Department | 8.04 |
| Mines | 5.88 |
| Weighted average | 6.66 |

Source: Casely-Hayford (1976)

manufacturers under the leadership of Kaiser Aluminum and Chemical Corporation, Reynolds Metals, The Aluminum Company of America, and Olin Mathieson to form the Volta Aluminum Company (VALCO) that would use most of the power to be produced by the dam when constructed. By encouraging a smelter to establish itself in Ghana, the Government was assured of a steady sale of electricity, and the overall cost of generating electricity was reduced so that the balance could be sold to the Electricity Department at a reasonable and economic figure. Financing for the project was provided by the International Bank for Reconstruction and Development, the Development Loan Fund of the United States, the United Kingdom Government and the Export-Import Bank of Washington.

High hopes were placed on this dam as a stimulant in accelerating the pace of industrialization by the provision of power from other dam sites, as evidenced in a speech delivered to the National Assembly by President Kwame Nkrumah. He said,

> The project provides for a return on the money invested in such a way that, in addition to the scheme being fully self-liquidating over the period of its estimated life of fifty years, the financial returns should suffice to cover from its own earnings any future power development which may be required by Ghana (Ghana Information Service, 1961, p. 5).

In particular the President had in mind future hydro development projects which will provide the power for irrigation water supply needs in agriculture, for the production of food crops and raw materials for industries which were envisaged at that time. The planners had also hoped that the development of this hydro-potential, together with the aluminum smelter would form the foundation for an accelerated development of an integrated aluminum industry by exploiting Ghana's own bauxite and other primary resources.

Despite all the unfulfilled dreams of this dam, Ghana is the only West African country that can boast of cheap electricity to both industrial and residential customers. The dam operated by the Volta River Authority (VRA) at Akosombo produces electricity today at an average cost of 0.40 pesewas/kwh (pesewa = 0.364 cents US). The Volta River Authority, a government-owned corporation, was set up at the time of the completion of the dam in 1965 by act of the National Assembly.

The Akosombo source of power accounts for 99 percent of the total power consumed in Ghana. The VRA has among its customers, the Electricity Corporation of Ghana (ECG) that distributes power for the general public and other industrial enterprises that do not buy direct from it. The Electricity Department of Ghana that existed was changed into the Electricity Corporation of Ghana at the same time VRA came into existence. It is estimated that between 20 and 22 percent of the population of Ghana enjoy electricity supply. The mines, VALCO, Akosombo Textiles, and Akosombo Township all buy their power needs directly from VRA. It also transmits power along a 320-km 161 kV line to Togo and Benin. Despite excess available energy, hence the export of electricity to neighbouring countries, the fact that the majority of the population are sparsely distributed in the rural areas, various studies have shown rural electrification to be uneconomical (Ghana Ministry of Planning, 1977).

All the six generating units of the dam with an installed capacity of 912 MW or a continuous nominal capacity of 792 MW have been put into service. Tables 11 and 12 show the distribution of energy consumption and peak power demand among VRA's customers. Because the dam was built primarily for aluminum smelting it is worthwhile to examine the utilization of the energy resource by VALCO in detail. The result of this exercise (displayed in Table 13) shows that VALCO has over the years used more than 60 percent of the operating capacity of the dam and has consumed between 88 and 99 percent of its electricity allocation. This not only results in large revenues to VRA to pay for its loan obligations but also ensures extra revenue for the maintenance and operation of capacity for supplying electricity to the rest of the country and neighbouring countries. VALCO paid 13.7 million cedis (cedi = $0.364 US) to VRA in 1976, which represents about 49 percent of the total revenue earned in that year by VRA.

Distribution of electricity by the ECG is restricted to the urban areas of the country, serving about 20 percent

Table 11. Annual energy consumed per class of VRA customers. -- 1 million kWh

| Year | VALCO | ECG | Mines | Akosombo Township | Akosombo Textiles | CEB[a] | Total |
|---|---|---|---|---|---|---|---|
| 1970 | 2012.4 | 564.8 | 206.8 | 7.2 | 14.8 | --- | 2806.0 |
| 1971 | 1919.0 | 659.3 | 226.5 | 8.8 | 20.8 | --- | 2834.6 |
| 1972 | 2263.8 | 699.4 | 242.6 | 9.0 | 20.9 | 1.3 | 3237.1 |
| 1973 | 2626.0 | 768.1 | 243.1 | 12.5 | 22.0 | 99.7 | 3771.4 |
| 1974 | 2734.8 | 839.5 | 251.0 | 11.0 | 19.3 | 127.8 | 3989.3 |
| 1975 | 2518.2 | 893.2 | 271.0 | 11.5 | 22.6 | 136.7 | 3853.2 |
| 1976 | 2644.9 | 980.1 | 278.3 | 9.7 | 23.0 | 155.3 | 4091.2 |

Source: Ghana Ministry of Economic Planning, 1977

[a]See a for Table 14.

Table 12. Distribution of peak power demand among VRA customers (1970-1977). -- in MW

| Year | Utilization | VRA Bulk Customer | | | | | |
|---|---|---|---|---|---|---|---|
| | | VALCO | ECG | Mines | Akosombo Textiles | Akosombo Township | CEB[a] |
| 1970 | 395 | 250 | 106 | 34 | 3 | 3 | --- |
| 1971 | 403 | 244 | 117 | 37 | 3 | 2 | --- |
| 1972 | 467 | 295 | 126 | 38 | 5 | 2 | 1 |
| 1973 | 514 | 315 | 135 | 38 | 4 | 2 | 20 |
| 1974 | 532 | 315 | 145 | 40 | 4 | 2 | 25 |
| 1975 | 559 | 315 | 172 | 40 | 4 | 2 | 26 |
| 1976 | 595 | 316 | 189 | 42 | 4 | 2 | 43 |
| 1977[b] | 708 | 400 | 208 | 44 | 4 | 2 | 50 |

Source: Ghana Ministry of Economic Planning, 1977

[a]CEB refers to Communaute Electrique du Benin, a joint Benin-Togo company.
[b]Projected

Table 13. Hydro-electric consumption by VALCO

| | 1970 | 1971 | 1972 | 1973 | 1974 | 1975 | 1976 |
|---|---|---|---|---|---|---|---|
| Peak power demand as % of total peak power | 63.0 | 60.5 | 63.2 | 61.3 | 59.2 | 56.4 | 56.5 |
| Energy consumed as % of maximum allocated | 91.9 | 89.8 | 87.8 | 95.2 | 99.1 | 91.3 | 95.5 |
| Energy consumed as % of total energy sold by VRA | 71.7 | 67.7 | 69.9 | 69.6 | 68.6 | 65.4 | 64.6 |

Source: Ghana Ministry of Economic Planning, 1977 of the population. Rural electrification continues to receive serious attention from the government, with the main obstacle being to minimize the cost per capita of providing the rural communities with power. Under its present policy objectives, the Government will encourage small communities to form viable large communities and priority will be given to areas where there are rural industries, health centers, educational institutions, and projects that require power such as water supply and irrigation.

Energy Resources

It may be concluded from the preceding that the planning that went into the construction of the Akosombo dam had its objectives as follows:

1. To allow a foreign investor (in this case, the Kaiser group) to consume much of the electricity produced, in the aluminum smelter, hence ensuring enough revenue to pay for the dam.
2. To prove to the outside world that with the success of the aluminum smelter other private investors were invited to invest in other ventures to warrant the construction of other hydro projects.
3. To provide adequate power from these developments to meet the expected demands in the agricultural sector.
4. Above all, to provide cheap electricity for the rest of the country, particularly the residential sector.

It is for these reasons that upon completion of the Akosombo dam, intensive studies were undertaken to identify other potential hydro sites on some of the other major rivers in the country. The Pra and Tano Rivers, in the south-western portion of the country, have a number of potential hydro sites. Possibilities exist for the development of a series of small hydro-electric stations in cascade along each of these rivers. Table 14 summarizes the potential sites as presently identified, together with the expected energy available and capacity cost indices.

In addition to these "small" sites, the current most economical sites that have received much Government attention are the Volta River at Kpong and Bui. Bui and Kpong are upstream and downstream, respectively, of the Akosombo Dam, on the Volta River. Construction at the Kpong site was started in 1977 and completion is expected at the end of 1981. Total major hydro resources of the country are now assessed at 1,216 MW, distributed by sites as in Table 15. Also shown in this table are the low and high cost indices of these hydro sites. These indicate two facts: that the era of cheap electricity will be over once the current capacity of the Akosombo Dam is fully utilized and that some of the objectives of the Government such as extending electricity to rural communities will not be realized without major geographical changes of the country, or availability of other

Table 14. Potential hydro sites on the Pra and Tano Rivers

| River | Site | Average Annual Energy (GWh) | Capacity Cost Index (1975 Prices-- U.S. $/kW) |
|---|---|---|---|
| Pra | Hemang | 232 | 1,264 |
| Pra | Awisam | 156 | 2,174 |
| Pra | Kojokrom | 95 | 2,538 |
| Pra | Abatumesu | 165 | 2,165 |
| Tano | Tanaso | 131 | 2,454 |
| Tano | Asuaso | 90 | 3,029 |
| Tano | Sedukrom | 66 | 2,280 |
| Tano | Jomuru | 69 | 2,270 |

Source: Casely-Hayford (1976)

Table 15. Major hydro resources of Ghana

| | Firm Capacity (MW) | Annual Energy (GWh) | Cost Index[a] ($/kW) | Energy Index Cost (U.S. mills/kWh |
|---|---|---|---|---|
| Akosombo (existing) | 768 | 5,625 | 144-273 | 2.1 |
| Kpong | 148 | 940 | 1,014-1,757 | 14.9 |
| Bui | 300 | 1,490 | 1,165- | 18.0 |

[a]Low estimate from Casely Hayford (1976). High estimate from New African (1977)

cheaper sources of alternate power. These changes might include those already outlined by the government in its development plan; formation of large, viable communities, rural industrialization, establishment of large educational institutions, etc.

## Ivory Coast

### Energy in the Economy

Like Ghana, Ivory Coast is currently not a major producer of crude oil, although recently discovered oil reserves ensures a production estimate of 10,000 barrels per day (West Africa, 1979b) by the end of the year 1981. Currently its entire consumption has to be met from imports.

Like all non-producing countries of the world, the cost per barrel of crude oil to the economy tripled from 1973 to 1974 in the oil crisis era (Table 16), resulting in crude oil costs taking 10.6 and 12.3 percent of the total export earnings in 1974 and 1975, respectively. With a progressive agricultural sector, Ivory Coast has been able to step up exports of agricultural products, notably cocoa, coffee, timber, etc., resulting in higher export earnings. Part of the higher export earnings is a result of higher prices for its exports during the period under consideration. However, with the current decline in prices of these commodities and higher world oil prices, expenditures on oil

Table 16. Crude oil consumption and cost of oil imports as a function of total exports in the Ivory Coast (1972-1977)

| Year | Annual Consumption (tonnes of crude oil) | Barrels per Day | Annual Cost of Oil Imports (mil CFA)[a] | Percent of Export Earnings | Cost per Barrel (CFA) | Cost per Barrel in US $ |
|---|---|---|---|---|---|---|
| 1972 | 1,115,068 | 22,713 | 6,352 | 4.6 | 766.2 | 3.83 |
| 1973 | 930,431 | 18,952 | 5,736 | 3.0 | 829.2 | 4.15 |
| 1974 | 1,655,680 | 33,725 | 31,043 | 10.6 | 2,521.84 | 12.60 |
| 1975 | 1,464,821 | 29,837 | 31,283 | 12.3 | 2,872.46 | 14.36 |
| 1976 | 1,529,626 | 31,157 | 35,692 | 9.1 | 3,138.46 | 15.69 |
| 1977 | 1,601,868 | 32,629 | 41,651 | 7.9 | 3,497.27 | 17.49 |

Source: Banque Centrale des Etats de l'Afrique de l'Ouest (BCEAO), 1979

[a]200 CFA = $1 U.S.

imports are bound to consume higher shares of export earnings. Thus, even though oil consumption increased in 1977 (approaching the 1974 level), expenditures on this commodity took 7.9 percent of the export revenues, a decline of 1.2 percent from the 1976 level of 9.1 percent.

Resources and Electricity Production

Electricity produced and distributed by the government-owned company Energie Electrique de Cote d'Ivoire (EECI) has relied on both thermal and hydro installations since 1968 (Table 17).

Average price of electricity is one of the highest in the coastal states of the region, being 17.9 CFA/kWh for industrial customers and 30.3 CFA/kWh for residential consumers. This is due in part to the dependence on some thermal production capacity with its variable fuel cost and is also due to the low average energy available from existing hydro plants. For example, the Kossou Plant on the Bandama River with 174 MW capacity is only able to produce 535 GWh of electricity annually, resulting in a low load factor of 35 percent. Similarly, the Ayame Complex (the second existing hydro dam) has a load factor of 57 percent with a capacity of 50 MW and an average energy availability of 250 GWh (U.N. Economic Commission for Africa, 1976).

Table 17. Installed capacity for electricity production in the Ivory Coast. -- MW

| Year | Hydro | Thermal | Total |
|---|---|---|---|
| 1968 | 50 | 87 | 137 |
| 1969 | 50 | 92 | 142 |
| 1970 | 50 | 125 | 175 |
| 1971 | 50 | 129 | 179 |
| 1972 | 166 | 133 | 299 |
| 1973 | 224 | 133 | 357 |
| 1974 | 224 | 126 | 350 |
| 1975 | 224 | 136 | 360 |
| 1976 | 224 | 288 | 512 |
| 1977 | 224 | 278 | 502 |

Source: United Nations (1976 and 1978)

In addition to existing capacity, Ivory Coast has two major hydro sources from which electricity could be produced; one, the hydro sites at Attakoro and Malamasso on the River Comoe have a total capacity of 360 MW and an annual energy availability of 1,300 GWh and the other, the Tiboto site, on the Cavally on the border with Liberia has a hydro capacity of 360 MW for an average annual energy production capacity of 2,500 GWh, implying a load factor of 79.2 percent, twice that of the Koussou plant. Due to the geography of this site, development of this latter site has to be on a joint basis with the Liberian government. Despite the high load factor this site can offer, no publicly announced negotiations between the two governments have been undertaken for the exploitation of this site. One reason for this may be the large distances from the plant site to the capital cities of the two countries, which call for heavy expenditures to be made for transmission lines, thus making the project less economical than other existing alternatives.

One alternative that the Ivory Coast government is pursuing to ensure relatively cheap and adequate supplies of electricity in the future is a joint agreement with the government of Ghana for an intertie of their electrical power systems. Feasibility studies being undertaken on this proposal are supported by a grant of 6 million Belgian francs from Belgium and, if successful, will foster a closer regional cooperation between the two countries (Ghana Ministry of Economic Planning, 1977).

## Togo

Like its closest neighbors, Ghana and Ivory Coast, Togo has to depend entirely on imports to meet its demand for petroleum products. Unlike its neighbors, however, no deposits of crude petroleum have been discovered, even though its entire offshore concession has been awarded to the American firm, Oceanic Resources, that has already started drilling for this precious commodity (West Africa, 1979b).

Its consumption of petroleum products (mainly in the form of crude oil) has increased from 1,915 barrels per day in 1974 after a decrease from 2,152 in 1972, to 3,248 barrels per day in 1977 (Table 18). The table also reveals the share of total export earnings that pay for the oil imports, ranging from 8.7 percent in 1972 to 12.8 in 1977. As with the Ivory Coast, Togo had to step up its production of export goods in order to pay for oil and other imports. Typical of these countries, Togo depends mainly on one major commodity--the export of phosphates. Physical production in 1977 was 48 percent more than that produced in 1976.

The major supplier of electric power is the National Electric Power Company (Compagnie de l'Energie Electrique

Table 18. Imports of petroleum products and associated expenditures: Republic of Togo (1972-1977)

| Year | Imports (tonnes) | Barrels Per Day | Cost of Oil Imports (million CFA) | Cost as Percent of Total Exports | Cost/Barrel (US $) |
|---|---|---|---|---|---|
| 1972 | 105,630 | 2,152 | 1,094 | 8.7 | 6.96 |
| 1973 | 102,921 | 2,096 | 1,078 | 7.8 | 7.05 |
| 1974 | 94,014 | 1,915 | 2,640 | 5.8 | 18.88 |
| 1975 | 99,635 | 2,029 | 2,786 | 10.3 | 18.81 |
| 1976 | 100,398 | 2,045 | 3,053 | 12.3 | 20.45 |
| 1977 | 159,478 | 3,248 | 5,006 | 12.8 | 21.11 |

Source: Banque Centrale des Etats de l'Afrique de l'Ouest (1976, 1979) du Togo, or CEET). In addition, a number of municipal authorities and certain private companies such as the Phosphate Mining Company (Compagnie Togolaise des Mines du Benin or CTMB) operate power-generating plants to meet their own requirements.

Installed capacity totalling 24 MW in 1977 (United Nations, 1978) comprises 22 MW from diesel-fueled thermal plants and 2 MW from the hydro plant at Palime; the only hydro plant in the country. This mix partly explains the high cost of electricity in the country, ranging from 16 CFA/kWh average for industrial customers to 22 CFA/kWh for residential consumers.

Togo's only hope for an internal hydro-electric power development in the future is a site on the border with Benin. This site on the Mono River has a capacity of 115 MW and a maximum annual energy yield of 375 GWh, resulting in a load factor of 37.2 percent (U.N. Economic Commission for Africa, 1976). However, to meet its short-term increasing needs and the requirements of Benin, an agreement to build a link with the power system in Ghana was reached between the three countries recently. Currently, power is being transmitted by a 350 km high-tension line from the Akosombo (Volta) dam to Lome and Cotonou, the capital cities of Togo and Benin, respectively. This power line is managed by a joint Togo-Benin electric company, the Communaute Energie du Benin, or CEB. A maximum of 50 MW of the Volta power has been allocated to this company. It may therefore, be assumed that Togo's share of this power is 50 percent, or 25 MW, imported from Ghana.

## Benin

With the recent discovery of oil from its offshore Seme field, Benin is expected to meet its consumption demand of crude petroleum from internal production, which is expected to commence at 15,000 barrels per day in 1981 (West Africa, 1979b). It has relied on imports to meet internal consumption ranging from 1,368 barrels per day in 1973 to 1,811 barrels per day in 1976. At the proposed production rate, Benin will be self-sufficient in meeting local demand and have a surplus for export.

Most importantly, oil imports have taken from 11 to 53 percent of total export earnings, explained partly by two reasons: the increased cost of fuel oil as a result of the 1973 oil crisis, reflected in column 6 of Table 19, and the inability of the economy to develop viable export sectors, resulting in decreasing export earnings over the years. Earnings from exports of oil will then be used partly to finance trade deficits accumulated in the seventies.

Electricity production and distribution in Benin is managed by the government-owned company, Societe Beninoise d'electricite et d'eau, or SBBE. Internal

Table 19. Imports of petroleum products and associated expenditures, Benin (1972-1977)

| Year | Petroleum Products Imports (tonnes) | Barrels/Day | Cost of Oil Imports (million CFA) | Cost as Percentage of Exports | Cost/Barrel (US $) |
|---|---|---|---|---|---|
| 1972 | 87,722 | 1,789 | 1,010.3 | 11.0 | 7.75 |
| 1973 | 67,158 | 1,368 | 1,416.2 | 14.5 | 14.18 |
| 1974 | 66,262 | 1,350 | 2,250.2 | 22.0 | 22.84 |
| 1975 | 86,200 | 1,756 | 2,579.2 | 38.0 | 20.12 |
| 1976 | 88,926 | 1,811 | 2,954.0 | 53.3 | 22.34 |
| 1977 | 71,503 | 1,456 | 2,990.2 | 39.1 | 28.12 |

Source: Banque Centrale des Etats de l'Afrique de l'Ouest (1979) production of electricity has been limited to a thermal capacity of 15 MW in 1977, partly explaining the price of electricity, which ranges from 16 CFA/kWh for industrial customers to 22 CFA/kWh for residential customers.

In addition to the feasibility of using its recently discovered crude petroleum in the production of electricity, Benin has two potential hydro sites that can be developed for electrical energy production. The first site, on the Mono river, is on the border with Togo and has a capacity of 115 MW and is estimated to yield 375 GWh of energy annually. The second site, fully in the territory of Benin on the Oueme River, has a capacity of 700 MW and an annual energy yield of 3,500 gigawatt-hours. These two sites represent load factors of 37.2 percent and 57.1 percent, respectively.

As mentioned earlier, Benin and Togo expect to meet their increasing demands for electricity (mainly in the capital cities) by the importation of electricity from Ghana's Volta River project by a joint Togo-Benin company, the CEB. Importation of power from Ghana may not result in an appreciable reduction of electricity rates in Benin and Togo because the joint company plans to utilize its profits to finance an expanded power distribution program. One of the consequences of the agreement with Ghana, however, was the cancellation of a proposed hydroelectric project on the

Mono River, because of the relatively cheaper electricity from Ghana.

## Niger

Niger is the only country in the region that exports primary energy in the form of uranium. However, Niger imports petroleum products to meet its internal demand in such sectors as transportation and the production of electricity. The transportation and electricity sectors, respectively, consume about 70.4 and 25.0 percent of all oil imports. Consumption of oil has increased from 1,227 barrels/day in 1971 to 2,085 barrels/day in 1976 (Table 20). Unlike other countries in the region, Niger did not cut back on consumption as a result of the 1973 crisis. Historically, oil imports have taken between 11 and 25 percent of export earnings. Like most of its neighbors, stepping up the production of its highest earnings export product, uranium, has helped alleviate the balance of payments position of the economy. Uranium exports have accounted for 60 and 64 percent of all export earnings in 1975 and 1976, respectively. It has been estimated by Glakpe and Smith (1979) that at a 15 percent per annum increase in the consumption of electricity and the official projected production rates of uranium, Niger will spend, on the average, 11.3 percent of all revenues from uranium exports per year

Table 20. Energy imports into the economy of Niger

| Year | Petroleum Products (tonnes) | Barrels/ Day | Cost of Imports (million CFA) | Cost as Percent of Exports | Cost/ Barrel (US $) |
|---|---|---|---|---|---|
| 1971 | 60,224 | 1,227 | 127.9 | 12 | 14.28 |
| 1972 | 62,649 | 1,276 | 146.3 | 11 | 15.70 |
| 1973 | 77,920 | 1,587 | 148.8 | 11 | 12.84 |
| 1974 | 77,954 | 1,588 | 313.9 | 24 | 27.08 |
| 1975 | 90,405 | 1,841 | 275.0 | 14 | 20.46 |
| 1976 | 102,280 | 2,085 | 352.5 | 11 | 23.15 |

Source: Banque Centrale des Etats de l'Afrique de l'Ouest, 1979 on the importation of oil. At the time this analysis was made, the world price of oil was about $18/barrel.

Electrical power in Niger is produced by diesel generators, and distribution is provided in the urban centers by the government-owned Electric Power Company (Societe Nigerrienne d'Electricite, or NIGELEC). The use of imported petroleum products for the production of electricity is reflected in its price ranging on the average for the year 1977 from 27 CFA/kWh for industrial customers to 29 CFA/kWh for residential customers.

Small deposits of coal discovered in the northern part of this country have been earmarked for steam plants for the production of electricity to serve exclusively the uranium production industry.

Total installed capacity has increased from 13 MW in 1968 to 20 MW in 1977 (United Nations, 1978). There is no doubt that the government of Niger, anticipating increases in the demand for electricity and the world developments in the price of petroleum products, recently signed an agreement with the Nigerian government for the purchase of electricity from the Kainji Dam on the River Niger. Today, there exists a 132-kv transmission line from Kainji to Niamey, the capital of the Republic of Niger. The maximum contracted capacity that Niger can import is reported as 30 MW (Le Sahel Hebdo, 1976). To express how the availability of this power source will affect the economy of the country, Le Sahel Hebdo (1976, p. 22), a national magazine, wrote "Ceci permet un developement de la consummation d'electrique sans autres investissements neuveaus."

In the first year of import of this source of power, the average price of electricity fell by 7.6 percent (between 1976 and 1977). However, recent developments in the availability of water to feed the dam in Nigeria may indicate to both governments a need to work for other more reliable sources of power. The unavailability of continued supply of water to feed this dam adversely affected the Nigerian economy in 1977 pointing out the large uncertainties in the reliability of this power source.

Niger has three undeveloped hydro sources for the production of electrical energy. The W-Barrage source has a capacity of 24 MW and is capable of producing 120 GWh of energy annually. The largest in the region is on the Niger River at Kandadji and has a capacity of 200 MW and can produce annually 1,200 GWh of energy. Earlier feasibility studies of this power source called for the installation of three stages of 25, 75 and 100 MW power plants (International Monetary Fund, 1968) but the plants have not been constructed partly because of the uncertainties regarding the seasonal variations of water level in the Niger River. The third source of power yet to be developed is the Dyodyonga on the Mekrou. This source has a capacity of 24.5 MW and 66 GWh of electrical energy could be derived from it annually. The proximity of this site to the Niger-Benin border calls for some form of joint development venture between these two countries.

## Upper Volta

Like most countries in the region Upper Volta depends entirely on imported petroleum products to feed such sectors as transportation, industry, and, importantly, the production of electricity. Over the last 6 years (1972-1977), consumption has remained below the 2,000 barrels per day mark, ranging from 1,250 in 1972 to 1,731 barrels per day in 1977 (Table 21). Like the Republic of Niger, Upper Volta has had to pay more than the average world price for petroleum products due to three reasons (among others):

1. Refining capabilities are not available. This country has to buy refined petroleum products ready for use and is thus forced to pay the high value added to the products in the refining process.
2. The country is a low-volume consumer; hence, it cannot fully take advantage of discounts that are involved in such transactions.
3. Being a landlocked country, inland transportation costs between the nearest port of delivery and the capital center added extra values to the products.

Upper Volta has relied totally on diesel generating plants for the production of electricity. Installed capacity

Table 21. Historical imports of petroleum products by Upper Volta (1972-1977)

| Year | Petroleum Products (tonnes) | Barrels/ Day | Costs of Oil Imports (mil. CFA) | Percentage of Exports | Costs per Barrel (US $) |
|---|---|---|---|---|---|
| 1972 | 61,349 | 1,250 | 1,311 | 25.5 | 14.37 |
| 1973 | 62,909 | 1,281 | 1,234 | 22.1 | 13.19 |
| 1974 | 70,545 | 1,437 | 2,246 | 25.8 | 21.41 |
| 1975 | 70,090 | 1,530 | 2,864 | 30.6 | 25.65 |
| 1976 | 65,406 | 1,332 | 2,700 | 21.3 | 27.76 |
| 1977 | 84,971 | 1,731 | 4,357 | 32.0 | 34.48 |

Source: Banque Centrale des Etats de l'Afrique de l'Ouest (1979) operated by the government-owned power company, VOLTELEC, totalled 28,010 kW at the end of 1978, distributed in five urban centers with the capital city Ouagadougou having the highest capacity of 18,380 kW. Average price of electricity in 1978 varied from 33.69 CFA/kWh at high voltage for industrial customers to 63 CFA/kWh of low voltage to residential customers.

With no deposits of fossil fuels, Upper Volta's hope of producing electricity from internal primary energy sources lie in the Noumbiel hydro site with a capacity of 60 MW and capable of delivering 400 GWh of electricity annually. Economic justification for putting up this plant is doubtful left to Upper Volta alone unless the power derived from such a plant can be used in supplying large electro-industrial complexes, as was the case with Ghana's Volta River Project.

However, the recent agreement between Ghana and Upper Volta, calling for a transmission network between the two countries to supply electricity to Ouagadougou from the Kpong Dam on the Volta river, promises to pave the way for a future joint Ghana-Upper Volta development of this hydro resource (New African, 1977).

## Summary

Examination of the share of exports taken by the importation of petroleum products for the non-petroleum producing countries, the primary energy resources of the countries suitable for electricity production, the institutions responsible for the production and distribution of electricity have been the subject of the preceding sections.

All the countries examined have varied amounts of hydro resources for immediate or future exploitation. Past installation of capacities to meet growing internal demands have revealed problems that were encountered or currently exist in such efforts. For some of the countries such as Ghana and Ivory Coast, the installation of large electro-industrial complexes by external investors was economic justification for harnessing some of these resources, with the existence of excess capacities in certain countries. For countries with rich natural resources such as Nigeria, the story is the opposite. Development of energy resources for the production of electricity has lagged behind industrial development, leading to shortages of power and, more importantly, high prices of electricity for all consumers.

The poorer countries, notably Upper Volta, Niger, Benin, and Togo, despite isolated hydro resources, were not lucky enough to attract foreign investors and hence continue to import expensive petroleum products for the production of electricity. The end result is high prices for electricity, which can be afforded by only a small portion of the population.

Although the cooperation between some of the countries has historically been sparse, acceleration of other efforts have to be undertaken in order to ensure the supply of electricity to all. If this is done, hard-earned foreign resources can be mobilized for the development of other sectors of the economy, notably the agricultural and manufacturing sectors, for the benefit of a greater proportion of the population.

# CHAPTER 4

## DEMAND FOR ELECTRICITY

The role of the energy sector in promoting economic growth in the developing and developed societies has been reviewed in the last chapter, and it can be concluded that the future transition of the developing economies depends largely on reliable and cheap availability of the common forms of energy.

Since future supply of electrical energy depends in large part on the production capacities existing today, few will disagree that careful planning for future consumption is imperative if developing countries are to proceed smoothly through the transitional stages of economic development. The important role of the energy sector and the required planning has come into sharp focus in recent years largely on account of the changes that have taken place especially in the international energy market. If unexpected events like these are not to exert strain on the developing and developed economies, continuous planning to take into account all possible changes in the market place is without doubt necessary.

The electricity sector interacts reciprocally with the economy: the demand exerted on its product by the economy at large and what this sector can economically supply in return. Simply put, planning in the electricity sector is striving for an economic balance between the demand and supply at any time period.

Determining the future demand for electricity is the subject of this chapter. This is certainly a difficult task considering that the developing countries under consideration are low-level consumers of the product and that in certain cases the establishment of an enterprise that consumes a relatively large amount of electricity can distort the historical trend in consumption. An example of this "discontinuity" is the case of Ghana at the time of commissioning the VALCO aluminum smelter in 1966. The country's load capacity increased 200 percent (from 100 to 300 MW) as a result of the partial completion of the Volta Dam.

Forecasting as accurately as possible the demand for any commodity, not just electricity, is critical in structuring supply activities for such a commodity, for its undersupply or oversupply can lead to economic imbalances. It is for these very reasons that over the years analytical tools and models have been developed in the planning of such areas of most progressive economies. Those tools or models relevant to this study are reviewed and an application is made to the countries of West Africa under study.

Forecasting the Demand for Electricity

Historically, planners of developing economies have relied on the "natural growth rate" in electricity consumption for scheduling supply capacities. The natural growth rate approach links historical consumption of electricity to changes in the rate of growth of the population in the region under consideration through minimal mathematical modelling efforts. The planning of capacities based on the results of such simplistic models tends to result in the prevalence of excess capacity or supply shortages in most economies. As Casely-Hayford (1976, p. 3) put it on the application of such a model to the Ghana situation:

> It is significant to note that on reviewing the forecast made in 1958 of Ghana's domestic load-growth potential, the actual load-growth fell considerably short of the forecast. For example the maximum demand forecast made in 1958 for the year ending 1968 was 280 MW as compared to the actual demand at the end of 1968, recorded as 107 MW.

Casely-Hayford continued by stressing that the problems involved in forecasting the growth of power demand in developing countries are of significant interest.

Currently, Ghana relies on a forecast prepared using the natural growth rate approach for scheduling electricity supply till the end of 1995. The model recognizes (but does not incorporate) the fact that the forecasts are sensitive to the economic trends that will exist in the country and the future planned growth in various sectors of the economy. Political changes that retard planned economic growth are also to be mentioned as forces affecting the direction of growth in electricity consumption.

In Ghana, the dependence on one simple planning approach which is devoid of economic forces has led to the existence of underutilization of supply capacities in electricity production. The result of this has been the unplanned export of electricity to neighboring Togo and Benin. Present indications are that Ghana would soon run out of production capacity, and Ghana is seriously negotiating the import of electricity from the Ivory Coast (West Africa, 1980).

At the other extreme is Nigeria that has been struggling with the problem of undersupply of electricity for some time now due to, among other reasons, the improper forecasting of demand and scheduling of supply facilities (Ukpong, 1976). The result has been frequent blackouts in the major industrial areas of the country. The economic losses resulting from these incidents are well documented in Ukpong (1973) and recently echoed by the Central Bank of Nigeria in its annual economic report of 1978.

In addition to the natural growth rate model of projecting electricity consumption are two major types of approaches:

1. time series modelling, and
2. econometric modelling

Time Series Models

Time series modelling presumes to know nothing about the real world casual relationships that affect the variable to be forecast. Instead, it examines the behavior of a time series of the variable in order to infer something about its future behavior. Two variables are assumed in a time series model; the variable to be forecast and the period of time in question. The model always assumes that some pattern or combination of patterns is recurring over time.

Like other modelling approaches, time series models can be deterministic or stochastic. Deterministic models are simple methods in the extrapolation of time series information.

The simplest extrapolation model is the linear trend model. If it is assumed that a series $y_t$ will increase in constant absolute amounts each time period, then $y_t$ can be predicted by fitting the trend line

$$y_t = c_1 + c_2 t \qquad (1)$$

where

$t$ = time

$y_t$ = the value of y in time t

It may be more realistic to assume that the series $y_t$ grows with constant percentage increase, rather than constant absolute increase. This is the basis of the <u>exponential growth time series model</u>. Mathematically,

$$y_t = f(t) = Ae^{rt} \tag{2}$$

where r and A are constants. The parameters A and r are estimated by taking the logarithms of both sides of (2) and fitting the log-linear regression.

$$\log y_t = c_1 + c_2 t$$

where $c_1 = \log A$

and $c_2 = r$

In this case A and r would be chosen to maximize the correlation between f(t) and $y_t$.

The result can be used to forecast dependent values for periods ahead of the estimation range, T. A forecast one period ahead would then be given by

$$\hat{y}_{T+1} = Ae^{r(T+1)} \tag{3}$$

A third extrapolation method is based on the <u>autoregressive model</u>:

$$y_t = c_1 + c_2 y_{t-1} \tag{4}$$

with a variation known as the logarithmic autoregressive model:

$$\log y_t = c_1 + c_2 \log y_{t-1} \tag{5}$$

Another class of deterministic models that are often used for forecasting consists of moving average models. In forecasting monthly time series, for example, the following model is used:

$$y_t = f(t) = \frac{1}{12}(y_{t-1} + y_{t-2} + \ldots + y_{t-12}) \tag{6}$$

The moving average method is useful if a likely value for the series next month is a simple average of its values over the past 12 months. It may be unrealistic, however, to assume that a good forecast of $y_t$ would be given by a simple average of its past values; hence recent values are weighted more heavily than others in the moving average method. A deterministic forecasting model that accomplishes this is the exponentially weighted moving average model (EWMA):

$$\hat{y}_{T+1} = \alpha y_T + \alpha(1 - \alpha)y_{T-1} + \alpha(1 - \alpha)^2 y_{T-2} \ldots$$

$$= \alpha \sum_{t=0}^{\infty} (1 - \alpha)^t y_{T-t} \tag{7}$$

where $\alpha$ lies between 0 and 1 and its value indicates how heavily the recent values are weighted relative to older ones.

Although the moving average forecasts are adaptive (i.e., they automatically adjust themselves to the most recently available data) they do not provide information about forecasts' confidence. The reason is that no regression is used to estimate the model, so that we cannot calculate standard errors nor can we describe or explain the stochastic (unexplained) component of the time series. Stochastic time series models attempt to relate the dependent variable $y_t$ to its past values and random disturbances and can be specified as linear or non-linear.

The simplest of stochastic time series models are the moving average models in which the process $y_t$ is described completely by weighted sum of current and lagged random disturbances. The second type is the autoregressive model in which $y_t$ depends on a weighted sum of its past values and a random disturbance term. The third type, called the mixed autoregressive-moving average model, is a combination of the previous two methods in which $y_t$ is a function of both lagged random disturbances and its past values as well as current disturbances.

Furthermore, in the utilization of stochastic time series models, we want to know whether the underlying stochastic process that generated the time series can be assumed to be invariant with respect to time. The models described above all assume that the process is fixed in time or is stationary. An example of a non-stationary stochastic process that better describes economic and business processes is known as the integrated autoregressive-moving average method, or simply, ARIMA.

Researchers engaged in forecasting have employed various time series techniques in economic forecasting. The evidence points out that the simple time series models can often outperform large econometric models in the short run (Uri, 1977). Pure time series approaches have been extensively criticized, however, because if resultant forecasts are poor, one is at a loss to provide an explanation because the models have no basis in economic theory. To improve accuracy in forecasting, a combined approach utilizing regression analysis (with its underlying economic theory) and a time series model has been suggested and tested by Uri (1976) and accurately forecasted the monthly peak electrical loads for a specific electric utility area in the United States.

Econometric Models

As the name implies, econometric models rely on economic theory in addition to statistical principles to estimate model parameters, and the results can be used to draw inferences about an economy. Such models are also used to forecast such economic determinants as the GNP, interest rates, etc.

Econometric models can be developed from systems of equations or simply by a one-equation relationship between the exogeneous and endogeneous variables. The former is desirable because, if formulated properly, the systems of equations should explain the interdependencies that may exist among the explanatory variables. Furthermore, single-equation models explain causality in only one direction; i.e., explanatory variables determine a dependent variable, but there is no "feedback" relationship between the variable and the explanatory variables. Often multi-equation models consist of a set of regression equations, which after having been estimated are solved simultaneously for the important variables. Moreover, simulation models can also consist of equations such as accounting identities, technological relationships, or simply behavioral rules of thumb (Pindyck, 1973; Hoffman and Jorgenson, 1977; Uwujaren, 1977).

Despite the criticisms levelled against econometric modelling (Mayer, 1977), consider the classical theory of consumer choice that states that the demand for goods and services consumed by an individual (or a household) is derived from the maximization of a utility function of the form

$$u = f(q_1, q_2, \ldots q_n) \quad (8)$$

where $q_1$, $q_2$, ... $q_n$ are the quantities of the different commodities consumed in a single time period. It is assumed that the utility function is not only an increasing and continuous function of each of the quantities but is also twice differentiable.

Given the utility function, the theory assumes that the consumer maximizes his satisfaction subject only to a budget constraint, i.e.,

$$\sum_{i=1}^{n} p_i q_i = y \tag{9}$$

The average prices $p_1$, $p_2$, . . . $p_n$ and disposable income y are taken as given to the consumer and they satisfy the following conditions:

$$y > 0 \text{ and } p_i > 0; \; i = 1, 2, \ldots n \tag{10}$$

The maximization of eq. (8) subject to eq. (9) is a constrained maximum problem and can be solved using the Lagrange multiplier approach. With this a necessary condition for the solution of this problem is that

$$u_i - \lambda p_i = 0; \; i = 1, 2, \ldots n \tag{11}$$

where

$$u_i \triangleq \left(\frac{\partial u}{\partial q_i}\right)$$

and λ is the Lagrange multiplier. In economic terms λ is the marginal utility of money or as can be shown from equations (9), (11), and the definition for $u_i$

$$\lambda = (\frac{\partial u}{\partial y})$$

Solving for λ from one of the equations of eq. (11), say i = n, we than have n - 1 equations left from eq. (11) and the addition of the budget constraint eq. (9), to such a system provides n equations with n unknowns. Realizing that the $u_i$ is a function of $q_i (i = 1, 2, \ldots, n)$, the solution of such a system of equations yields the following demand functions:

$$q_i = f_i(p_1, p_2, \ldots, p_n, y) \qquad (12)$$

for $i = 1, 2, \ldots, n$

It should be noted that equal proportionate changes in prices and income do not affect the constraint in eq. (9) and thus will not affect the values of the qs that maximize the utility function. Thus we can write the last equation as:

$$q_i = f_i(p_1/p, p_2/p \ldots, p_n/p, y/p) \qquad (13)$$

for $i = 1, 2, \ldots n$

where p is an index of general prices commonly known as the consumer price index (CPI). The reason for preferring the latter form of the demand equation is simple. Because the $q_i$s are physical quantities we wish to maintain the right-hand side quantities (or determinants) in the so-called "real" terms to remove any effects of inflation or deflation. The last equation therefore states that the demand for $q_i$ is a function of relative prices for all commodities and of real disposable income.

In addition to prices and income, other factors such as tastes not identified in the utility function determine consumer demand. These other factors, denoted by $x_j$ for $j = 1, 2 ..., m$, may be incorporated in the demand equation. Finally, the demand equation takes the form

$$q_i = f_i(p_1/p, p_2/p, ..., p_n/p, y/p, x_1, x_2, ..., x_m) \quad (14)$$

Because the utility function is not measurable in practice, statistical analysis begins directly with the demand functions. The exact functional form is rarely deduced theoretically but is commonly determined empirically. Equation (14) is a general function for empirical estimation of demand analysis. However, there are several reasons that in practice a single regression equation is not specified in a study so as to include all factors that have causal influence on the dependent variable under study. First, it is legitimate to make the demand theory as simple as possible, taking into explicit account only the main causal factors. Second, statistical data may be lacking for certain variables. Finally, the causal factors may be highly intercorrelated and therefore the inclusion of a large number of explanatory variables in the model may increase the standard errors of the estimated coefficients and tend to obscure the importance of more relevant explanatory variables in the equation.

## Specification of Demand Models for Estimation

### The Residential Sector

The determinants of the demand for a commodity consumed by an individual or household have been developed based on the premises of the classical theory of consumer demand. On this basis, the following functional relationships for the demand of electricity in the residential sector of the West African countries are proposed for estimation. These are:

$$QR = F(PE, INC, NHS) \tag{15}$$

$$PQR = F(PE, PINC, PNHS) \tag{16}$$

QR = total electricity consumption in the residential sector (kWh/yr)

PE = average price of electricity (in real terms)

INC = total disposable income of all households (in real terms)

NHS = number of households with access to electricity

PQR = QR/POP

PINC = INC/POP

PNHS = NHS/POP

where PQR, PINC, and PNHS are values of QR, INC, and NHS, respectively, normalized with population (POP).

Specific functional forms based on eqs. (15) and (16) are presented with the following notation. The variables in parentheses apply if we specify a regression equation based on the general form of eq. (16).

Y = QR (or PQR)

$X_1$ = PE

$X_2$ = INC (or PINC)

$X_3$ = NHS (or PNHS)

then

$$Y_t = b_0 + b_1X_{1t} + b_2X_{2t} + b_3X_{3t} + \mu_t \quad (17)$$

$$\ln Y_t = b_0 + b_1\ln X_{1t} + b_2\ln X_{2t} + b_3\ln X_{3t} + \mu_t \quad (18)$$

$$\ln Y_t^* = b_0 + b_1\ln X_{1t}^* + b_2\ln X_{2t}^* + b_3\ln X_{3t}^* + \mu_t \quad (19)$$

$$\ln Y_t^{**} = b_0 + b_1\ln X_{1t}^{**} + b_2\ln X_{2t}^{**} + b_3\ln X_{3t}^{**} + \mu_t \quad (20)$$

where

$$Y_t^* = Y_t - \alpha Y_{t-1} \qquad Y_t^{**} = Y_t - \alpha_1 Y_{t-1} - \alpha_2 Y_{t-2}$$

$$X_{1t}^* = X_{1t} - \alpha X_{1t-1} \qquad X_{1t}^{**} = X_{1t} - \alpha_1 X_{1t-1} - \alpha_2 X_{1t-2}$$

$$X_{2t}^* = X_{2t} - \alpha X_{2t-1} \qquad X_{2t}^{**} = X_{2t} - \alpha_1 X_{2t-1} - \alpha_2 X_{2t-2}$$

Although there are other functional forms, the most common in econometric work are the linear forms, which relates the dependent variable $y_t$ directly to the explanatory variables, and the double-logarithmic form, which relates the natural logarithms of all variables in a linear way. The latter form is the more desirable for one reason, the important concept of elasticity in economics is given by the coefficients of the equation once it has been estimated.

Consider, for example, Eq. (18) with QR, PE, INC, and NHS. Price elasticity of demand ($\varepsilon$) for electricity is defined as

$$\varepsilon = \frac{\partial PE}{\partial QR} \cdot \frac{PE}{QR}$$

which equals $b_1$ (the coefficient of $\ell_n$ PE) in the functional specification. In all the functional specifications, $\mu_t$ is a disturbance term denoting the error involved in not including all the explanatory variables in the functional specification. The reasons for specifying the regressions forms, Eq. (19) and Eq. (20), are explained later when the problems involved in estimating regression equations are considered.

## The Industrial and Commercial Sector

In deriving a demand for electricity specification in the industrial and commercial sectors it is assumed that a particular industrial or commercial group strives to minimize the cost of all inputs subject only to its production function. This optimization problem can be formulated if we assume that the firm demands n inputs $X_1, X_2, \ldots X_n$. Let $p_1, p_2, \ldots, p_n$ be average unit prices associated with these inputs. Then the firm's total cost is given by

$$C = p_1X_1 + p_2X_2 + \ldots + p_nX_n$$

We wish to minimize this function subject to the production function

$$Q = F(X_1, X_2, \ldots, X_n)$$

where Q is the output of the firm. The solution to this problem yields the following demand for inputs functions:

$$X_i = F_i(p_1, p_2, \ldots, p_n, Q^*)$$

with $Q^*$ being an output target.

In order to obtain realistic forecasts for electricity consumption in this sector of the economies of the West African countries, the following functional relationship is suggested:

INDCON = F(PRICE, EMPL, OUTPUT)

where

INDCON = the electricity consumption in the combined sector

PRICE = the real average price for electricity to this sector

EMPL = employment in this sector

OUTPUT = real output registered by the sector

The inclusion of the level of employment in the demand function stems from the one difference between an energy material such as electricity and other inputs. This difference arises from the recognition that electricity is desired not for its own sake but because it enables a flow of services or goods to be produced from existing industrial durables and the labor force that operates or manages such investments.

Specifically, models based on the linear and double logarithmic relationships have been estimated for the combined industrial and commercial sectors. If

$Y$ = INDCON

$X_1$ = PRICE

$X_2$ = EMPL

$X_3$ = OUTPUT

then the model forms estimated are the same as in Eqs. (17) through (20).

## Estimation of Regression Equations

Estimation of the regression models, Eqs. (17) through (20), for the two sectors of the economies involve determining values for the coefficients $b_0$, $b_1$, $b_2$, and $b_3$.

Formally, consider the multiple-regression model

$$Y_t = b_0 + b_1X_{1t} + \ldots b_kX_{kt} + \mu_t;$$

$t = 1, \ldots, n$

$Y_t$ = the $t^{th}$ observation on the dependent variable (or "regressand")

$X_{it}$ = the $t^{th}$ observation on the $i^{th}$ independent variable (or "regressor")

$\mu_t$ = the $t^{th}$ value of the disturbance term

$b_i$ = the coefficient of the $i^{th}$ independent variable

Statistical assumptions mainly about the error term are needed to obtain values for the coefficients. These assumptions are:

1. The expected, or mean value of the disturbance or error term, is zero, i.e., $E(\mu_t) = 0$.
2. The variance of the error term is a constant and therefore independent of t:

   $$V(\mu_t) = E(\mu_t - 0)^2 = E(\mu_t) = \sigma_\mu^2$$

3. The values of the disturbance term are independent of one another so that the covariance between the error terms corresponding to any two observations, $\mu_t$ and $\mu_s$, is zero.

   $$Cov(u_t, u_s) = E(\mu_t \mu_s) = 0$$

4. The error term is independent of all the values of the regressors, or zero covariance between $\mu_t$ and each $X_{it}$,

   $$Cov\ (\mu_t X_{it}) = E(\mu_t X_{it}) = 0$$

These four assumptions about the behavior of the disturbance term allow k+1 "normal equations" with k+1 unknowns, $b_0$, $b_1$, $b_2$, . . ., $b_k$ to be solved for. The normal equations can also be obtained if we start with the objective of minimizing the sum of squared deviations. This is the ordinary least squares (OLS) method. The assumptions above are necessary in order to examine the statistical properties such as expected value, and variance of the estimators of the coefficients.

The solution of the normal equations has been made possible by the availability of computer programs such as PLANETS and SPSS that accept the data ($Y_{it}$, $X_{it}$) and the form of the desired regression equation and then produce estimates of the coefficients and their statistical properties. Those properties relevant to this study are now reviewed.

## Single Equation Estimation--Problems and Properties

The explicit determination of a regression equation is the estimation of the coefficients of the model by solving simultaneously the normal equations. The final product is a summary of the relationship between Y (the dependent variable) and the set of independent variables, the Xs. The equation may be used for several purposes. It may be used to evaluate the importance of individual Xs, to analyse the effects of policy that involves changing values of the Xs, or to forecast values of Y for a given set of Xs. Even though the last use of the regression equations is the primary concern of this chapter we shall be interested in examining the effect of the Xs on dependent variables especially as they relate to differences between countries.

Although the regression equation is the final product, we are also interested in the adequacy of the overall quality of the regression equation, the importance of the individual coefficients (by hypotheses testing), and above all, the validity of the basic assumptions that led to the derivation of the normal equations.

The most widely used measure of the adequacy of fit of a regression equation is the well-known multiple determination coefficient, $R^2$. This is defined as

$$R^2 = 1 - \frac{\text{Unexplained variation in Y}}{\text{Total variation in Y}}$$

$$= 1 - \frac{\Sigma(Y_i - \hat{Y})^2}{\Sigma(Y_i - \overline{Y})^2}$$

where $Y_i$, $\hat{Y}$, and $\overline{Y}$ are, respectively, the observed, predicted, and sample mean values of the dependent variable. If the model fits the data well, the value of $R^2$ is close to unity, and if the expected model results in a poor fit to the set of observations, the $R^2$ value is closer to zero.

To construct confidence intervals and to perform tests of hypotheses about the parameters in the regression model, we have to make an additional assumption about the probability law of the error terms. These are assumed to be distributed normally.

To test the null hypothesis (say for the parameter $b_1$), $H_0: \beta_1 = \beta_1^0$, where $\beta_1$ is the least squares estimate of $b_1$ and $\beta_1^0$ is a constant chosen by the investigator, the appropriate test statistic is the t-statistic, having a

Student's t distribution. Its critical values have been tabulated. The definition for t is

$$t = (\beta_1 - \beta_1^0)/\text{standard error of } b_1$$

The test is carried out by comparing the observed value (calculated from the above definition) with the appropriate tabulated critical t value. The usual test is for $\beta_1^0 = 0$ in which case t reduces to the ratio of $\beta_1$ to its standard error.

To test model deficiencies in regression analysis, a simple and effective method is the examination of the residuals. The $i^{th}$ residual is defined as

$$e_i = Y_i - \hat{Y}_i$$

Corresponding to $e_i$, we also have the $i^{th}$ standardized residual $e_{is}$

$$e_{is} = \frac{e_i}{s}$$

where s is the standard deviation of residuals. If our assumption about the error proves correct, the residuals should be distributed approximately as independent normal deviates. This is checked by a plot of the standardized residuals as ordinate against the time order in which the observations occur. In general, when the model is correct, the standardized residuals tend to fall between 2 and -2 and are randomly distributed about zero. This method of analysing residuals is a very useful tool for uncovering hidden structures in the data.

One of the standard assumptions in the regression model is that the error terms $\mu_i$ and $\mu_j$ associated with the $i^{th}$ and $j^{th}$ observations are uncorrelated. This assumption may not be realistic, especially in a time-series analysis in which the error term may be correlated with its past values. In other words the error term can be expressed as a function of its past values. Detection of the presence of autocorrelation is afforded by the Durbin-Watson (DW) statistic. Like other "statistics", critical values of the DW statistic are available in tables. In this test we have lower and upper critical values $d_l$ and $d_u$ for various values of the number of independent variables k and sample size n. The test works this way. If DW < $d_l$, we reject the null hypothesis and accept the hypothesis of positive autocorrelation $\rho > 0$. If DW > $d_u$, we do not reject the null hypothesis. If $d_l$ < DW < $d_u$, the test is inconclusive. On the other hand, if DW > 4 - $d_l$, we reject the null hypothesis and accept the hypothesis of negative autocorrelation $p < 0$. If DW < 4 - $d_u$, we do not reject the null hypothesis. If 4 - $d_u$ < DW < - $d_l$, the test is inconclusive.

The presence of correlated errors distorts estimates of standard errors, confidence intervals, and statistical tests. For forecasting purposes recognition of autocorrelation and the taking of corrective measures will ensure lower forecast errors.

A model for correcting autocorrelation is obtained by writing the error term as a linear function of its past value:

$$\mu_t = \rho\mu_{t-1} + v_t; \; v_t \sim N(0, \sigma_v^2) \text{ and } |\rho| < 1$$

This is known as the first-order autocorrelation model. Introduction of this into the general linear regression model leads to the following transformation of variables:

$$Y_t^* = Y_t - \rho Y_{t-1}$$

$$X_t^* = X_t - \rho X_{t-1}$$

and the regression equation to be estimated becomes

$$Y_t^* = b_0(1 - \rho) + b_1 X_t^* + v_t$$

assuming only a two-variable model. For a multi-variable model the general regression Eq. (19) is obtained. The logarithmic form is the choice of the analyst.

Similarly, a second-order autocorelation model

$$\mu_t = \rho_1\mu_{t-1} + \rho_2\mu_{t-2} + v_t$$

results in the general regression specification Eq. (20) here shown in logarithmic form.

In the case of the first-order autocorrelation model, it can be proven (Pindyck and Rubinfeld, 1976) that the forecast error is smaller--by a factor of $(1 - \rho^2)$--than would be the case if we did not take autocorrelation into account.

## Regression Results

Except for the country of Benin[1], two sectors, residential and industrial and commercial, were identified for each country and regression specifications, Eq. (17) through Eq. (20), were estimated using annual time series data for the period 1960-1977. The equations yielding the best results are tabulated in Table 22. The statistics presented include the estimated regression coefficients and their t-ratios, $R^2$, estimated standard error of estimate (SE) and the Durbin-Watson statistic. In order to present all results in a single table, the independent variables are listed under generic headings. Thus income may be total personal real disposable income, total personal real income

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[1]Due to lack of sufficient data, the total demand (DEMAND) for electricity in Benin was estimated by the functional specification

$$\text{DEMAND} = F(\text{GDP})$$

where GDP is the real gross domestic product--the total output of the economy. The double-logarithmic functional form was found to perform best.

Table 22. Energy demand equations. -- t ratios in parentheses below estimated coefficients

| Regression Result | Regression Equation | Sector | Constant | Price | Income | Employment or Number of Subscribers | $R^2$ | DW | SE[a] |
|---|---|---|---|---|---|---|---|---|---|
| <u>Nigeria</u> | | | | | | | | | |
| 1. | 18 | IND[b] | 6.489<br>(3.341) | -0.679<br>(-4.836) | 0.890<br>(4.720) | 0.839<br>(4.098) | 0.984 | 1.635 | 0.085 |
| 2. | 18 | RES(16)[c] | 1.253<br>(1.400) | -0.304<br>(-2.231) | 0.623<br>(4.416) | 0.274<br>(5.188) | 0.977 | 1.664 | 0.082 |
| 3. | 19 | RES(16) | 1.276<br>(1.591) | -0.306<br>(-2.527) | 0.620<br>(4.912) | 0.275<br>(5.812) | 0.991 | 1.745 | 0.072 |
| 4. | 19 | RES(15) | 2.881<br>(0.992) | -0.310<br>(-2.212) | 0.627<br>(4.724) | 0.285<br>(6.121) | 0.998 | 1.713 | 0.072 |
| <u>Ivory Cóast</u> | | | | | | | | | |
| 1. | 19 | IND | -5.307<br>(-2.814) | -0.661<br>(-4.401) | 0.494<br>(3.944) | 1.303<br>(7.261) | 0.975 | 1.362 | 0.058 |
| 2. | 17 | RES(15) | 8.287E+7<br>(2.310) | -0.493E+7<br>(-3.254) | 0.758E-4<br>(0.737) | 298.747<br>(14.255) | 0.992 | 2.006 | 0.108E+8 |
| 3. | 18 | RES(15) | 4.487<br>(1.188) | -0.783<br>(-5.926) | 0.297<br>(1.586) | 0.699<br>(8.632) | 0.996 | 1.681 | 0.052 |
| 4. | 18 | RES(16) | 2.603<br>(1.523) | -0.560<br>(-3.717) | 0.373<br>(2.648) | 0.713<br>(14.805) | 0.992 | 2.154 | 0.045 |
| 5. | 19 | RES(16) | 2.365<br>(1.604) | -0.555<br>(-4.404) | 0.393<br>(3.287) | 0.706<br>(19.159) | 0.998 | 2.332 | 0.040 |
| <u>Benin</u> | | | | | | | | | |
| | 18 | ALL[d] | -8.381<br>(-9.847) | | 1.026<br>(27.743) | | 0.986 | 1.414 | 0.052 |

Table 22--Continued

| Regression Result | Regression Equation | Sector | Constant | Price | Income | Employment or Number of Subscribers | $R^2$ | DW | SE[a] |
|---|---|---|---|---|---|---|---|---|---|
| Togo | | | | | | | | | |
| 1. | 17 | IND | 6.824E+7 | -0.242E+7 | 0.558E-3 | | 0.937 | 1.537 | 0.571E+7 |
| | | | (3.535) | (-2.727) | (2.719) | | | | |
| 2. | 19 | IND | 10.172 | -0.606 | 0.377 | | 0.998 | 1.463 | 0.111 |
| | | | (2.393) | (2.727) | (2.388) | | | | |
| 3. | 20 | IND | 11.434 | -0.701 | 0.336 | | 0.999 | 1.725 | 0.094 |
| | | | (3.683) | (-4.296) | (2.920) | | | | |
| 4. | 19 | RES(15) | -5.772 | -1.022 | 1.010 | | 0.998 | 1.930 | 0.110 |
| | | | (1.029) | (-4.329) | (5.038) | | | | |
| Niger | | | | | | | | | |
| 1. | 18 | IND | -5.028 | -0.621 | 0.812 | 0.448 | 0.976 | 0.949 | 0.104 |
| | | | (-0.735) | (-2.448) | (2.715) | (2.343) | | | |
| 2. | 19 | IND | -0.851 | -0.752 | 0.655 | 0.451 | 0.998 | 1.820 | 0.082 |
| | | | (-0.186) | (3.699) | (3.536) | (3.236) | | | |
| 3. | 18 | RES(16) | 2.203 | -0.832 | 0.887 | 1.139 | 0.957 | 0.906 | 0.120 |
| | | | (0.723) | (-3.063) | (3.009) | (5.050) | | | |
| 4. | 19 | RES(16) | 7.734 | -0.654 | 0.398 | 1.344 | 0.981 | 1.695 | 0.089 |
| | | | (2.598) | (-3.403) | (1.436) | (5.462) | | | |
| 5. | 20 | RES(16) | -2.995 | -1.316 | 1.288 | 0.712 | 0.985 | 2.305 | 0.089 |
| | | | (-1.104) | (-4.834) | (5.038) | (3.162) | | | |
| 6. | 18 | RES(15) | -9.762 | -0.800 | 0.846 | 0.833 | 0.976 | 0.985 | 0.114 |
| | | | (-1.840) | (-3.107) | (3.243) | (4.386) | | | |

Table 22--Continued

| Regression Result | Regression Equation | Sector | Constant | Price | Income | Employment or Number of Subscribers | $R^2$ | DW | SE[a] |
|---|---|---|---|---|---|---|---|---|---|
| 7. | 19 | RES(15) | -2.333<br>(-0.409) | -0.682<br>(-3.568) | 0.449<br>(1.656) | 1.073<br>(5.622) | 0.998 | 1.709 | 0.087 |
| 8. | 20 | RES(15) | -14.744<br>(-3.270) | -1.240<br>(-4.753) | 1.236<br>(5.625) | 0.441<br>(2.421) | 0.998 | 2.298 | 0.083 |
| **Ghana** | | | | | | | | | |
| 1. | 19 | RES(15) | -3.906<br>(0.815) | -0.195<br>(-0.862) | 1.066<br>(4.864) | | 0.998 | 2.241 | 0.138 |
| 2. | 19 | RES(16) | -2.615<br>(-1.541) | -0.235<br>(-1.136) | 1.026<br>(3.480) | | 0.971 | 2.256 | 0.137 |
| 3. | 19 | IND | 11.822<br>(4.416) | -0.459<br>(-4.486) | 0.522<br>(3.971) | | 0.998 | 1.995 | 0.089 |
| **Upper Volta** | | | | | | | | | |
| 1 | 18 | IND | -99.487<br>(-2.682) | -0.850<br>(-0.787) | 4.882<br>(3.122) | | 0.529 | 2.583 | 0.228 |
| 2. | 18 | RES(15) | 8.759<br>(15.054) | -0.291<br>(-2.724) | | 0.973<br>(33.152) | 0.944 | 1.698 | 0.026 |

Footnotes:

a. SE denotes the "standard error of regression."
b. IND denotes the industrial and commercial sectors combined.
c. RES( ) denotes the residential sector model based on regression equation in parentheses.
d. ALL denotes the total economy.

per capita, or real gross domestic product, etc., depending on the category of demand that is involved. As expected, the non-linear (double-logarithmic) equations produced better results than the linear ones. Also correction for autocorrelation through first- and second-order models of the error term produced superior estimates of the t-ratio and the Durbin-Watson statistic. Except in the case of Upper Volta, $R^2$ values have been found to be greater than 90 percent, implying that the omitted explanatory variables account for less than 10 percent of the variation in the dependent variable.

In agreement with the theory, the income and price coefficients turn out the correct signs (positive for income and negative for price) in all the estimated equations, even though a very small number of these coefficients are statistically insignificant at the 5 percent confidence level.

Derived from the energy demand equations are the important policy parameters, income and price elasticities. Their values for the two sectors of the economies are presented in Table 23. The income and price elasticities do not differ appreciably from those reported by Yao (1980 p. 91 and 99) except for the price elasticity in the residential sector of the Ivory Coast. He reported -0.200 and -0.404 respectively for the short and long run. Researchers analysing world energy demand profiles argue that income

Table 23. Price and income elasticities for electricity demand

| | Price Elasticity | Income Elasticity |
|---|---|---|
| Residential Sector | | |
| Nigeria | - 0.310 | 0.627 |
| Ivory Coast | - 0.783 | 0.279 |
| Togo | - 1.022 | 1.010 |
| Niger | - 1.240 | 1.236 |
| Ghana | | 1.066 |
| Upper Volta | - 0.291 | |
| Industrial and Commercial Sector | | |
| Nigeria | - 0.679 | 0.890 |
| Ivory Coast | - 0.661 | 0.494 |
| Togo | - 0.752 | 0.336 |
| Niger | - 0.752 | 0.665 |
| Ghana | - 0.459 | 0.522 |
| Upper Volta | | 4.882 |

elasticities in the residential sector should be higher and price elasticities lower than in the developed countries (Pindyck, 1979). Except for Upper Volta, the estimated elasticity coefficients lie in the range of values for the developed economies (Taylor, 1975).

The utility of the demand equations is to forecast the demand for electricity in both sectors outside the estimation period assuming the structure of the economies will not change drastically. Specifically, we are interested in the forecast period 1980 to 1989, inclusive. The overall low standard error of estimates obtained for all regression equations provide confident forecasts of electricity demand into the future.

To forecast the dependent variable, values for the independent variables during the forecast period have to be known. To do this we again rely on the past (1960-1977) movement of these variables in order to project their values. Time-series analysis of these variables enabled their future values to be obtained in most cases. However, realistic assumptions about the movement of other variables (e.g., prices) were made to obtain forecasts for the dependent variables. It is to be stressed that the overall objective of this research--to develop an analysis tool for the examination of alternatives in the supply of electricity--still holds in this respect. Thus, the projected values of the independent variables in this study are just one set of values out of many that could be used in the study. The results of the projections of both independent and dependent variables are presented in Appendix A.

# CHAPTER 5

## THE INVESTMENT PROBLEM

As development proceeds in West Africa, decision making in various sectors of the economy will become more and more complex. The electrical energy production sector is no exception. Factors that will contribute to this complexity are multi-dimensional.

First, different energy sources have complementary functions in progressive interconnected power systems. For example, as demand for irrigation water increases, hydro power plants will be required to reduce output due to the extra demand on available water resources. Other energy sources that will contribute to this complexity are fossil fuels, mainly fuel oil, coal, and gas; new technologies such as thermal and fast neutron breeder reactors; pumped storage; direct use of the sun's energy; and biomass utilization in electricity production.

The second factor is due to the variability in characteristics of existing technologies: gas turbines have low capital but high generation costs; fossil fuels higher capital but lower generation costs; nuclear reactors, high capital and low generation costs; and hydro power, costs (depending on the site) and generation costs near zero. Thus the optimum balance of plants in the production system at any point in time will depend on the relative capital and generation costs of the alternative energy sources. Also, future system balance will depend on both the inherited and the expected structure of the power system for which decisions have to be made today.

A third factor stems from the evolution of the structure of the economies of the region that have made them vulnerable to unexpected high fuel and factor prices since 1973 and will continue to do so in the light of present world developments.

A fourth factor that will contribute to the complexity of the decision making in the electricity production sector is the recent preliminary decision of these countries to pool their resources in development efforts, particularly in the energy sector. Whereas before demand and generation regions were single, future optimal plant balance will also depend on multi-country demand and generation possibilities.

A fifth concern that will definitely affect future decisions is what has come to be known in the latter part of this century as "environmental problems." Thorndike (1976) partially identifies four types of environmental damage:

1. Threats to human health and safety,

2. Damage to economic resources and to material well-being.
3. Reduction in "enjoyment of life" of a psychological-aesthetic character.
4. Damage to non-human environments.

Environmental damages resulting from electrical energy production include such effects as air pollution, which can cause lung disease and diminish recreational opportunities. Socio-economic effects would include loss of livelihood, high morbidity and mortality rates following resettlement, especially in connection with major man-made lakes projects with high risks where population densities are increased as a result of relocation; relocation in a quite different environment; and inadequate nutritious food during and following resettlement.

The problem of determining optimum investment policies in the face of rapid increases in demand, the high costs of factor inputs and their associated uncertainties, enlargement of service market area, the large number and diversity of alternative investment policies, and above all the numerical tedium of evaluating in depth even a single policy have motivated the development and application of mathematical models to assist the engineering economist in the examination and evaluation of such policies.

Following is a discussion of some of the relevant methods that have been developed in an attempt to delineate a method and to subsequently improve and adapt it to the investments in electricity supply problems of the countries of West Africa.

## Investment Decision Theory

Numerous methods on the appraisal of investment decisions exist in the literature. Amongst these are

1. The benefit-cost ratio approach
2. The rate of return approach
3. Optimization models that are based on a single-objective criterion or multi-objective criteria.

The cost-benefit ratio approach is applicable when choosing one of a set of independent mutually exclusive projects. In analysis, direct and indirect costs of a project or set of projects are compared with benefits that will result from implementing alternative projects. It is important that costs and benefits be expressed in monetary units. That alternative with the highest benefit-to-cost ratio is usually selected as the most desirable alternative for implementation. Expressing benefits and costs in present worth values are desirable when alternatives have to be evaluated over long periods of time as is the case in this study. Such analyses are full of uncertainty. There are difficulties in calculating the indirect costs of a project (such as environmental damage); benefits are also difficult to estimate accurately. Hence it is not surprising to obtain different estimates of the cost-to-benefit ratio from different analysts working on the appraisal of the same alternative projects. For the developing economies, where scarcity of capital is a problem, everything possible should be done to relate a proposed project to the benefits it will yield to the economy at large when this approach is taken.

In the cost-benefit ratio analysis, a discount rate is assumed in the calculation of present worths of costs and benefits. Determination of an interest rate resulting from equating total benefits and costs is the objective of the rate of return approach to project analysis. This interest rate then represents the minimum rate of return on capital investments for the investor. It can be compared with other available interest rates to determine whether the project is better or worse than alternative uses of capital. If a project is expected to yield less than this minimum, it should not be undertaken, for there are presumably more productive uses of capital elsewhere. It lays particular emphasis on the profitability per unit of capital invested and is therefore used mostly by private investors. This method is used by international lending institutions providing money for development projects in developing countries. An evidence of this is given by Van Der Tak (1966). The systematic development of this method and its application to the Guri Project (the choice between hydro and thermal plants) in Venezuela is the subject of his work.

Multi-objective criteria programming derives its application in decision analysis when planning or investment problems are characterized by many conflicting objectives. Typically, these may be environmental, social, benefit, cultural, political, etc. in the developing economies. The method, still in the developmental stages, has been applied in various forms to such problems as water-resources management (Goicoechea, 1977) and land use planning (Armijo and Bulfin, 1979). A multi-objective model serves as an aid to a group of decision makers in choosing a satisfying feasible set of alternatives. This implies the input of the decision makers at every stage of the model building from choosing a collection of goals and defining the corresponding objective functions to reaching the stated goals.

In analysing investments in electrical energy supply systems in West Africa, or for that matter any developing economy, multi-objective planning criteria are desirable if complementary uses of primary resources are considered as are found in hydro schemes. Such an analysis may call for delivering irrigation water and supply electric power to the community while still trying to maintain certain minimum water levels in the reservoir itself and downstream to accommodate environmental, navigational, fishing, and recreational interests.

A special case of the multi-objective criteria optimization is the single-objective optimization approach. Single-objective simply means that one of the conflicting objectives in the multi-objective consideration totally overrides all other objectives.

In what follows, a review of the material on single-objective optimization is undertaken; a plausible single-objective criterion is delineated for the West African countries and a general mathematical model for the electricity supply industry is formulated.

## Single-objective Mathematical Programming

The application of mathematical programming methods and computer analyses for investment decisions and, in particular for problems faced in electric power system planning and operation began in the late 1950s by Massé and Gibrat (1957) who solved an investment problem using linear programming. A subsequent paper by Bessiere and Massé (1964) and a book by Massé (1962) formulated the problem more generally.

Regardless of its simplicity, this first attempt demonstrated that the method was feasible and fruitful. Since then the contributions made on many fronts in the area are reflected in the large body of literature available on the subject. A large reference list of modelling variations is contained in the book by Turvey and

Anderson (1977). Manne (1971) utilized mixed integer programming codes for project evaluation; Gately (1970) specifically applied integer programming approach to investment planning for the electric power industry.

Non-linear programming has been used in cases where the analysts wish to include effects of economies or diseconomies of scale. Bessière (1970) and Cazalet (1970) utilized non-linear programming techniques, and Rogers (1970) introduced network-type algorithms for planning capacity extensions in electric power systems. The computational inefficiency of these algorithms has required either considerable aggregation of the investment decision variables or a restriction to relatively short planning horizons.

Various investigators have used dynamic programming in analysing the planning and operation of electric power systems in an effort to circumvent the problems associated with other models--inefficiency, unavailability of computer programs, aggregation, etc. Lindqvist (1962) used this approach to determine operating schedules for long-range storage reservoirs on mixed hydro-thermal systems. This technique also was used by Peterson (1973) to study the expansion of electric power systems, and at a more practical level Kuiper (1973) applied a similar methodology for the analyses of alternative sequences of hydro-electric power developments for the Brazil electric power system.

Simulation models that directly integrate the load duration curve have been used by Taylor and Boal (1969) for estimating the generation savings associated with different operation schemes and investment programs. The assumption underlying these models is that, although one cannot derive or obtain satisfactory system parameters, simulation of the markets under assumed parametric values will provide the decision maker with useful information for bracketing the probable outcomes of policy changes. This was the approach taken by Jacoby (1971) when he performed analyses in electric power investments for West Pakistan.

On the general front of energy modelling, work has been done on a limited scale in recent years on the modelling of energy systems as an aid to planning. The Brookhaven Energy Model, developed by Hoffman (1973), optimizes with the aid of linear programming, the fuel mix with respect to cost, resource consumption, and environmental considerations in a given planning year. It is a static formulation that specifies the optimal mix and the assignment of resources to demand sectors. The model developed by Baughman (1973) at the Massachusetts Institute of Technology is intended to examine a medium to long-range dynamic interfuel competition and also to investigate the interdependencies and cross ties between the important competing sources of energy in the U.S. economy.

It is apparent from the preceding that, whatever the model type, energy models have been used and are available for supporting the electric power industry. The variety of models reviewed varies from capital budgeting decision making to answering environmental questions associated with electric power production.

However, much still exists to be done in the energy modelling area. Specifically, in the scheduling and operation of electric power systems, recognition must be given to uncertainties involved in deriving demand and supply paths of a region or country. These uncertainties are prevalent in such parameters as factor inputs, technological change, discount rates, and above all, the inclusion of multiple demand and generation regions as in this study. In such cases the direct inclusion of demand functions in supply models (as opposed to their exogeneous determination) should provide a better basis for making decisions in this crucial sector of any economy.

## Mathematical Model for Scheduling Investment in Electrical Power Systems

As previously discussed, electric power systems form a complex of installations with many intricate technologies and economic relationships. The continued development of new power sources to meet ever-increasing demand, interaction with past and future developments, and the interaction with the economy as a whole are complex and intricate. The solution to this problem was addressed in this research and was determined by mathematical programming coupled with computer analyses.

The following formulation is partially based on the work of Turvey and Anderson (1977), who couched the problem in cost minimization form using linear programming. Linear programming was defined by Skrapek, Korkie and Daniel (1976, p. 227) as a

> technique that deals with the problem of optimizing a linear function of a finite number of variables subject to constraints that are linear inequalities. Linear programming problems often involve allocating scarce resources among activities that vary in profitability and in the amount of each resource needed to produce one unit of the activity. The constraint inequalities represent the restriction that the total amount of each resource used must not exceed the limited supply.

The great variety of problems to which linear programming can be applied is indeed remarkable. It is used in curve-fitting problems for such different objectives as minimizing the sum of squares, minimizing the maximum deviation, or minimizing the sum of absolute deviations. In the field of business it is applied to shipping problems, allocation problems, production scheduling, game problems, etc. In the operation of thermal systems, it is used in the allocation of high-pressure steam to various end uses such as bleeding steam from a turbine at various pressures and the simultaneous generation of power--a process known as cogeneration.

For this study, therefore, the planning objective of the model is to minimize the present worth of all investments and production costs associated with power generation in the time horizon under consideration.

Definitions of the following subscripts and decision variables are:

d = regions of demand; d = 1, ... D.

g = regions of generation; g = 1, ... G

D and G may or may not be equal.

h = hydro-electric-type of plant, denoting a hydro site in the region of generation; h = 1, ... H

j = type of thermal plant; j = 1, ... J

i = type of fuel (coal, gas, oil, etc.) i = 1, ... I

t = investment period; t = 1, ... T where T is the planning horizon

$\Delta t$ = time interval between investment periods (= 1 year in this study)

v = vintage of j or h types of plant, comprising the initial plant composition of the system between v = -V to 0 and the plant that will be installed between v = 0 and t.

N(ijgvt) = the quantity of fuel i burned in the thermal plant j, in generation region g, of of vintage, v, and in time period t (Btu).

X = initial installed capacity (or size) of a new plant (kW)

$\bar{X}$ = Capacity expansion (kW) of a hydro plant.

U = the operating capacity of a plant (kW)

M = transmission capacity (kW)

The following are the input parameters used in the model:

C = the discounted capital investment costs per unit of capacity (size) of a plant ($/kW)

P = the discounted production costs (excluding fuel costs) per unit of power output ($/kW)

Y = the discounted fuel cost per unit of energy burned ($/Btu)

e = conversion factor of natural resource (fuel) into electrical energy

L = the discounted cost of transmission lines per unit of power capacity, per unit distance ($/kW/km)

s = distance between two regions (km)

B = budget allocation to the electrical production sector in the economy.

Q = the demand for electricity

a = power plant load factor

R = primary fossil energy resource from internal or external sources (Btu)

Then the objective function is the sum of the following terms:

1. Discounted capital investment in new plants.

$$\sum_{g=1}^{G}\sum_{v=1}^{T}\sum_{j=1}^{J} C(jvg)X(jvg) + \sum_{g=1}^{G}\sum_{v=1}^{T}\sum_{h=1}^{H} [C_r(hvg)X(hvg)\delta(hvg) + C_e(hvt)\bar{X}(hvg)]$$

(thermal plants) (hydro plants)

where investments in hydro plants are represented by two terms:

a. That cost due to the capital cost of building reservoirs, dams, waterways, and other infrastructure such as roads and bridges. This cost is purely a function of the maximum power capacity that the site can offer. It is expended only once. Because this is a first cost, it is multiplied by the delta kronecker operator $\delta(hvg)$ having the following meaning:

$$\delta(hvg) = \begin{cases} 0 \text{ if hydro site h is not selected} \\ 1 \text{ if hydro site h is selected} \end{cases}$$

b. That cost due to the expansion of existing capacity, mainly in the purchase of new equipment such as generators and turbines.

2. Discounted production cost of plants. This is made up of expenditure on the upkeep of plants and the wages paid to operating and maintenance personnel:

$$\sum_{t=1}^{T} \sum_{v=-V}^{t} \sum_{g=1}^{G} \sum_{d=1}^{D} \left[ \sum_{j=1}^{J} P(jdgvt)U(jdgvt) + \sum_{h=1}^{H} P(hdgvt)U(hdgvt) \right]$$

3. Discounted fuel costs.

$$\sum_{t=1}^{T} \sum_{v=-V}^{t} Y(ijgvt)N(ijgvt) + \sum_{t=1}^{T} \sum_{v=-V}^{t} \sum_{i=1}^{I} Y(ijgvt)N(ijgvt)$$

$$+ \sum_{t=1}^{T} \sum_{v=-V}^{t} Y(ijgvt)N(ijgvt)$$

In this formulation, the first term represents the fuel cost associated with the operation of gas turbines (j=1), which consume gas (i=1) as fuel only. The second term represents the fuel cost associated with steam turbine plants, which are assumed to consume any of the three types of fuel.

The last term represents cost for internal combustion oil-fired plants only (j=3, i=3).

4. Discounted transmission cost. Where transmission lines between two regions do not exist and also when existing transmission lines are incapable of transmitting an incremental power increase, the feasibility of erecting new transmission lines is taken into account. The discounted cost is thus:

$$\sum_{g=1}^{G} \sum_{d=1}^{D} \sum_{t=1}^{T} L(gdt)M(gdt)s(gd)$$

The search for optimum new capacities X(jvg), $\overline{X}$(hvg), X(hvg) and for optimum operating schedules U(jdgvt), U(hdgvt), N(ijgvt) are subject to a number of important conditions called constraints. These are:

1. Demand constraints. Sufficient plants must operate during each planning period to meet the total energy demanded. This is modelled as

$$\sum_{v=-V}^{t} \sum_{g=1}^{G} \sum_{d=1}^{D} \left[ \sum_{j=1}^{J} U(jdgvt) + \sum_{h=1}^{H} U(hdgvt) \right] \Delta t \geq \sum_{d=1}^{D} Qdt$$

for t = 1, ... T.

2. Plant availability constraint. This expresses the fact that no plant can be operated above its peak

available capacity, i.e., the actual capacity less that fraction shut down for maintenance or repairs. Other factors such as alternative uses of resource (hydro systems, for example) will reduce the maximum operable capacity of the plant.

a. For thermal plants, this constraint is:

$$\sum_{d=1}^{D} U(jdgvt) \leq a(jgvt)X(jvg)$$

for $j = 1, \ldots J$

$t = 1, \ldots T$

and $v = -V, \ldots t$

$g = 1, \ldots G$

b. For hydro plants, the constraint is

$$\sum_{d=1}^{D} U(hdgvt) \leq a(hgvt)\overline{X}(hvg)$$

for $h = 1, \ldots H$

$t = 1, \ldots T$

$v = -V, \ldots t$

and $g = 1, \ldots G$

3. <u>Resource availability constraints for thermal plants</u>. This constraint applies to the availability of fuels and expresses the limitations on internal production capabilities for such fuels or availability from external sources

$$\sum_{v=-V}^{t} \sum_{j=1}^{J} N(ijgvt) \leq R(igt)$$

$g = 1, \ldots G$

$i = 1, \ldots I$

and $t = 1, \ldots T$

where R(igt) denotes the upper limit on natural resources i available during the planning period t, in generation region g.

4. Resource availability constraints for hydro plants. This expresses the fact that addition of capacity to an existing hydro site cannot exceed the initial maximum capacity determined by feasibility studies. This is modelled as

$$\sum_{v=1}^{T} \overline{X}(hvg) \leq \sum_{v=1}^{T} X(hvg)\delta(hvg)$$

for $h = 1, \ldots H$

$g = 1, \ldots G$

5. Technological constraints. This constraint applies to thermal plants and expresses the fact that a hundred-percent conversion of thermal to electrical energy is impossible. Thus, for each thermal plant,

$$N(ijgvt) \cdot e \leq \sum_{d=1}^{D} U(jdgvt) \cdot \Delta t$$

for $i = 1, \ldots I$

$j = 1, \ldots J$

$g = 1, \ldots G$

$v = -V, \ldots t$

and $t = 1, \ldots T$

6. <u>Budget constraint</u>. This constraint expresses the limitation on capital availability for new plants, either from internal or external sources, in any particular planning period. This is modelled as:

$$\sum_{j=1}^{J} C(jvg)X(jvg) + \sum_{h=1}^{H} [C_e(hvg)\overline{X}(hvg)$$

$$+ C_r(hvg)X(hvg)\delta(hvg)] \leq B(v)$$

for $g = 1, \ldots G$

and $v = 1, \ldots T$

where B(v) is the budget allocation for capital investments in plants of vintage v.

7. <u>Derivation of incremental transmission required</u>. Because transmission line capacity is a function of the power carried, an expression for the power

exchange between two regions in any planning is expressed as

$$M(gdt) = \sum_{v=-V}^{t} \sum_{j=1}^{J} [U(jdgvt)-U\{jdgv(t-1)\}]$$

$$+ \sum_{v=-V}^{t} \sum_{h=1}^{H} [U(hdgvt)-U\{hdgv(t-1)\}]$$

for $t = 1, \ldots T$

8. Other constraints. These are conditions imposed on the problem as a result of the nature of the variables used in the model. These are:

a. Constraints on integer variables.

$$\sum_{v=1}^{T} \delta(hvg) \leq 1$$

for $h = 1, \ldots H$

$g = 1, \ldots G$

b. Non-negativity constraints on all variables

$U(jdgvt) \geq 0$

$U(hdgvt) \geq 0$

$\overline{X}(hvg) \geq 0$

$X(jvg) \geq 0$

$\delta(hvg) \geq 0$

$M(gdt) \geq 0$

$N(ijgvt) \geq 0$

Mathematical Description of Planning Model

The planning model formulated above can be written using matrix and vector notations. For brevity, assume a static formulation, more than one hydro site, and one demand and generation region.

Z = a diagonal matrix whose elements represent the maximum feasible power capacities of the hydro sites

z = a vector containing the installed capacity decision variables of the hydro sites

y = a vector of installed plant capacity decision variables, both thermal and hydro. The vector z is contained in y

f = a vector of constraint requirements for budget constraints only. Because we are considering a static (one time period) formulation, f therefore contains only one element

x = a vector of all decision variables excluding the integer variables

c = a vector of cost coefficients associated with the vector x c' = transpose of c

$\delta$ = a vector containing the 0-1 integer variables

d = a vector of cost coefficients associated with the vector y.

d' = the transpose of d

b = a vector of constraint requirements on all other constraints

A = a matrix of input-output coefficients for all other constraints

q = a vector containing the cost coefficients associated with the elements of the matrix Z

q' = the transpose of q.

As an example, let there be H hydro sites in the region and J thermal plant possibilities (such as gas turbine technology, nuclear, coal-fired, or oil-fired internal combustion), and let there be K other constraints in addition to the budget constraint, then the matrices have the following elements:

$$Z = \begin{bmatrix} X_1 & & & \\ & X_2 & & \\ & & \ddots & \\ & & & X_H \end{bmatrix}$$

$$z' = [z_1, z_2, \ldots z_H]$$

$$y' = [z_1, z_2, \ldots z_H, y_{H+1}, y_{H+2} \ldots y_M]$$

$$\equiv [y_1, y_2, \ldots y_H, y_{H+1}, \ldots y_M]$$

where

$$M = H + J$$

and

$$z_\ell = y_\ell \text{ for } \ell = 1, 2, \ldots, H$$

$$x' = [y_1, y_2, \ldots, y_{H+1}, \ldots y_M, \ldots$$

.... all other non-integer decision variables] $N > M$

$$\equiv [x_1, x_2, \ldots, x_N]$$

so that

$$c' = [c_1, c_2, \ldots, c_N]$$

$$d' = [d_1, d_2, \ldots, d_M]$$

$$q' = [q_1, q_2, \ldots, q_H]$$

$$\delta = [\delta_1, \delta_2, \ldots, \delta_H]$$

$$A = \begin{bmatrix} a_{11} & \cdots & a_{1N} \\ \vdots & & \vdots \\ a_{K1} & \cdots & a_{KN} \end{bmatrix}$$

$$b' = [b_1, b_2, \ldots, b_K]$$

Then the planning problem is to

minimize $\qquad q'Z\delta + c'x$

subject to

$z \leq Z\delta$ (hydro resource availability)

$q'Z\delta + d'y \leq f$ (budget constraint)

$A x \leq b$ (all other constraints)

$\delta = 0$ or $1$ (integer constraints)

$x \geq 0$ (non-negativity constraints)

where the objective function is written as the sum of a fixed charge or "set-up cost" for the hydro sources and a term containing the variable cost contributions. The first constraint is the equivalent of the "hydro resource availability" modelled earlier and the second represents the budget constraint in the static (one planning period) formulation.

In this compact form, integer 0-1 variables occur in both the objective function and some of the constraint conditions. These arise from the recognition of fixed first capital outlay considerations in the construction of hydro plants. Integer variables other than 0-1 multipliers would have enetered the problem if the indivisibility of plant capacities were taken into account. By these we mean plant components (such as turbines) being available in only certain discrete sizes.

The question of whether the problem is linear or non-linear depends on how the cost coefficients are handled. If these coefficients are considered constant then the resulting mathematical formulation falls under the general problem area of linear mixed integer programming (LMIP) in which the integer variables can take only the values 0 or 1. The cost coefficients on the set-up cost term are realized on redefining the product q'Z in the objective function. Let

$$w' = q'Z$$

then w (the transpose of w') is a vector of cost coefficients for the integer variables $\delta$.

Non-linearities, however, can occur in various terms. First, the recognition of economies of scale associated with plant capacities will cause the objective function and the budget constraints to be non-linear unless the economy of scale relationship happens to be an inverse one with plant size. The existence of economy of scale in plant sizes and in particular electric power plant systems has been the subject of much research. Huettner (1974) has developed some specific relationships for steam-generating plants using cost function formulation and regression analysis on data for a number of operating plants. Secondly, non-linearities can also be introduced if the random nature of some or all of the coefficients and constraint requirements is taken into account. The mathematical model that results falls under the general area of stochastic programming.

## Number of Variables and Constraints in Programming Model

The degree of difficulty in solving any mathematical programming problem is proportional to the number of variables and constraints contained in the model formulation. Consider the multi-demand-generation region model formulated earlier and define the following:

$H_n$ (n=1, ... G) = the number of hydro sites in the region n

P = the number of thermal plant-fuel combinations

T = the planning horizon (say 10 years)

I = total number of fuel types

then Tables 24 and 25 can be constructed giving in general the number of variables and constraints in the model. One simplification introduced in order to derive this table is

Table 24. Number of variables in planning model by type

| | Types of Variable | Number of Variables (general formulation) | Number of Variables Under Assumed Parameter Values |
|---|---|---|---|
| 1. | U(jdgvt) | $J \times D \times G \times \sum_{k=2}^{T+1}$ | 9,555 |
| 2. | U(hdgvt) | $D \times \sum_{k=2}^{T+1} \times \sum_{n=1}^{G} H_n$ | 7,280 |
| 3. | X(jvg) | $G \times J \times T$ | 210 |
| 4. | $\overline{X}$(hvg) | $T \times \sum_{n=1}^{G} H_n$ | 160 |
| 5. | $\delta$(hvg) | $T \times \sum_{n=1}^{G} H_n$ | 160 |
| 6. | M(gdt) | $G(G-1)T$ | 420 |
| 7. | N(ijgvt) | $G \times P \times \sum_{k=2}^{T+1}$ | 2,275 |
| | | Total | 20,060 |

Table 25. Number of constraints in planning model by type

| Type of Constraint | Number of Constraints (general formulation) | Number of Constraints Under Assumed Parameter Values |
|---|---|---|
| 1. Demand Constraint | $T$ | 10 |
| 2. Plant Availability Constraint | | |
| a. Thermal | $J \times G \times \sum_{k=2}^{T+1} k$ | 1,365 |
| b. Hydro | $\sum_{h=1}^{G} H_n \times \sum_{k=2}^{T+1} k$ | 1,040 |
| 3. Resource Availability --thermal | $G \times I \times T$ | 210 |
| 4. Resource Availability --hydro | $G \times \sum_{n=1}^{G} H_n$ | 112 |
| 5. Technological Constraints | $G \times J \times \sum_{k=2}^{T+1}$ | 1,365 |
| 6. Budget Constraint | $T$ | 10 |
| 7. Incremental Transmission | $G(G-1)T$ | 420 |
| 8. Other Constraints | $\sum_{n=1}^{G} H_n$ | 16 |
| | Total | 4,548 |

the assumption that all plants available in the electrical power system before planning time period 1 are given the vintage 0, thus in the model formulation

$$-V = 0$$

The tables also show the computation of the total number of variables and constraints in a realistic case that assumes the following:

$G = D = 7$

$H_1 = 2$

$H_2 = 3$

$H_3 = 3$

$H_4 = 1$

$H_5 = 2$

$H_6 = 3$

$H_7 = 2$

$P = 5$

$I = 3$

$T = 10$

$J = 3$

Under these conditions, there are 20,060 variables of which 160 are integer (0-1) variables, and a total of 4,548 constraints.

# CHAPTER 6

## APPLICATION OF THE PLANNING MODEL TO WEST AFRICAN COUNTRIES

The planning model formulated in the preceding chapter encompasses the entire electrical energy system, including all resources, generation capacities, and demand requirements. The model can easily be disaggregated and can be an effective decision tool on a local, regional, country, or multi-country level.

Mathematically, depending on the degree of accuracy required or motive of the analyst, it can be made to accept linear or non-linear parameters and integer or non-integer decision variables and to recognize the stochastic nature of some or all of the cost and input-output coefficients and the constraint requirements.

Whatever is decided on, the mathematical model can be used effectively as a decision tool in a number of areas and situations, for example:

1. To determine the least-cost mix of capacity between hydro and fossil plants to be added to the system. The plant mix decision is made by finding an economic balance between investment and operating costs. Size of plants added to the system, the location of these plants, destinations of

electrical energy, and investment costs, and above all, the timing of these additions (vintage) and expenditures are useful decision policy outputs from this exercise.

2. To determine the least-cost mix of fossil fuel between coal, oil, and natural gas for any given planning period. This exercise will yield outputs such as required quantity of fuel, flow of energy between countries, and most importantly, the cost of such transactions to an individual country's economy.
3. To determine the least-cost mix of power output between plants for any planning period. The utilization of the model at this level will enable production costs (operating, maintainance, distribution), level of operation (power output), and cost per unit of output of individual plants to be structured to yield the so-called load duration curve of the entire electrical energy system.
4. To determine the storage capacity and operating policy with respect to demand for power, irrigation water, flood control, and navigational demands in water resource systems. As mentioned earlier, striving for a balance between agricultural and industrial production is one of the problems faced by developing countries.

5. To study the impact and optimal allocation of resources in the situation of capital investment shortage.
6. To assess the economic impact of future energy shortage through the integration of the demand and supply models.
7. To predict the impact of higher fuel prices on consumption by determining the cost of production of unit output in conjunction with appropriate rate of return on investment.

In the age of the availablity of high-speed computers, the large number of decision variables and constraints on the model is not a limiting factor. What is limiting, however, is the availability of large, efficient computer programs to handle all the mathematical variations that might result in the realistic treatment of the parameters of the planning model.

In what follows, a simplified version of the general planning model is derived, a discussion on the input data required for this version is provided, and various feasible paths (called scenarios) of electrical energy supply strategies for the West African countries under consideration are proposed for computer analyses.

## A Simplified Version of the General Planning Model

Because of the unavailability of adequate information especially on the cost data in the planning problem, and efficient mixed integer computer codes and of the limitation of the available computer system to handle large numbers of variables of the planning model, it is proposed to synthesize a one-region, deterministic, non-integer version of the planning model for the individual West African countries and a combination resulting from joint development effort expectations.

In this case the general model is reduced to the following problem:

$$\sum_{v=1}^{T} \sum_{j=1}^{J} C(jv)X(jv) + \sum_{v=1}^{T} \sum_{h=1}^{H} C(hv)X(hv)$$

(Discounted Capital Investment Costs)

$$+ \sum_{t=1}^{T} \sum_{v=-V}^{t} \sum_{j=1}^{J} P(jvt)U(jvt)$$

$$+ \sum_{t=1}^{T} \sum_{v=-V}^{t} \sum_{h=1}^{H} P(hvt)U(hvt)$$

(Discounted Production Costs)

$$+ \sum_{t=1}^{T} \sum_{v=-V}^{t} Y(ijvt)N(ijvt)$$

(Discounted Fuel Costs, i=1, j=1 only)

$$+ \sum_{t=1}^{T} \sum_{v=-V}^{t} \sum_{i=1}^{I} Y(ijvt)N(ijvt)$$

(Discounted Fuel Costs, j=2 only)

$$+ \sum_{t=1}^{T} \sum_{v=-V}^{t} Y(ijvt)N(ijvt)$$

(Discounted Fuel Costs, i=3, j=3 only)

The above objective function is subject to the following reduced constraints:

1. Demand constraint

$$\sum_{v=-V}^{t} \sum_{j=1}^{J} U(jvt)\Delta t + \sum_{v=-V}^{t} \sum_{h=1}^{H} U(hvt)\Delta t \geq Q_t$$

for t=1, ... T

2. Plant availability constraint

   a. For each thermal plant,

$$\sum_{v=-V}^{t} U(hvt) \leq \sum_{v=-V}^{t} a(jvt)X(jv)$$

for h=1, ... H;   t = 1, ... T

b. For each hydro plant,

$$\sum_{v=-V}^{t} U(hvt) \leq \sum_{v=-V}^{t} a(hvt)X(hv)$$

for h=1, ... H

t=1, ... T

3. Resource availability constraint

$$\sum_{v=-V}^{t} \sum_{j=1}^{J} N(ijvt) \leq R(it)$$

for i=1, ... I

t=1, ... T

4. Technological constraint--apply to thermal plants only

$$\sum_{i=1}^{I} N(ijvt)\ e \geq U(jvt)\Delta t$$

for j=1, ... J

v=-V, ... t

5. Budget constraint--the constraint of the availability of capital for new plants

$$\sum_{j=1}^{J} C(jv)X(jv) + \sum_{h=1}^{H} C(hv)X(hv) \leq B(v)$$

for v=1 ... T

6. Hydro resource availability

$$\sum_{v=1}^{T} X(hv) \leq XMAX(h)$$

for h=1, ... H

where XMAX(h) is the hydro power capacity available at hydro site h for future development.

7. Non-negativity constraint on all decision variables

$$U(jvt) \geq 0$$
$$U(hvt) \geq 0$$
$$X(hv) \geq 0$$
$$X(jv) \geq 0$$
$$N(ijvt) \geq 0$$

This simplification in the general planning model reduces the problem to a more manageable one for computer analysis. By using the number of constraints and variables tables developed earlier and assuming the following

$I = 3$     $H = 3$

$J = 3$     $P = 5$

$T = 10$

the resulting one-region, non integer, deterministic linear programming model has 775 decision variables and 638 constraints.

Adaptation of Planning Model for Computer Analysis

Before discussing the requirements, sources and transformation of data required, a brief summary integrating what has been do so far and its incorporation into a computer package is necessary. First, the models formulated assume the availability of a large linear programming computer code that can accept and solve large numbers of variables and constraints problems as obtained here. To this end the XMP programming code developed by Roy Marsten of The University of Arizona has been employed for this purpose. This code employs one-dimensional arrays that contain all the parameters of the problem under consideration. However, the model formulation is in terms of multi-dimensional decision variables and parameters. To ease the difficulty in interpreting XMP outputs, a general code CONVRT developed in connection with this research produces a one-to-one correspondence between the XMP decision variables and the multi-dimensional variables of the planning model.

Secondly, XMP requires that the objective function coefficients, the input-output coefficients of the constraint matrix and the constraint requirements be submitted column by column. To make the resulting planning program flexible for sensitivity studies, a general code (LPCOMB) has been developed to generate internally all the coefficients involved in the program at any time.

Finally, Figure 4 describes pictorially the integration of the various elements of this research, the inputs required, and the outputs that result from using this package.

## Data Requirements of the Model

In order to provide an appraisal or critique of the input or internal generation of data required for the supply model, the required data are summarized.

1. Demand for electricity during each planning period over the planning horizon.
2. Resource availability. This includes the primary energy resources available internally or externally, and the costs ($/Btu) associated with producing and delivering these energy sources to secondary conversion systems--electric power plants.
3. Present generation capacities by technologies available in country or region.
4. Feasible technologies available for implementation during the planning horizon. Costs ($/kW) of installing and operating are required as input to the supply model.
5. Power plant load factors.
6. Budget data. This is the amount of capital allocated to the electricity production sector in each planning period for the installation of new plants.

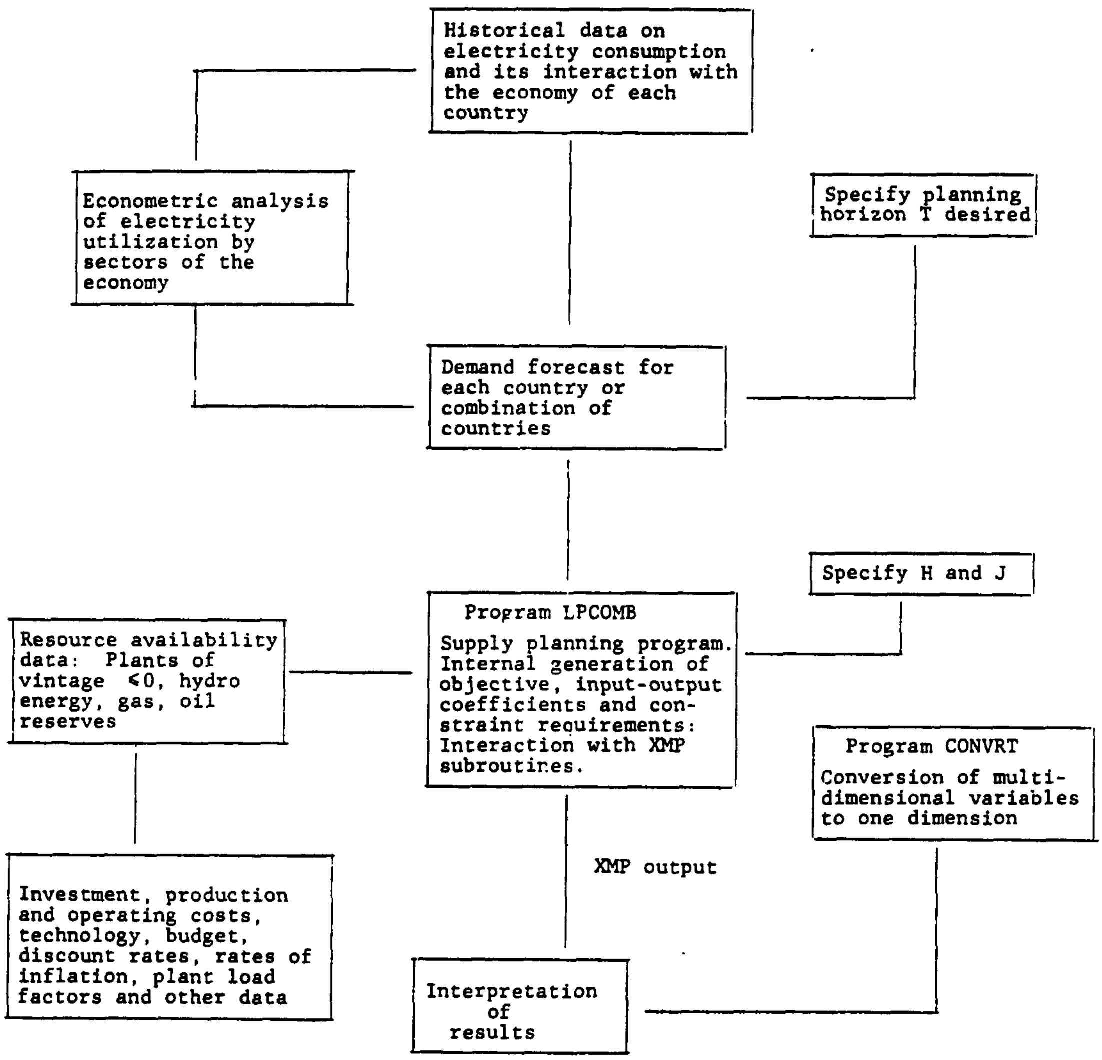


Figure 4. Method of energy system planning

The demand for electricity has already been covered in an earlier chapter and no discussion on its derivation is provided here except to say that it is the critical factor that drives the supply model to optimality. For the West African countries, the demand for electricity has been considered as indirectly determined. By this it is meant that the demand for electricity is determined once the variations in the endogeneous variables of the econometric models are established. The variations in the independent variables for this research are based on their past values and are assumed to change at the same rate (or hold the same functional form) into the future. One may run into a problem with this approach; e.g, if one assumes (based on the past rate of growth) that the price of unit electricity to consumers in planning period t equals $p_t$, then the cost of producing this unit of electricity would necessarily be less than $p_t$. But the cost is determined from the output of the supply model. If the cost happens to be greater than the selling price projected, then an iterative solution of the supply model is imperative. The rate of growth (or the empirical formula) for each of the independent variables are presented for each country in Appendix A.

However, demand relationships can be directly included in the supply model to avoid the iterative solution of the resulting supply program. If $C_t$ is the total cost of providing electricity in planning period t, then the cost of producing a unit output (i.e., \$/kWh) is

$$c_t = C_t/Q_t \tag{21}$$

where $Q_t$ is the total demand in the planning period. Thus the selling price $p_t$ should at least equal $c_t$, a break-even situation. Assume that the investment in the electricity system is to yield at least $r_t$ percent per year over the unit cost of production,

then

$$p_t \geq (1 + r_t)\ c_t \tag{22}$$

Substitute Eq. (21) into Eq. (22),

$$p_t \geq C_t/Q_t\ (1 + r_t)$$

or

$$p_t \cdot Q_t \geq C_t(1 + r_t) \tag{23}$$

The interpretation to the last relationship is that the total revenue from the sale of electricity in planning period t should at least equal the total cost of producing it plus a return on the investment. Thus the treatment of the selling price as a variable in the supply model introduces a "revenue greater than cost" constraint, which may be linear or non-linear depending on the functional form of the demand relationship, $Q_t$.

Primary energy resources and present installed plant capacities in the countries under consideration are well documented in Chapter 3 of this report. However, the future costs associated with procuring these resources are unknowns in this situation. The primary energy resources available in this study are natural gas, coal, and oil in the form of diesel fuel. The present (1980) value of these resources in the world market was the starting point for the determination of future values of these resources. For example, let $Y_0$ be the present 1980 value of oil (\$/Btu),[1] then the present worth of fuel oil for future planning period t is

$$Y_t = Y_0(1 + g_y)^t(1 + r_y)^{-t}$$

where

$g_y$ = the rate of increase or decrease in unit cost of fuel oil between planning periods

$r_y$ = the discount rate

[1]If the world price of oil is reported as Z dollars per barrel, and since one barrel of oil is equivalent to $5.8 \times 10^6$ Btu, then $Y_o$ (\$/Btu) = $Z \times (5.8 \times 10^6)^{-1}$.

As mentioned earlier, feasible technologies for implementation in these countries in the next 10 years are assumed to be hydro, steam turbine, gas turbine, and diesel-fired internal combustion generation plants. Nuclear and solar technologies are ruled out as not feasible on account of the infancy in their development even in the developed economies. Lack of qualified personnel to implement and operate nuclear plants is also a drawback for its utilization in West Africa. The main drawback in solar technology, in addition to its infancy, is its relatively higher cost compared to other readily available technologies.

The present worth of future costs of installing and operating the feasible technologies are handled in the same way as for primary energy resources. Present 1980 estimated costs of installation and operating plants were obtained from various sources such as the U.S. Federal Power Commission annual reports, feasibility studies of plant sites and annual reports of the power industries in Ghana and Nigeria, and economic survey reports for all the countries under study.

Available electrical energy from the plants are described by plant load factors (PLF). These are not fixed quantities but have upper limits of 1. Past experience from the operation of plants in the various countries under study, especially Ghana and Nigeria, has suggested probable values for PLF in future plant operations.

Future budget allocation to the power sector is estimated from development plans and annual financial account statements of the countries involved from various published sources.

The type of data involved in this study, their availability, and the sources of those available reveal the non-deterministic nature of any study on this subject. However, the development of a model from demand and supply interactions allows the realistic variations (or sensitivities) in the data and the subsequent effect on policy implications to be obtained without much further effort. Thus, the inputs of all policy makers connected with the power sector and the national economy of these countries are a must to effectively analyse the options available to each country or region.

## Primary Energy Development Alternatives

Various scenarios have been analysed for the countries of the region with the demand-supply model. The alternatives analysed are divided into two categories: individual country alternatives and joint development options.

Individual Country Alternatives

These are the options available to each country to implement for the supply of electrical energy. These options, which are subject to satisfying the total demand projections (Table 26) are described under each country heading. Total demand projections are the summation of sectorial projections listed in Appendix A.

Benin. Based on the resources available to Benin (both internal and from external sources) the following scenarios are deemed feasible.

Scenario 1 assumes that Benin continues to implement the present mode of supplying electricity to the economy. To rely on the 25 MW power from Ghana, and install new thermal plants if needed to satisfy extra demand.

Scenario 2 assumes the possibility of total dependence on thermal plants if Ghana decides to cut off its power to Benin.

Scenario 3 assumes the addition of 700-MW hydro power resource to scenario 2.

Scenario 4 assumes the possiblity of developing the 700-MW power resource in addition to the 25-MW import from Ghana and the utilization of thermal plants to supply the demand, if the demand warrants.

Table 26: Total Projected Demand for Electricity in all Seven Countries: 1980-1989. -- billion kWh

| Year | Niger | Nigeria | Togo | Upper Volta | Bemin | Ghana | Ivory Coast |
|---|---|---|---|---|---|---|---|
| 1980 | 0.1672 | 4.631 | 0.2585 | 0.0856 | 0.0832 | 8.24 | 2.178 |
| 1981 | 0.2030 | 4.958 | 0.2513 | 0.0979 | 0.0924 | 8.84 | 2.418 |
| 1982 | 0.2387 | 5.398 | 0.2399 | 0.1119 | 0.1027 | 9.38 | 2.740 |
| 1983 | 0.2702 | 5.683 | 0.2401 | 0.1279 | 0.1141 | 9.91 | 3.152 |
| 1984 | 0.3311 | 6.085 | 0.2527 | 0.1462 | 0.1267 | 10.45 | 3.670 |
| 1985 | 0.3994 | 6.516 | 0.2697 | 0.1672 | 0.1408 | 11.01 | 4.314 |
| 1986 | 0.4536 | 7.007 | 0.2834 | 0.1911 | 0.1564 | 11.61 | 5.115 |
| 1987 | 0.5159 | 7.507 | 0.2920 | 0.2185 | 0.1737 | 12.23 | 6.120 |
| 1988 | 0.5735 | 8.047 | 0.2984 | 0.2497 | 0.1930 | 12.89 | 7.394 |
| 1989 | 0.6297 | 8.628 | 0.3060 | 0.2855 | 0.2143 | 13.58 | 9.041 |

Ghana. The scenarios for Ghana are built around its existing and remaining hydro resource capacities. The first scenario assumes the utilization of 866-MW (916 MW total minus 50 MW allocated to Togo and Benin) existing plant during the planning period and the possibility of developing the new resources outlined in Chapter 3. The second scenario is not very different from the first except that the possibility of not renewing the contract to supplying Togo and Benin makes available the full existing capacity (916 MW) to Ghana's economy.

Ivory Coast. Ivory Coast currently depends on its 224-MW hydro power plant and diesel-fueled thermal plants to meet its electrical energy demands. Scenario 1 assumes that Ivory Coast continues this supply mode but installs new thermal plants if desired during the planning period.

Scenario 2 assumes that in addition to the existing hydro system and new thermal plant possibilities, the phased development of the 360-MW hydro resource available is undertaken.

Niger. Scenario 1 assumes Niger continues to import electricity from Nigeria during the planning horizon up to a maximum of 30 MW and the possibility of deveoping its two hydro sources if and when feasible.

Scenario 2 assumes that Niger relies on the 30 MW from Nigeria but due to budget constraints and the lack of enough demand relies on new thermal developments to meet its remaining demand.

Scenario 3 assumes that no power flows from Nigeria to Niger because of a higher growth rate of the Nigerian economy or the unavailability of enough head in the hydro dam at Kainji and thus Niger is totally reliant on thermal plants for meeting its demand.

Scenario 4 assumes the cut-off of Nigerian power and the reliance on the development of Niger's own hydro sources and thermal plant possibilities.

Nigeria. Scenario 1 assumes the export of 30 MW of power from the Kainji hydro dam to Niger and the availability of 730 MW to its own economy. In addition all the remaining hydro sources on the Niger and Benue Rivers are available for development when feasible.

Scenario 2 is the same as scenario 1 except that, due to the unavailability of energy from some other existing source(s), no export of electricity to Niger is allowed.

Scenario 3 places emphasis on the availability of energy sources other than hydro in the Nigerian power system. Thus, the possibility of the Nigerian authorities to decide on the installation of small thermal systems rather than large hydro plants is the theme of the scenario. Apart from the available installed capacity of 730 MW at

Kainji, new hydro resources to be developed total 700 MW (200 MW at Kainji and 500 MW at Jebba).

Togo. This region lacks primary energy resources, hence it is dependent on import of electricity from Ghana and the import of diesel fuel for its internal combustion engines. Two simple scenarios are considered:

1. The continued import of electricity from Ghana during the planning horizon, not to exceed 25 MW.
2. The reliance on thermal plants only for the supply of electrical energy during the planning horizon.

Upper Volta. As noted earlier, Upper Volta relies on thermal plants (diesel-fueled) to meet its electricity demand obligations.

Scenario 1 assumes that reliance on thermal plants only will be continued in the planning horizon.

Scenario 2 assumes the availability of 60 MW hydro power resource and seeks to find what investments are involved and when they should be made during the planning horizon.

## Joint Development Options

As stated earlier one of the objectives of this research was to apply the planning model to examine the economic gains to be made in pooling the resources of the countries involved in the joint development of primary energy resources into electrical energy. Given the level of cooperation that has hitherto existed between various countries of the region and above all the geographical locations of these countries, the following levels of cooperation are proposed for analysis with the planning model.

1. Nigeria-Niger cooperation: Due to (a) the proximity of the two countries, (b) the recognition of the present exchange of energy between these two countries, and (c) the availability of uranium deposits in Niger which Nigeria may want to use in the long run for the production of electricity, it is deemed feasible to examine the economic gains that these two countries would achieve in the planning horizon.
2. Togo-Benin cooperation: These two countries are also candidates for joint development projects in the electrical energy sector because:
   a. They share a common border.
   b. An electric grid already exists between their capital cities.
   c. They have already established a common company, the CEB, to buy and distribute electricity imported from Ghana.

d. Budget constraints for each economy and the unavailability of fossil fuels in these regions make this venture a feasible option.

3. Ghana-Ivory Coast-Upper Volta: This level of co-operation in addition to the close proximities of the countries involved has been in the making for a long time and continues to be in the planning stages of each country's development plans.

4. Ghana-Upper Volta: This co-operation is derived from option number 3 for only one reason: the Ivory Coast removes itself from the union of (3) and decides to pursue other options such as teaming up with Liberia, a close neighbor.

5. Ghana-Ivory Coast-Togo-Benin-Upper Volta: This option is a combination of options (2) and (3) for the reasons given in these options.

6. Nigeria-Niger-Togo-Benin: This option is feasible for two reasons: (a) Transmission capacity already exists between Nigeria and Niger, and between Benin and Togo, and a union of this type will require only a transmission capacity between Benin and Nigeria whose capital cities are not far from each other; and (b) Benin with a 700-MW hydro resource will need capital investments from a country like Nigeria to develop this renewable energy source.

7. Ghana-Ivory Coast: This option is derived from option (3) for one reason only: it may not be feasible to link Upper Volta with Ghana and Ivory Coast due to the low demand exhibited in the former which would make investments in transmission capacity expensive.

The above seven joint development options are analysed subject to the total demand for electricity expected from each country in the planning period.

## Scenario Results

In addition to adapting the general planning model to the West African countries, the previous sections also proposed various alternatives at the individual and joint-country levels for future electricity supply. In this section, the results of analysing these alternatives with the computer model are presented. Detailed composition of plants and the incremental contribution of each plant type to the total cost of producing electricity are presented in Appendix B.

Benin. Four scenarios were analysed for this country (Figure 5), ranging from total dependence on thermal plants to the phased development of its 700-MW hydro site. The present worth of total expenditures on the supply of electricity was determined to be

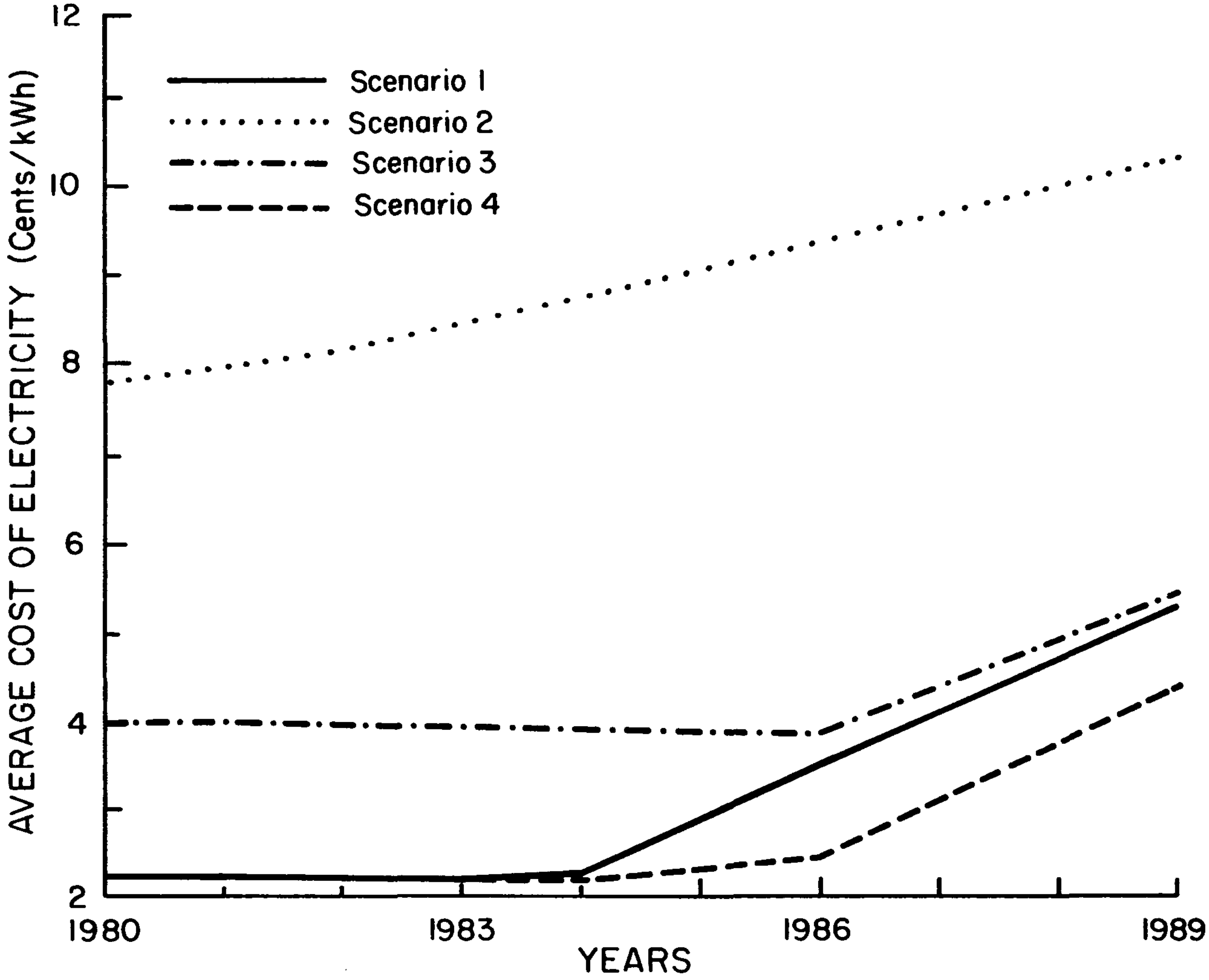


Figure 5. Scenario results for Benin

approximately $49 billion if scenario 1 is pursued with the development of no new capacities during the planning interval 1980-1989.

The optimal present worth of total costs projected by scenario 2 is $140 million. This is made up of continued operation of its existing thermal plants and the installation of new thermal plants.

Scenario 3 is the introduction of the 700-MW hydro resource into the second alternative. This yields an optimal cost outlay of $77 million. The electrical system would be composed of partial development of Benin's own hydro resource and the operation of the existing thermal plants in the later years of the planning horizon.

Finally, the fourth alternative, based on the availability of 25-MW power from Ghana and the partial development of Benin's own hydro resource and utilisation of thermal plants projects the minimum expenditure to be $46 million.

_Ghana_. The results of the analyses for Ghana tend to reflect the situation in the country's electricity supply sector today--the shortage of electrical power in the immediate future if supply is not obtained from outside sources. The results of the first scenario advocate the development of all hydro resources, the utilization of the existing facility to its full capacity less the contracted supply to neighboring countries and supplementation of the supply with new thermal developments at a present value of $5 billion. The second scenario predicts a 5 percent reduction in this cost should Ghana decide to cut off supply to other countries, yielding total expenditures of $4.76 billion. Detailed results of the two scenarios are presented in Figure 6.

Ivory Coast. Two scenarios have been analysed: one relies on the supply of electricity from the present hydro and thermal installations with installation of thermal plants only when demand exceeds present capacity provisions. This scenario is projected to cost $4.2 billion with thermal plant installations every year during the planning horizon. As to be expected, scenario 2 is more attractive than scenario 1, scenario 2 would cost $3.5 billion and would comprise both new thermal and hydro installations. Average costs of producing electricity by the two scenarios in each period of the planning horizon are shown in Figure 7.

Niger. Niger has three sources that could supply the electricity needs of the major sectors of the economy. These are the installation of new thermal plants, the development of its own hydro resources, and the importation

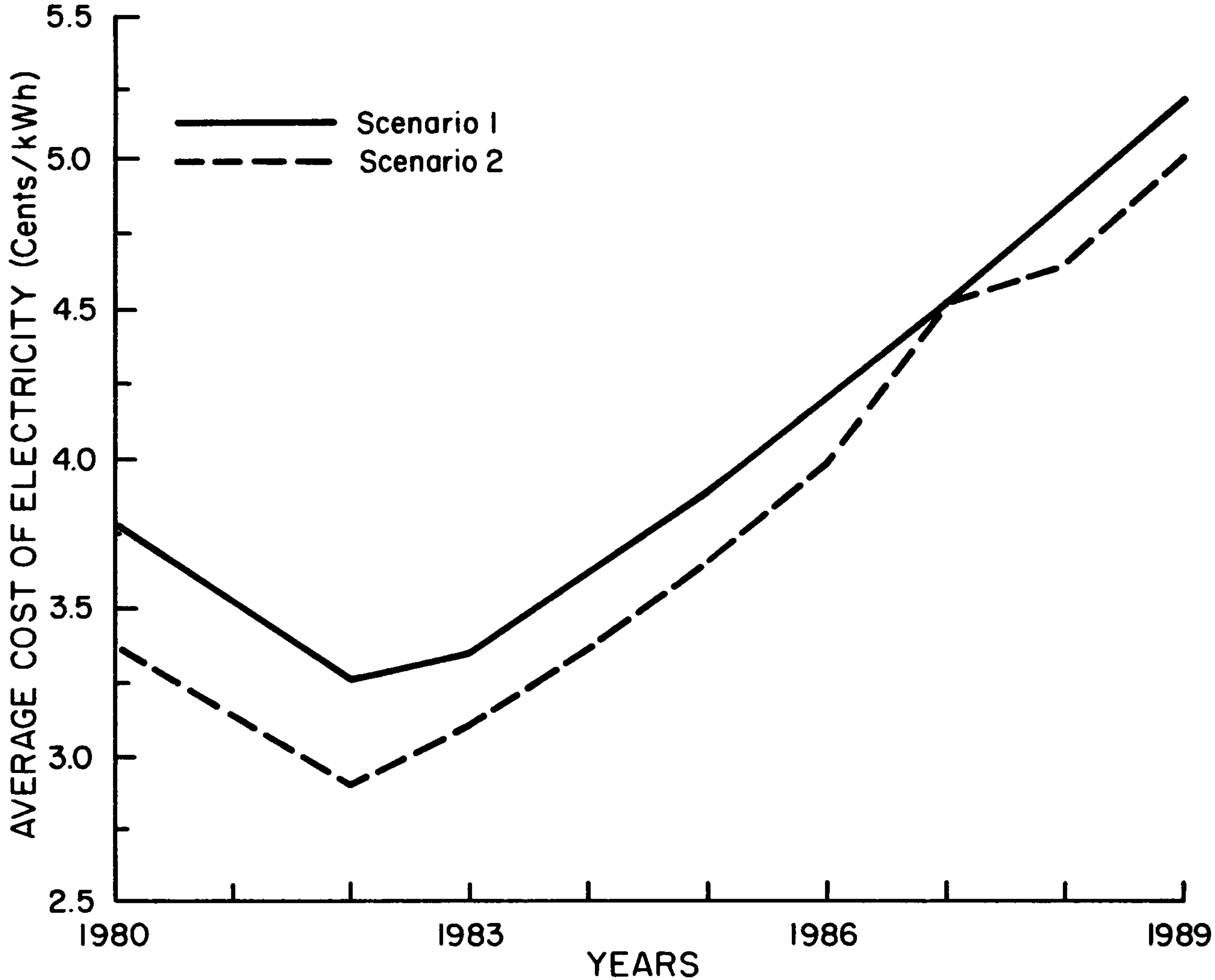


Figure 6. Scenario results for Ghana

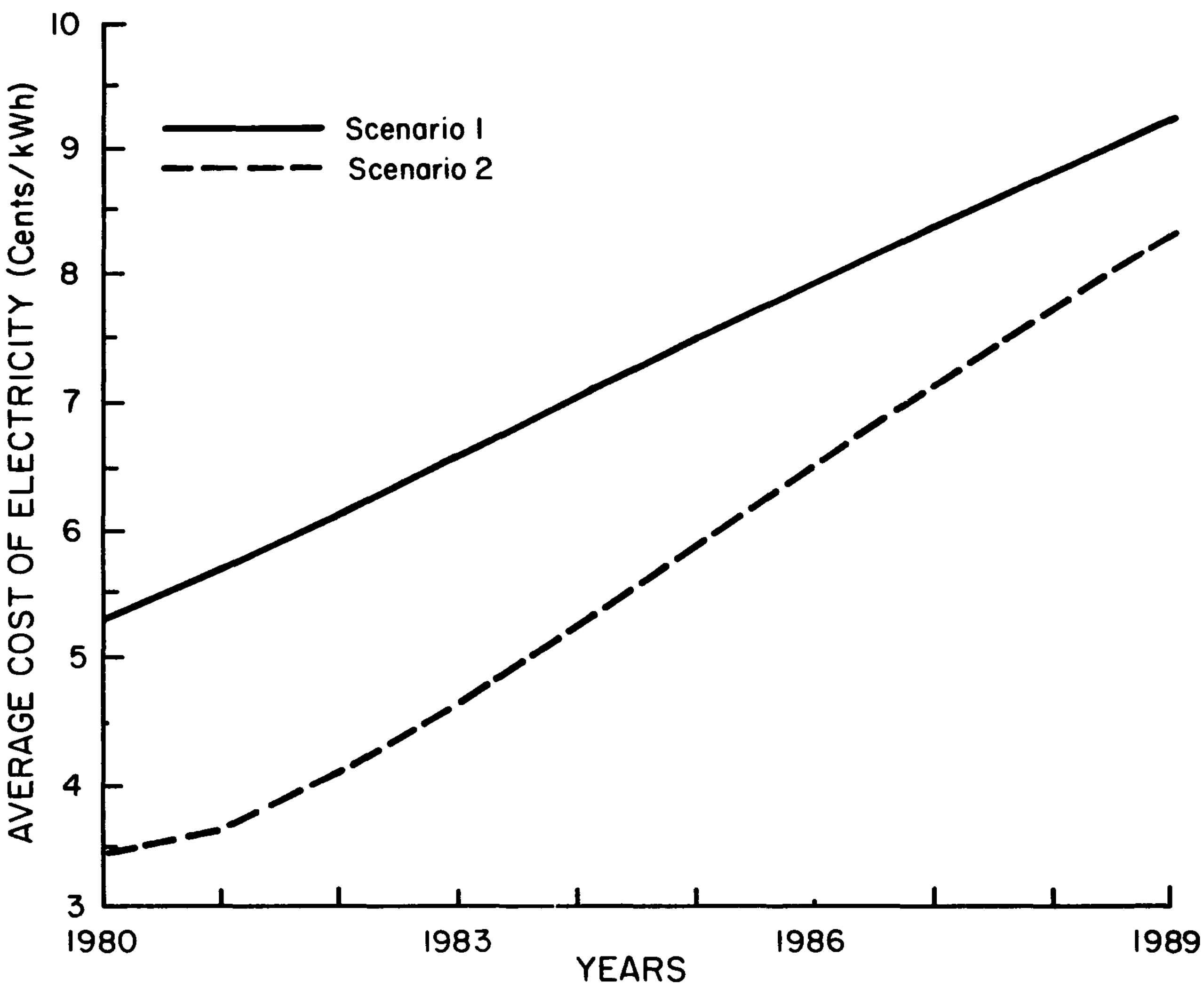


Figure 7. Scenario results for Ivory Coast

of electricity from neighbouring Nigeria, limited to a maximum of 30 MW.

Various levels of combination of these sources gave rise to the analyses of four scenarios and their results are presented in Figure 8. Total costs (in 1980 dollars) are projected as $118, $215, $370, and $161 billion, respectively.

Nigeria. The simulation results for this resource-rich country show little difference between alternatives. The cheapest alternative, however, is the second one with a total cost of $2.30 billion. This is followed closely by alternative 1 with a total cost of $2.32 billion. Alternative 3, which lays more emphasis on the installation of thermal energy systems costs $2.33 billion to implement. Average costs of producing electricity are presented in Figure 9.

Even though alternative 3 was biased towards thermal installations, the optimal capacity installations differ very little from the other two scenarios. No installation of new capacities is predicted, except that initial thermal plants are put on-line earlier in the planning period to provide energy that would have been produced from new hydro sources.

Togo. In the absence of any major oil discovery, Togo has two options for the supply of electricity during

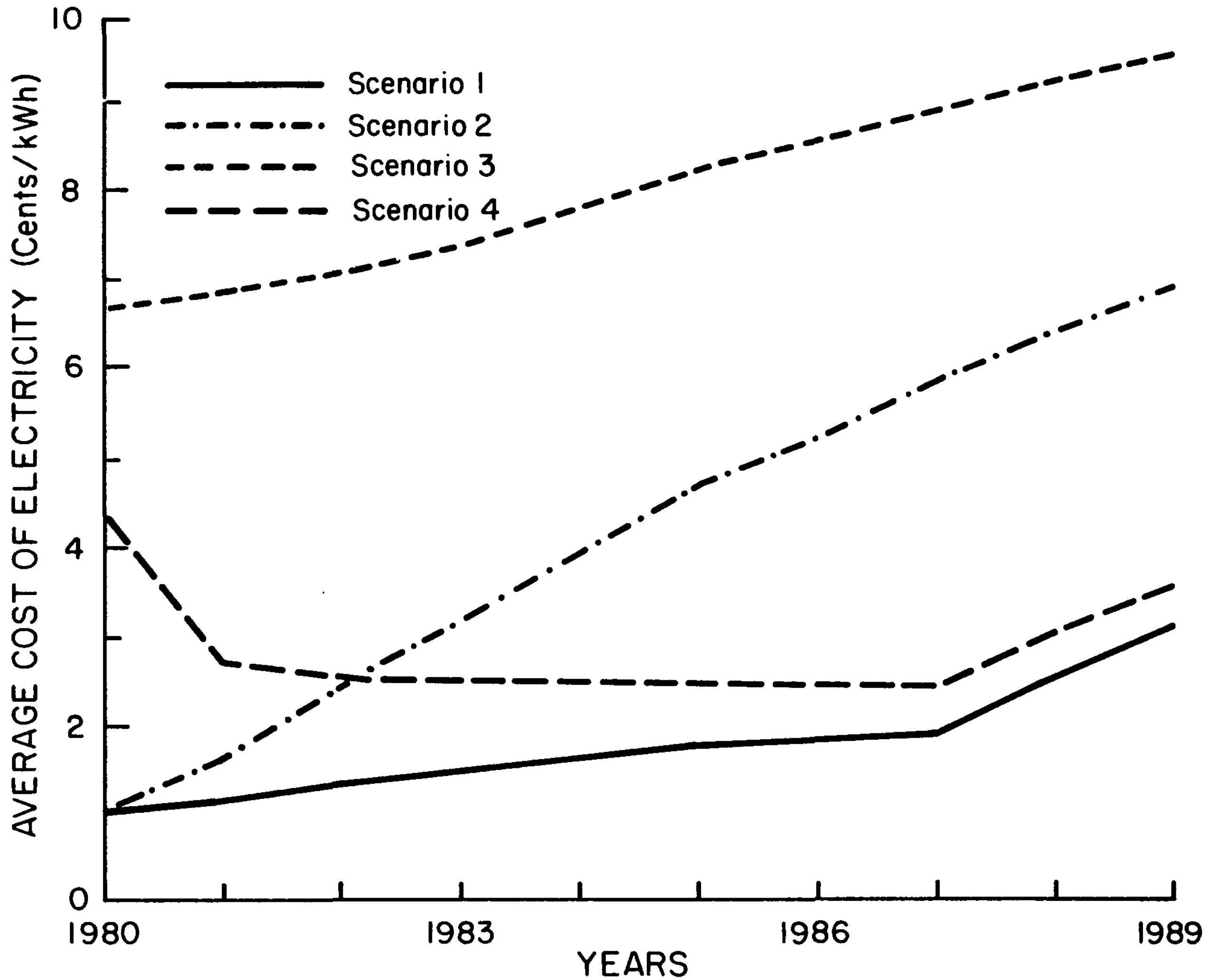


Figure 8. Scenario results for Niger

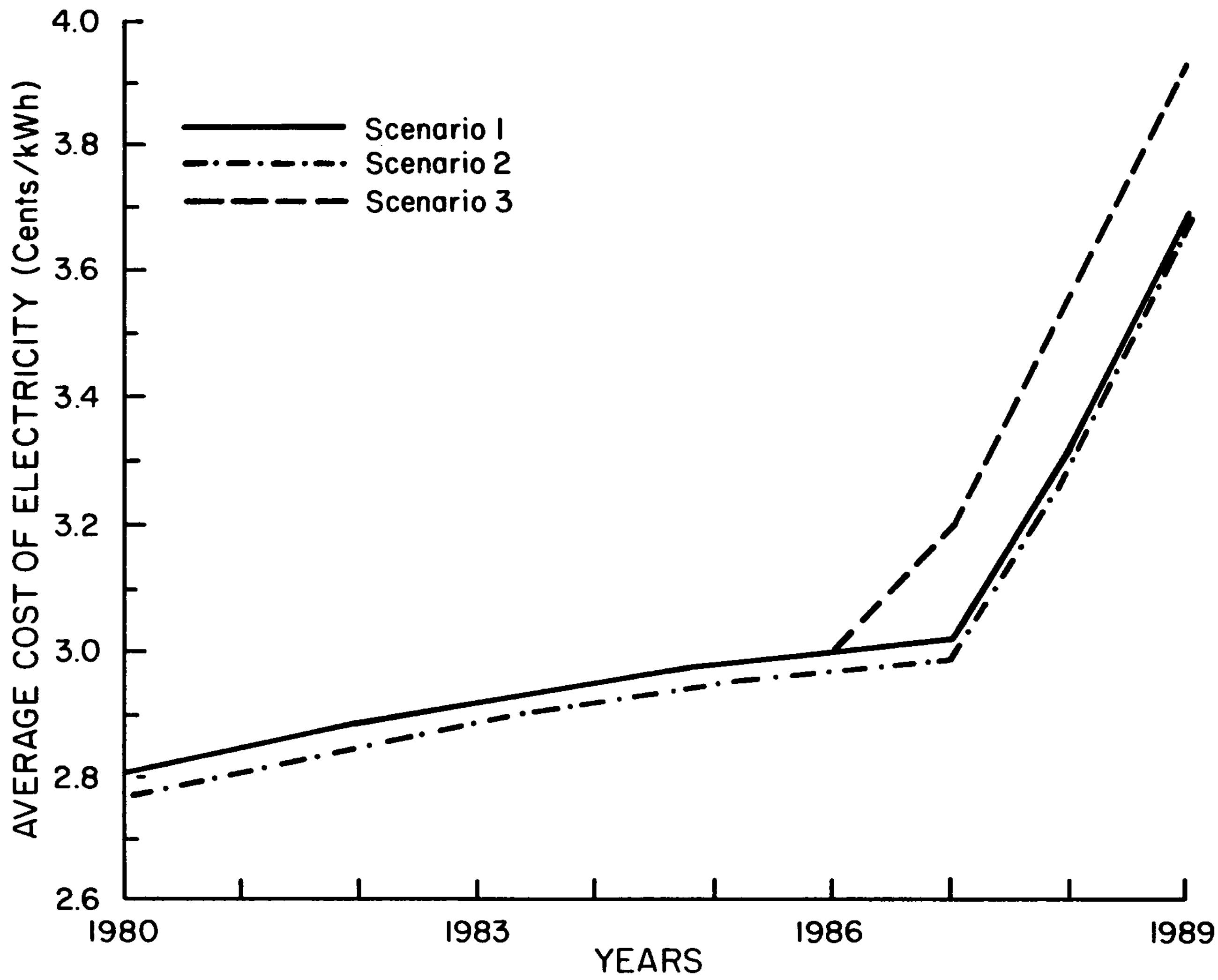


Figure 9. Scenario results for Nigeria

the planning periods: to continue to purchase electricity from Ghana at the full capacity (25 MW) or to depend on oil imports to produce its needs should Ghana decide to cut off its supply. The second option is more expensive and is predicted to be approximately $250 million. The first option will cost half that of the second, $127 million. The average cost implications of these scenarios in producing electricity are presented in Figure 10.

Upper Volta. Barring the development of its only hydro resource (scenario 2), the only feasible option for Upper Volta is the dependence on existing and new thermal plants for the supply of electiricity (scenario 1). Projected expenditures for scenario 2 total $128 million and for scenario 1 $163 million. The high cost of the thermal option is reflected in the cost of the electricity produced (Figure 11).

## Results for Joint Development Projects

Various levels of capacities for new installations have been obtained for the seven scenarios analysed under joint development possibilities. In all scenarios hydro development before thermal installations is suggested by the optimal plans (Tables 27 and 28). This is reflected in the lower cost of producing electricity by combinations of countries with abundant hydro resources (Table 29). The combinations more favoured are the eastern countries of the

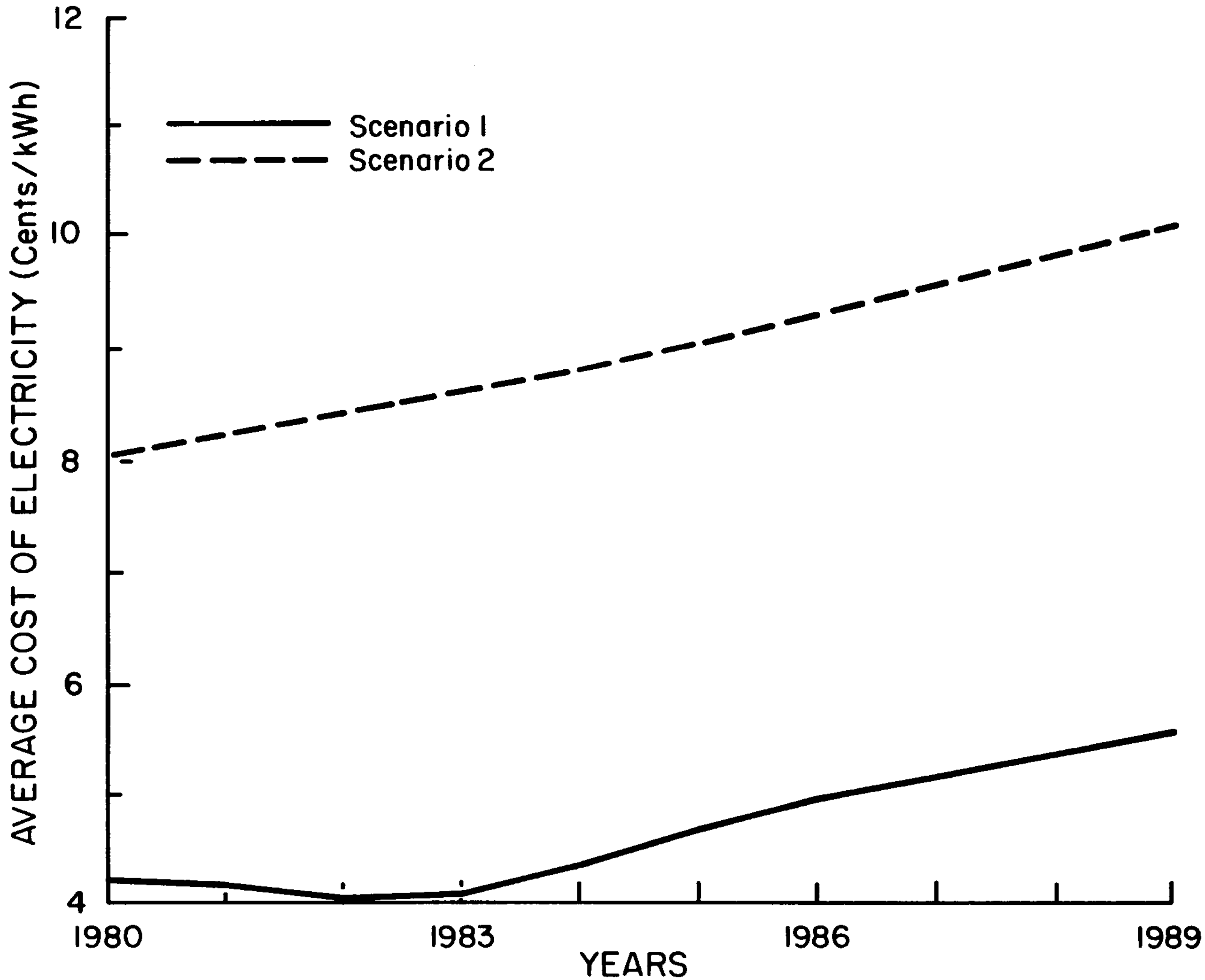


Figure 10. Scenario results for Togo

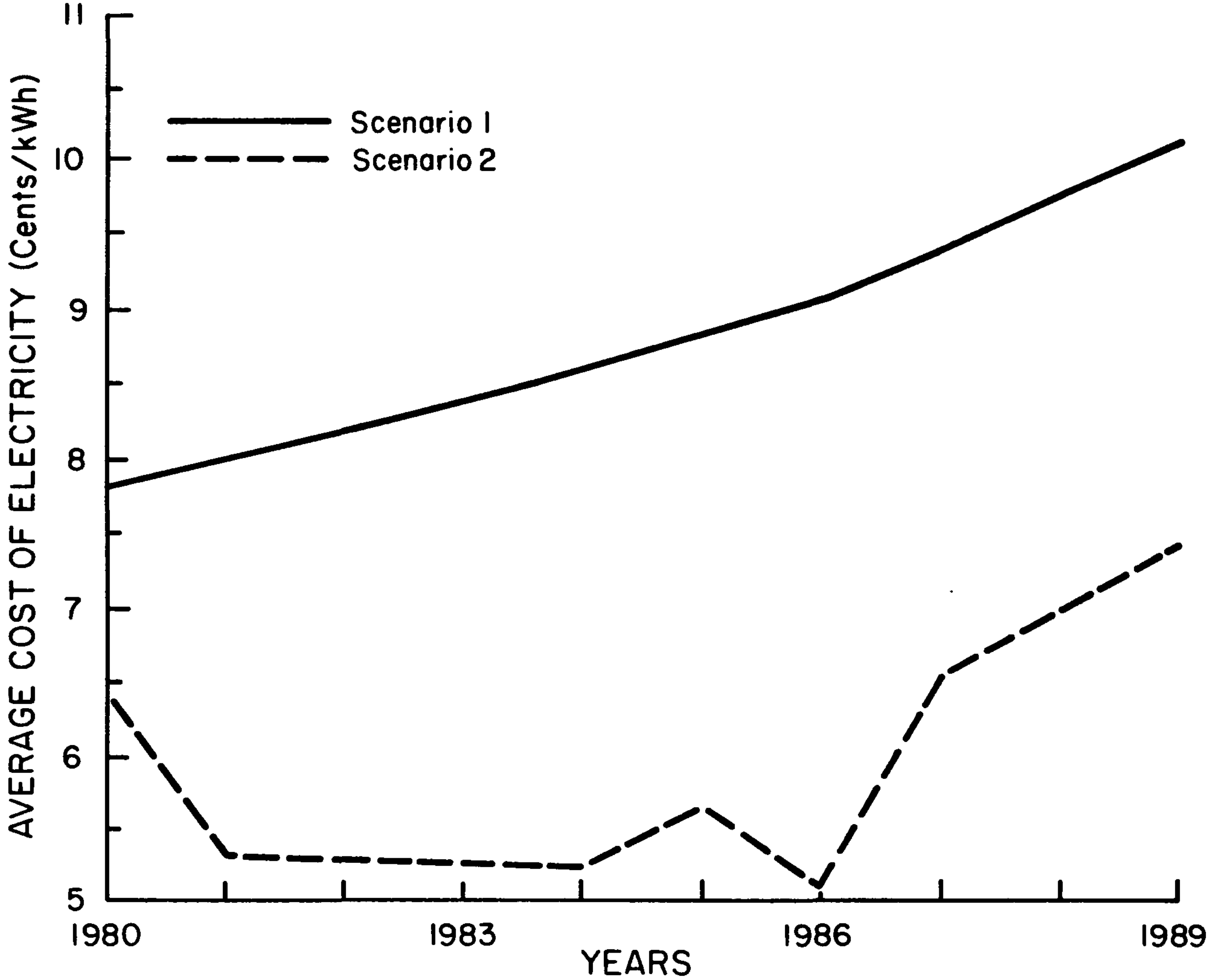


Figure 11. Scenario results for Upper Volta

Table 27. Hydro Plant Installations in Joint Development Projects. -- MW

| Planning Period | Scenario[a] 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| 1980 | 79 | 18 | 291 | 77 | 473 | 252 | 30 |
| 1981 | 66 | 0.4 | 184 | 218 | 756 | 72 | 447 |
| 1982 | 70 | | | 119 | 212 | 76 | 256 |
| 1983 | 75 | 2.1 | | | 149 | 84 | |
| 1984 | 82 | 5.1 | | | | 95 | |
| 1985 | 91 | 6.2 | | | | 105 | |
| 1986 | 99 | 5.9 | | | | 113 | |
| 1987 | 102 | | | | | 116 | |
| 1988 | 71 | | | | | 122 | |
| 1989 | | | | | | | |

[a]The countries involved in each scenario are:

Scenario #1--Nigeria and Niger
Scenario #2--Togo and Benin
Scenario #3--Ghana, Ivory Coast, and Upper Volta
Scenario #4--Ghana and Upper Volta
Scenario #5--Ghana, Ivory Coast, Togo, Benin, and Upper Volta
Scenario #6--Nigeria, Niger, Togo, and Benin
Scenario #7--Ghana and Ivory Coast.

Table 28. Thermal Plant Installations in Joint Development Projects. -- MW

| Planning Period | Scenario[a] | | | | | | |
|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 1980 | | | 624 | 272 | | | 800 |
| 1981 | | | | | | | |
| 1982 | | | 77 | | | | |
| 1983 | | | 155 | | | | |
| 1984 | | | 174 | 4.4 | | | 25 |
| 1985 | | | 199 | 95 | 107 | | 194 |
| 1986 | | | 229 | 100 | 233 | | 224 |
| 1987 | | | 267 | 105 | 271 | | 262 |
| 1988 | | | 317 | 111 | 321 | | 311 |
| 1989 | | | 384 | 118 | 388 | | 376 |

[a]The countries involved in each scenario are:

Scenario #1--Nigeria and Niger
Scenario #2--Togo and Benin
Scenario #3--Ghana, Ivory Coast, and Upper Volta
Scenario #4--Ghana and Upper Volta
Scenario #5--Ghana, Ivory Coast, Togo, Benin, and Upper Volta
Scenario #6--Nigeria, Niger, Togo, and Benin
Scenario #7--Ghana and Ivory Coast

Table 29. Average cost of producing electricity for Joint Development Projects. -- cents/kWh.

| Planning Period | Scenario[a] | | | | | | |
|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 1980 | 2.62 | 2.67 | 5.93 | 3.20 | 3.46 | 2.74 | 5.39 |
| 1981 | 2.66 | 2.66 | 4.82 | 2.88 | 2.78 | 2.76 | 4.68 |
| 1982 | 2.70 | 2.64 | 5.13 | 2.78 | 2.82 | 2.77 | 4.64 |
| 1983 | 2.73 | 2.65 | 5.47 | 3.06 | 2.97 | 2.78 | 4.93 |
| 1984 | 2.75 | 2.69 | 5.83 | 3.34 | 3.34 | 2.79 | 5.24 |
| 1985 | 2.78 | 2.74 | 6.20 | 3.67 | 3.77 | 2.80 | 5.63 |
| 1986 | 2.80 | 2.78 | 6.58 | 4.00 | 4.25 | 2.31 | 6.04 |
| 1987 | 2.81 | 2.80 | 6.98 | 4.34 | 4.76 | 2.81 | 6.46 |
| 1988 | 2.90 | 3.14 | 7.40 | 4.69 | 5.30 | 2.81 | 6.91 |
| 1989 | 3.31 | 3.50 | 7.84 | 5.05 | 5.87 | 2.17 | 7.37 |

[a]The countries involved in each scenario are:

Scenario #1--Nigeria and Niger
Scenario #2--Togo and Benin
Scenario #3--Ghana, Ivory Coast, and Upper Volta
Scenario #4--Ghana and Upper Volta
Scenario #5--Ghana, Ivory Coast, Togo, Benin, and Upper Volta
Scenario #6--Nigeria, Niger, Togo, and Benin
Scenario #7--Ghana and Ivory Coast.

region: Togo, Benin, Niger, and Nigeria. This advantage is due mainly to the high unexploited resources of Benin and Nigeria. As pointed out in the chapter on resources of the region, Ivory Coast and Ghana are the only countries to the west that have appreciable hydro resources. The inclusion of Upper Volta in the share of these resources in addition to rising demand forecasts for Ghana and Ivory Coast leaves these three countries with only thermal options once the hydro sources are exhausted. This is predicted to be at the end of 1982 (scenario 3).

The search for optimal scheduling and cheaper supply of electricity was the reason for constructing and analysing feasible options in this study. The implications of these results as far as individual countries are concerned are dealt with in the final chapter.

# CHAPTER 7

## CONCLUSIONS AND RECOMMENDATIONS

This dissertation began with an examination of the meaning of economic development for the developing countries in general. Past performance of the economies of seven West African countries, Ghana, Nigeria, Upper Volta, Togo, Benin, Ivory Coast, and Niger based on the gross national product indicator was compared with that of other "moderately" and "fully" developed economies. It is concluded that negative growth rates in GNP per capita left little room for the diversification of economic production in these countries.

The agricultural sector in these countries plays an important role in the economies, employing (at subsistence levels) at least 70 percent of the economically active population but is not doing much to improve the quality of life of the people. A solution proposed lies in the resource transformation (mainly labor) from this sector, where productivity is low, to the manufacturing and service sector, where productivity is higher. A total neglect of the agricultural sector is, however, not advocated because both sectors have reciprocative roles to play in any progressive economy. Furthermore, advocating resource transformation from agriculture to industry presents the individual developing countries with many problems. The smallness of the domestic markets, due in part to the smallness of the countries themselves and present low levels of per capita incomes, prevent industry from taking full advantage of the economies of scale that prevail in the economies of modern industry. In addition, the rising cost of some factors of production that have to be imported with minimal earnings from agricultural exports leaves this proposition unattractive. One such factor of production that can hardly be substituted for in modern industry and was examined in this study is electricity, or electrical energy.

In response to all the problems presented, the dissertation had the following objectives:

1. To identify the determinants of electricity consumption in the residential sector and the industrial and commercial sector of the economies of the selected West African countries.
2. To project the value of the determinants during a planning horizon of 10 years (1980-1989) and thus obtain the sectorial and total expected demands for electricity.
3. To develop a mathematical electricity supply model for computer analysis with built-in resource limitations to supply at least the total projected demands. Various other constraints such as budgetary and technological were also to be explicitly recognized.

4. To analyse feasible alternatives (scenarios) at the individual country level and for increased service market areas based on electricity supplied jointly by two or more countries.

## Results

Price, income, and the employment of labor were found to be the major determinants for the demand of electricity in the industrial and commercial sector of most of the countries analysed. Price elasticities ranged from -0.459 for Ghana to -0.752 for Niger. This implies for example, that a 1 percent change in price of electricity will effect a 0.75 percent change in the demand for electricity in this sector in Niger. Income elasticities had a wider range of values for the same sector; 0.336 for Togo and 0.890 for Nigeria, were extreme values. The value of 4.882 obtained for Upper Volta, is considered too large compared with that for the other countries and is thus considered unacceptable.

Income, price, and the number of households having access to electricity explain in most cases the more than 90 percent variability in the demand for electricity in the residential sector. Estimates of price elasticities range from -0.291 for Upper Volta to -1.240 for Niger. The fact that the price elasticity is not different from zero at the 5 percent confidence level for Ghana shows that Ghanaians did not consider price of electricity a factor in its demand. This, however, holds for the estimation period only. An explanation for this may lie in the relatively low price paid for electricity during this time period. This low price was partly due to the low cost of supply from the sole hydro-electric dam at Akosombo.

In the residential sector income and price were found to be elastic i.e., absolute values greater than 1 for Togo and Niger, and income elastic for Ghana. However, price and income were found to be elastic in the industrial and commercial sector across countries. The highest values for price elasticity and for income elasticity were derived from the demand equations for Niger and Nigeria, respectively.

Demand forecasts for the countries were based on the assumption that the structure of the economies will not change appreciably in the next 10 years. If structural changes are to occur it is expected to take place first in Nigeria, which is presently trying to convert its petro-dollar revenues into industrial development projects. However, because its path of economic development is proceeding despite various drawbacks, it can be said that its economic structure will remain approximately the same in the short or medium term. On these grounds, it must be said that the demand equations obtained are for the medium term.

On account of the aluminum smelter, Ghana's total electricity demand is expected to continue to be higher than that of any other country in the region during the planning horizon. Nigeria, however, is expected to demand more than any other country beginning in the early 1990s if industrial projects on the drawing board today come onstream.

Results indicate that hydro sources should be developed to optimum capacity before thermal installations are considered. This rule is violated due to budgetary restrictions for such countries as Upper Volta. However, common development strategies strongly favour total exploitation of hydro sources to the extent that Ghana, Ivory Coast, and Upper Volta will demand additional electricity from thermal sources in the middle 1980s.

All countries, with the exception of Ghana, will benefit more from joint development options during the 1980-1989 period than if each pursued its individual development policy. The countries that will benefit most are those that currently depend on thermal production methods. These are Togo, Benin, and Upper Volta. Niger is expected to be sufficient in its supply with 30 MW from Nigeria, unless Nigeria decides otherwise.

Ghana's minimal losses from joint development efforts arise from exportation of 50 MW of "cheap" electricity to Togo and Benin. This will have to be replaced by thermal options later in the planning period. A joint development with Upper Volta is most favoured on account of the latter's low-demand profile and some hydro sources. A joint development with Ivory Coast, Togo, Benin, and Upper Volta will not reduce Ghana's cost of electricity due to the low energy yields of hydro sites in the other countries and higher demands, particularly in the Ivory Coast.

A study of this nature made possible by the availability of a policy analysis tool such as reported here will indicate in monetary terms what losses or gains will accrue to any particular country, and the tool can be used to structure a pricing policy for compensation if a body like ECOWAS controls the supply of commodities in the region.

The results of this study are sensitive to the input data to the supply model. Most importantly, the scheduling of installations and the total costs involved during the plan period depend greatly on the projections for demand for electricity made with the econometric models. Due to the lack of information, comparison of forecasted values with those of electric power authorities in the various countries can only be performed for one country--Nigeria. Table 30 shows a progression of forecasts made by the National Electric Power Authority in 1976, 1977, and 1978.

The following observations are made on the entries of Table 30; downward revisions prevail in all forecasts by NEPA between forecast periods. For the year 1977 NEPA's forecast of 1978 consumption was in error by 22 percent which is

Table 30. Comparison of total electricity consumption forecasts: Nigeria (1978-1985)

| Consumption Period | Total Electricity Consumption: billion kWh | | | |
|---|---|---|---|---|
| | Forecast[a] Year: 1976 | Forecast Year: 1977 | Forecast Year: 1978 | This Study |
| 1978 | 4.80 | 4.40 | 3.60[b] | 4.00 |
| 1979 | 5.73 | 5.30 | 4.80 | 4.33 |
| 1980 | 7.03 | 6.20 | 5.40 | 4.63 |
| 1981 | 8.91 | 8.00 | 8.00 | 4.96 |
| 1982 | 11.08 | 10.00 | 10.00 | 5.31 |
| 1983 | 12.82 | N/A | 10.80 | 5.68 |
| 1984 | 14.07 | N/A | N/A | 6.09 |
| 1985 | 15.51 | N/A | N/A | 6.52 |

[a]NEPA, 1976, 1977, 1978

[b]Actual consumption

Note: N/A = not available

twice the error of forecast made in this study. Furthermore, the 1976 forecast of 1978 consumption is 33 percent higher than actually consumed.

To achieve zero error in the forecast of the amount of electricity to be consumed is impossible but minimizing the error will ensure a better utilization of both capital and natural resources. It is thus worthwhile to compare the projected installation time table of NEPA and that derived from this study.

The installations planned by NEPA (Table 31) reflect the forecasts of electricity consumption by this agency possibly as early as 1975--the year of introduction of the last development plan. As such, these installations have been budgeted for by the government of Nigeria and are already under construction. If demand forecasts exceed actual consumption by as much as 33 percent, excess capacity is bound to remain in the system until demand catches up with supply potentials. The table also shows the optimal capacity expansions for Nigeria and the results if Niger, Togo, Benin, and Nigeria operate under a joint development plan. The latter results indicate a better utilization of resources than projected by NEPA.

A much better utilization of this excess capacity is expected if Nigeria and Benin are linked immediately by transmission lines so that electricity can flow from Nigeria

Table 31. Comparison of Power Development Options for Nigeria (1980-1984)

| Year | Capacity of Installation Program by NEPA (MW) | Optimal Capacity of Installation Program for Nigeria (MW) | Optimal Capacity of Installation Program for Nigeria, Niger, Togo, Benin (MW) |
|---|---|---|---|
| 1980 | 500 | 168 | 253 |
| 1981 | 300 | 66 | 72 |
| 1982 | 100 | 70 | 76 |
| 1983 | 400 | 75 | 84 |
| 1984 | 400 | 81 | 95 |

as far as the Ivory Coast. It may be argued that Nigeria has budgeted for excess capacity for two reasons:

1. The lessons of the past when shortages led to economic losses.
2. Planning for anticipated higher growth rates in demand especially by the industrial sector.

Whatever the reasons are, an immediate link with Benin will not only distribute over the whole region the excess capacity that would exist in Nigeria but will also allow the flow from Benin to the other countries including Nigeria, when Benin develops its 700 MW resource. This link-up if implemented, will solve the problems of the countries in the western portion of the region for the medium term.

## Recommendations for Future Work

This study examined the optimal scheduling of technologies for the supply of electricity in the West African countries on a national aggregated level. The results of this study are acceptable if it is assumed that all electricity consumption takes place at one point in any particular country. Alternatively, if consumption centers can exchange electricity at any time through existing transmission lines, the results of this study are acceptable. However, in some of the countries involved, this is not the case unless we make the further assumption that consumption is greatest in the capital cities of these countries. Niger is an example. It has been concluded for this country that it should not install new plants during the plan period. However, other demand centers, due to the unavailability of transmission lines, will not benefit from the relatively cheaper energy expected from Nigeria.

For the joint development options, it is also assumed that transmission lines exist between countries. This is only the case for some of the countries; between Ghana, Togo, Benin, and possibly Ivory Coast in the near future. In all cases the solution of the general multi-generation, multi-demand model should provide the optimal flow paths of electricity exchange and the marginal cost contributions of transmission facilities to the cost of electricity.

The planning model as formulated and programmed accepts three thermal technologies: gas turbine, steam turbine, and diesel-fueled generators. An easy addition to the model is its extension to analyse solar, nuclear, and other technologies that may become feasible in the post-1990 period when new hydro sources become scarce.

One reason for the difference in the predictions of this study and the installation plans of NEPA is the difference in projected demands for electricity. A good forecasting technique should provide forecasts with little error. More work should therefore be done on the forecasting of consumption for the countries involved. The models used in this study should forecast well for the residential sector with the assumptions of utility maximization and little structural changes. However, modelling the industrial and commercial sector should consider the technologies of processes, government perceptions, and above all, the availability of other inputs. It is the view that the industrial and commercial sector of the developing countries which are totally government controlled should be easier to model once all the relevant information becomes available. Whatever modelling techniques are used, long-term forecasts (beyond 10 years) are necessary to structure capacity of installations.

In addition to the availability of long-term forecasts, the introduction into the planning model of constraints such as minimum construction periods and discrete capacity installations are necessary for realistic structuring of capacity and operation. The former constraint can be taken care of in the planning model by setting appropriate decision variables to zero, whereas the latter involves integer variables.

Finally, the region of West Africa as stated earlier comprises 14 countries that have come under the economic union of ECOWAS. A natural extension of this study is the inclusion of the remaining countries in the planning. No new modelling is involved but the number of decision variables will increase tremendously. However, the availability of high-speed computers with large memories and easy access to efficient programming algorithms should allow analyses of many alternatives for policy implementations.

# APPENDIX A

## SECTORIAL ELECTRICITY DEMAND PROJECTIONS

COUNTRY: GHANA

INDUSTRIAL ELECTRICITY PROJECTIONS

| YEAR | CONSUMPTION (KWH) | OUTPUT (CEDI) | PRICE (PESEWA/KWH) |
|---|---|---|---|
| 1980 | .7638E+10 | .9924E+09 | 2.13 |
| 1981 | .8400E+10 | .1094E+10 | 2.13 |
| 1982 | .8904E+10 | .1206E+10 | 2.13 |
| 1983 | .9396E+10 | .1329E+10 | 2.13 |
| 1984 | .9897E+10 | .1464E+10 | 2.13 |
| 1985 | .1042E+11 | .1614E+10 | 2.13 |
| 1986 | .1096E+11 | .1778E+10 | 2.13 |
| 1987 | .1153E+11 | .1959E+10 | 2.13 |
| 1988 | .1213E+11 | .2159E+10 | 2.13 |
| 1989 | .1276E+11 | .2378E+10 | 2.13 |

RESIDENTIAL ELECTRICITY PROJECTIONS

| YEAR | CONSUMPTION (KWH) | INCOME (CEDI) | PRICE (PESEWA/KWH) |
|---|---|---|---|
| 1980 | .4009E+09 | .4504E+10 | 1.23 |
| 1981 | .4346E+09 | .4854E+10 | 1.23 |
| 1982 | .4708E+09 | .5231E+10 | 1.23 |
| 1983 | .5099E+09 | .5637E+10 | 1.23 |
| 1984 | .5522E+09 | .6074E+10 | 1.23 |
| 1985 | .5980E+09 | .6545E+10 | 1.23 |
| 1986 | .6475E+09 | .7052E+10 | 1.23 |
| 1987 | .7011E+09 | .7598E+10 | 1.23 |
| 1988 | .7590E+09 | .8186E+10 | 1.23 |
| 1989 | .8218E+09 | .8819E+10 | 1.23 |

COUNTRY:IVORY COAST

INDUSTRIAL ELECTRICITY PROJECTIONS

| YEAR | CONS'TION (KWH) | OUTPUT (CFA) | PRICE (CFA/KWH) | EMPL'MENT |
|---|---|---|---|---|
| 1980 | .1275E+10 | .1207E+12 | 3.9340000 | 64461 |
| 1981 | .1344E+10 | .1338E+12 | 3.7160000 | 67178 |
| 1982 | .1459E+10 | .1483E+12 | 3.4980000 | 69895 |
| 1983 | .1620E+10 | .1644E+12 | 3.2800000 | 72612 |
| 1984 | .1827E+10 | .1822E+12 | 3.0620000 | 75329 |
| 1985 | .2086E+10 | .2019E+12 | 2.8440000 | 78046 |
| 1986 | .2404E+10 | .2237E+12 | 2.6260000 | 80763 |
| 1987 | .2794E+10 | .2479E+12 | 2.4080000 | 83480 |
| 1988 | .3275E+10 | .2746E+12 | 2.1900000 | 86197 |
| 1989 | .3876E+10 | .3043E+12 | 1.9720000 | 88914 |

RESIDENTIAL ELECTRICITY PROJECTIONS

| YEAR | CONS'TION (KWH) | INCOME (CFA) | PRICE (CFA/KWH) | SUBS. |
|---|---|---|---|---|
| 1980 | .2357E+09 | .5237E+12 | 7.4270000 | 307354 |
| 1981 | .2804E+09 | .5586E+12 | 6.9620000 | 357238 |
| 1982 | .3348E+09 | .5959E+12 | 6.4970000 | 415185 |
| 1983 | .4013E+09 | .6357E+12 | 6.0320000 | 482496 |
| 1984 | .4832E+09 | .6780E+12 | 5.5670000 | 560677 |
| 1985 | .5850E+09 | .7232E+12 | 5.1020000 | 651477 |
| 1986 | .7129E+09 | .7714E+12 | 4.6370000 | 756923 |
| 1987 | .8756E+09 | .8227E+12 | 4.1720000 | 879371 |
| 1988 | .1086E+10 | .8775E+12 | 3.7070000 | 1021551 |
| 1989 | .1363E+10 | .9358E+12 | 3.2420000 | 1186629 |

COUNTRY:NIGER

INDUSTRIAL ELECTRICITY PROJECTIONS

| YEAR | CONS'TION (KWH) | OUTPUT (CFA) | PRICE (CFA/KWH) | EMPL'MENT |
|---|---|---|---|---|
| 1980 | .1202E+09 | .9129E+11 | 10.3285784 | 9489 |
| 1981 | .1433E+09 | .9791E+11 | 9.7764926 | 10335 |
| 1982 | .1668E+09 | .1050E+12 | 9.2541740 | 11255 |
| 1983 | .1919E+09 | .1126E+12 | 8.7600032 | 12257 |
| 1984 | .2193E+09 | .1207E+12 | 8.2924504 | 13347 |
| 1985 | .2496E+09 | .1295E+12 | 7.8500696 | 14534 |
| 1986 | .2836E+09 | .1388E+12 | 7.4314939 | 15826 |
| 1987 | .3219E+09 | .1488E+12 | 7.0354312 | 17232 |
| 1988 | .3651E+09 | .1596E+12 | 6.6606602 | 18762 |
| 1989 | .4139E+09 | .1711E+12 | 6.3060266 | 20426 |

RESIDENTIAL ELECTRICITY PROJECTIONS

| YEAR | CONS'TION (KWH) | INCOME (CFA) | PRICE (CFA/KWH) | SUBS. |
|---|---|---|---|---|
| 1980 | .4696E+08 | .9355E+11 | 11.1470000 | 17258 |
| 1981 | .5975E+08 | .9600E+11 | 10.0500000 | 18992 |
| 1982 | .7186E+08 | .9851E+11 | 8.9530000 | 20899 |
| 1983 | .8726E+08 | .1011E+12 | 7.8560000 | 22996 |
| 1984 | .1118E+09 | .1037E+12 | 6.7590000 | 25303 |
| 1985 | .1497E+09 | .1064E+12 | 5.6620000 | 27839 |
| 1986 | .1700E+09 | .1092E+12 | 5.6620000 | 30629 |
| 1987 | .1940E+09 | .1121E+12 | 5.6620000 | 33696 |
| 1988 | .2085E+09 | .1150E+12 | 5.6620000 | 37068 |
| 1989 | .2159E+09 | .1180E+12 | 5.6620000 | 40777 |

COUNTRY:NIGERIA

INDUSTRIAL ELECTRICITY PROJECTIONS

| YEAR | CONS'TION (KWH) | OUTPUT (1972=100) | PRICE (PENCE/ | EMPL'MENT |
|---|---|---|---|---|
| 1980 | .2892E+10 | .1879E+03 | .9166240 | 298680 |
| 1981 | .3038E+10 | .1921E+03 | .9166240 | 309346 |
| 1982 | .3188E+10 | .1964E+03 | .9166240 | 320012 |
| 1983 | .3342E+10 | .2008E+03 | .9166240 | 330678 |
| 1984 | .3500E+10 | .2053E+03 | .9166240 | 341344 |
| 1985 | .3663E+10 | .2098E+03 | .9166240 | 352010 |
| 1986 | .3657E+10 | .2145E+03 | .9074578 | 362676 |
| 1987 | .4030E+10 | .2193E+03 | .9074578 | 373342 |
| 1988 | .4208E+10 | .2242E+03 | .9074578 | 384008 |
| 1989 | .4391E+10 | .2292E+03 | .9074578 | 394674 |

RESIDENTIAL ELECTRICITY PROJECTIONS

| YEAR | CONS'TION (KWH) | INCOME (NAIRA) | PRICE (PENCE/KWH) | SUBS. |
|---|---|---|---|---|
| 1980 | .1739E+10 | .1709E+11 | .9166290 | 296144 |
| 1981 | .1920E+10 | .1857E+11 | .9166290 | 349159 |
| 1982 | .2120E+10 | .2018E+11 | .9166290 | 411630 |
| 1983 | .2341E+10 | .2194E+11 | .9166290 | 485239 |
| 1984 | .2585E+10 | .2384E+11 | .9166290 | 571963 |
| 1985 | .2853E+10 | .2590E+11 | .9166290 | 674131 |
| 1986 | .3150E+10 | .2815E+11 | .9166290 | 794482 |
| 1987 | .3477E+10 | .3058E+11 | .9166290 | 936243 |
| 1988 | .3838E+10 | .3323E+11 | .9166290 | 1103207 |
| 1989 | .4237E+10 | .3610E+11 | .9166290 | 1299840 |

COUNTRY: TOGO

INDUSTRIAL ELECTRICITY PROJECTIONS

| YEAR | CONSUMPTION (KWH) | OUTPUT (CFA) | PRICE (CFA/KWH) |
|---|---|---|---|
| 1980 | .2113E+09 | .8037E+11 | 6.52 |
| 1981 | .2029E+09 | .8924E+11 | 6.52 |
| 1982 | .1904E+09 | .9909E+11 | 6.52 |
| 1983 | .1893E+09 | .1100E+12 | 6.52 |
| 1984 | .2007E+09 | .1221E+12 | 6.52 |
| 1985 | .2164E+09 | .1356E+12 | 6.52 |
| 1986 | .2286E+09 | .1505E+12 | 6.52 |
| 1987 | .2360E+09 | .1671E+12 | 6.52 |
| 1988 | .2410E+09 | .1855E+12 | 6.52 |
| 1989 | .2472E+09 | .2059E+12 | 6.52 |

RESIDENTIAL ELECTRICITY PROJECTIONS

| YEAR | CONSUMPTION (KWH) | INCOME (CFA) | PRICE (CFA/KWH) |
|---|---|---|---|
| 1980 | .4722E+08 | .4878E+11 | 9.05 |
| 1981 | .4836E+08 | .5000E+11 | 9.05 |
| 1982 | .4958E+08 | .5125E+11 | 9.05 |
| 1983 | .5080E+08 | .5254E+11 | 9.05 |
| 1984 | .5205E+08 | .5385E+11 | 9.05 |
| 1985 | .5333E+08 | .5520E+11 | 9.05 |
| 1986 | .5465E+08 | .5658E+11 | 9.05 |
| 1987 | .5599E+08 | .5799E+11 | 9.05 |
| 1988 | .5737E+08 | .5944E+11 | 9.05 |
| 1989 | .5879E+08 | .6093E+11 | 9.05 |

COUNTRY: UPPER VOLTA

INDUSTRIAL ELECTRICITY PROJECTIONS

| YEAR | CONSUMPTION (KWH) | OUTPUT(CFA) | AVERAGE PRICE(CFA/KWH) |
|---|---|---|---|
| 1980 | .5365E+08 | .4603E+11 | 21.12 |
| 1981 | .6168E+08 | .4695E+11 | 20.06 |
| 1982 | .7092E+08 | .4788E+11 | 19.06 |
| 1983 | .8153E+08 | .4883E+11 | 18.11 |
| 1984 | .9372E+08 | .4980E+11 | 17.20 |
| 1985 | .1077E+09 | .5078E+11 | 16.34 |
| 1986 | .1238E+09 | .5179E+11 | 15.53 |
| 1987 | .1423E+09 | .5281E+11 | 14.75 |
| 1988 | .1636E+09 | .5386E+11 | 14.01 |
| 1989 | .1880E+09 | .5492E+11 | 13.31 |

RESIDENTIAL ELECTRICITY PROJECTIONS

| YEAR | CONSUMPTION (KWH) | PRICE (CFA/KWH) | NO. OF CUSTOMERS |
|---|---|---|---|
| 1980 | .3199E+08 | 21.12 | 17785 |
| 1981 | .3621E+08 | 20.06 | 19895 |
| 1982 | .4099E+08 | 19.06 | 22255 |
| 1983 | .4640E+08 | 18.11 | 24893 |
| 1984 | .5252E+08 | 17.20 | 27843 |
| 1985 | .5944E+08 | 16.34 | 31140 |
| 1986 | .6727E+08 | 15.53 | 34826 |
| 1987 | .7613E+08 | 14.75 | 38946 |
| 1988 | .8615E+08 | 14.01 | 43550 |
| 1989 | .9748E+08 | 13.31 | 48697 |

APPENDIX B

DETAILED SCENARIO RESULTS

FOR ALL COUNTRIES

Table B-1. Detailed results for Benin: Scenario #1

| Plant Type | Planning Period | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 |
| Thermal 3 (initial) | | | | | | | | | | |
| Unit cost (cents/kwhr) | | | | | 8.61 | 8.84 | 9.07 | 9.31 | 9.56 | 9.82 |
| Hydro import | | | | | | | | | | |
| Unit cost (cents/kwhr) | 2.26 | 2.24 | 2.22 | 2.20 | 2.18 | 2.16 | 2.14 | 2.12 | 2.10 | 2.08 |
| Average unit cost (cents/kwhr) | 2.26 | 2.24 | 2.22 | 2.20 | 2.26 | 2.90 | 3.53 | 4.13 | 4.72 | 5.30 |

Table B-2 Detailed results for Benin: Scenario #2

| Plant Type | Planning Period 1980 | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 |
|---|---|---|---|---|---|---|---|---|---|---|
| Thermal 3 (initial) | | | | | | | | | | |
| Unit cost | 7.81 | 8.00 | 8.20 | 8.40 | 8.61 | 8.84 | 9.07 | 9.31 | 9.56 | 9.82 |
| Thermal 3 (new) | | | | | | | | | | |
| Capacity (kw) | | | | 1277 | 1806 | 2006 | 2227 | 2473 | 2745 | 3047 |
| Unit cost | | | | 9.40 | 9.61 | 9.82 | 10.05 | 10.29 | 10.53 | 10.79 |
| Average unit cost | 7.81 | 8.00 | 8.20 | 8.48 | 8.78 | 9.09 | 9.39 | 9.70 | 10.00 | 10.32 |

Table B-3. Detailed results for Benin: Scenario #3

| | Planning Period | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Plant Type | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 |
| Thermal 3 (initial) | | | | | | | | | | |
| Unit cost | | | | | | | | 9.31 | 9.56 | 9.82 |
| Hydro (new) | | | | | | | | | | |
| Capacity (kw) | 16626 | 1848 | 2052 | 2279 | 2531 | 2810 | 3120 | | | |
| Unit cost | 4.06 | 4.04 | 4.01 | 3.99 | 3.96 | 3.93 | 3.91 | 3.89 | 3.87 | 3.85 |
| Average unit cost | 4.06 | 4.04 | 4.01 | 3.99 | 3.96 | 3.93 | 3.91 | 4.43 | 4.94 | 5.46 |

Table B-4. Detailed results for Benin: Scenario #4

| Plant Type | Planning Period | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 |
| Hydro (new) | | | | | | | | | | |
| Capacity (kw) | | | | | 335 | 2810 | 3120 | | | |
| Unit cost (cents/kwhr) | | | | | 3.91 | 3.87 | 3.84 | 3.82 | 3.80 | 3.78 |
| Thermal (initial) | | | | | | | | | | |
| Unit cost | | | | | | | | 9.31 | 9.56 | 9.82 |
| Hydro (import) | | | | | | | | | | |
| Unit cost | 2.26 | 2.24 | 2.22 | 2.20 | 2.18 | 2.16 | 2.14 | 2.12 | 2.10 | 2.08 |
| Average unit cost | 2.26 | 2.24 | 2.22 | 2.20 | 2.20 | 2.35 | 2.48 | 3.14 | 3.79 | 4.42 |

Table B-6. Detailed results for Ghana: Scenario #1

| Plant Type | Planning Period 1980 | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 |
|---|---|---|---|---|---|---|---|---|---|---|
| Thermal 2 (new) | | | | | | | | | | |
| Capacity (MW) | 435 | | | | | | 78 | 100 | 106 | 111 |
| Unit cost (cents/kwhr) | 8.06 | 8.52 | 9.26 | 9.32 | 9.15 | 9.14 | 9.34 | 9.58 | 9.83 | 10.09 |
| Hydro 1 (new) | | | | | | | | | | |
| Capacity (MW) | | 103 | 192 | 5 | | | | | | |
| Unit cost (cents/kwhr) | | 3.65 | 3.62 | 3.61 | 3.59 | 3.58 | 3.56 | 3.55 | 3.53 | 3.52 |
| Hydro 2 new) | | | | | | | | | | |
| Capacity (MW) | 3.5 | 70 | | | | | | | | |
| Unit cost (cents/kwhr) | 3.37 | 3.34 | 3.32 | 3.31 | 3.29 | 3.28 | 3.26 | 3.25 | 3.23 | 3.22 |
| Hydro 3 (new) | | | | | | | | | | |
| Capacity (MW) | | | | 41 | | | | | | |
| Unit cost (cents/kwhr) | | | | 3.65 | 3.64 | 3.62 | 3.60 | 3.59 | 3.57 | 3.56 |
| Hydro 1 (initial) | | | | | | | | | | |
| Unit cost | 1.70 | 1.68 | 1.66 | 1.65 | 1.63 | 1.62 | 1.60 | 1.59 | 1.57 | 1.56 |
| Average unit cost | 3.79 | 3.52 | 3.27 | 3.36 | 3.63 | 3.90 | 4.21 | 4.53 | 4.87 | 5.21 |

Table B-7. Detailed results for Ghana: Scenario #2

| | Planning Period | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Plant Type | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 |
| Thermal 2 (new) | | | | | | | | | | |
| Capacity (MW) | 336 | | | | | 31 | 95 | 100 | 106 | 111 |
| Unit cost (cents/kwhr) | 8.06 | 8.60 | 9.78 | 9.29 | 9.06 | 9.10 | 9.35 | 9.57 | 9.82 | 10.08 |
| Hydro 1 (new) | | | | | | | | | | |
| Capacity (MW) | | 142 | 158 | | | | | | | |
| Unit cost (cents/kwhr) | | 3.65 | 3.63 | 3.61 | 3.60 | 3.58 | 3.56 | 3.55 | 3.53 | 3.52 |
| Hydro 2 (new) | | | | | | | | | | |
| Capacity (MW) | 38 | 36 | | | | | | | | |
| Unit cost (cents/kwhr) | 3.37 | 3.35 | 3.33 | 3.31 | 3.30 | 3.28 | 3.27 | 3.25 | 3.24 | 3.22 |
| Hydro 3 (new) | | | | | | | | | | |
| Capacity (MW) | | | 24 | 17 | | | | | | |
| Unit cost (cents/kwhr) | | | 3.69 | 3.66 | 3.65 | 3.63 | 3.62 | 3.60 | 3.59 | 3.57 |
| Hydro 1 (initial) | | | | | | | | | | |
| Unit cost (cents/kwhr) | 1.70 | 1.68 | 1.66 | 1.65 | 1.63 | 1.62 | 1.60 | 1.59 | 1.57 | 1.56 |
| Average unit cost | 3.38 | 3.15 | 2.91 | 3.12 | 3.38 | 3.67 | 4.00 | 4.53 | 4.66 | 5.01 |

Table B-8. Detailed results for Ivory Coast: Scenario #1

| Plant Type | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 |
|---|---|---|---|---|---|---|---|---|---|---|
| | Planning Period | | | | | | | | | |
| Thermal 2 (new) | | | | | | | | | | |
| Capacity (MW) | 24 | 38 | 52 | 66 | 83 | 104 | 129 | 161 | 205 | 265 |
| Unit cost (cents/kwhr) | 8.06 | 8.25 | 8.44 | 8.65 | 8.86 | 9.08 | 9.32 | 9.56 | 9.81 | 10.07 |
| Thermal 3 (initial) | | | | | | | | | | |
| Unit cost (cents/kwhr) | 7.25 | 7.44 | 7.64 | 7.85 | 8.07 | 8.30 | 8.53 | 8.78 | 9.04 | 9.30 |
| Hydro 1 (initial) | | | | | | | | | | |
| Unit cost (cents/kwhr) | 1.70 | 1.68 | 1.66 | 1.65 | 1.63 | 1.62 | 1.60 | 1.59 | 1.57 | 1.56 |
| Average unit cost | 5.30 | 5.70 | 6.14 | 6.59 | 7.05 | 7.50 | 7.94 | 8.38 | 8.80 | 9.22 |

Table B-9. Detailed results for the Ivory Coast: Scenario #2

| Plant Type | Planning Period | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 |
| Thermal 2 (new) | | | | | | | | | | |
| Capacity (MW) | | | | | 61 | 104 | 129 | 161 | 205 | 265 |
| Unit cost (cents/kwhr) | | | | | 8.85 | 9.07 | 9.31 | 9.55 | 9.80 | 10.06 |
| Hydro 1 (new) | | | | | | | | | | |
| Capacity (MW) | 318 | 42 | | | | | | | | |
| Unit cost (cents/kwhr) | 3.75 | 3.73 | 3.72 | 3.70 | 3.68 | 3.67 | 3.65 | 3.64 | 3.62 | 3.61 |
| Thermal 3 (initial) | | | | | | | | | | |
| Unit cost | 7.25 | 7.44 | 7.64 | 7.85 | 8.07 | 8.30 | 8.53 | 8.78 | 9.04 | 9.30 |
| Hydro 1 (initial) | | | | | | | | | | |
| Unit cost | 1.70 | 1.68 | 1.66 | 1.65 | 1.63 | 1.62 | 1.60 | 1.59 | 1.57 | 1.56 |
| Average unit cost | 3.46 | 3.64 | 4.12 | 4.65 | 5.27 | 5.91 | 6.54 | 7.15 | 7.74 | 8.32 |

Table B-10. Detailed results for Republic of Niger: Scenario #1

| Plant Type | Planning Period | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 |
| Hydro 1 (new) | | | | | | | | | | |
| Capacity (KW) | | 3589 | 5901 | 6693 | 8590 | 11297 | 8974 | 10312 | | |
| Unit cost (cents/kwhr) | | 2.54 | 2.53 | 2.51 | 2.49 | 2.47 | 2.46 | 2.44 | 2.43 | 2.42 |
| Thermal 3 (initial) | | | | | | | | | | |
| Unit cost (cents/kwhr) | | | | | | | | | 8.51 | 8.79 |
| Hydro import | | | | | | | | | | |
| Unit cost(cents/kwhr) | 1.02 | 1.01 | 1.00 | 0.99 | 0.98 | 0.97 | 0.96 | 0.95 | 0.94 | 0.93 |
| Average Unit Cost | 1.02 | 1.17 | 1.37 | 1.52 | 1.66 | 1.79 | 1.86 | 1.92 | 2.57 | 3.14 |

Table B-11. Detailed results for Republic of Niger: Scenario #2

| Plant Type | Planning Period | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 |
| Thermal 2 (new) | | | | | | | | | | |
| Capacity (KW) | | | | | | | 1357 | 8371 | 7737 | 7547 |
| Unit cost (cents/kwhr) | | | | | | | 9.37 | 9.61 | 9.87 | 10.13 |
| Thermal 3 (initial) | | | | | | | | | | |
| Unit cost (cents/kwhr) | | 6.88 | 7.09 | 7.30 | 7.53 | 7.76 | 8.00 | 8.25 | 8.51 | 8.79 |
| Hydro imports | | | | | | | | | | |
| Unit cost (cents/kwhr) | 1.02 | 1.01 | 1.00 | 0.99 | 0.98 | 0.97 | 0.96 | 0.95 | 0.94 | 0.93 |
| Average Unit Cost | 1.02 | 1.64 | 2.46 | 3.20 | 3.94 | 4.68 | 5.22 | 5.88 | 6.43 | 6.92 |

Table B-12. Detailed results for Republic of Niger: Scenario #3

| Plant Type | Planning Period | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 |
| Thermal 2 (new) | | | | | | | | | | |
| Capacity (kw) | | | | 2281 | 6973 | 9.71 | 7285 | 8371 | 7737 | 7547 |
| Unit cost (cents/kwhr) | | | | 8.71 | 8.93 | 9.15 | 9.39 | 9.63 | 9.89 | 10.15 |
| Thermal 3 (initial) | | | | | | | | | | |
| Unit cost (cents/kwhr) | 6.68 | 6.88 | 7.09 | 7.30 | 7.53 | 7.76 | 8.00 | 8.25 | 8.51 | 8.79 |
| Average unit cost | 6.68 | 6.88 | 7.09 | 7.39 | 7.82 | 8.24 | 8.59 | 8.93 | 9.26 | 9.58 |

Table B-13. Detailed results for Republic of Niger: Scenario #4

| Plant Type | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 |
|---|---|---|---|---|---|---|---|---|---|---|
| | Planning Period | | | | | | | | | |
| Hydro 1 (new) | | | | | | | | | | |
| Capacity (kw) | 15960 | 16596 | 6935 | 6693 | 8590 | 11297 | 8974 | 10312 | | |
| Unit cost (cents/kwhr) | 2.57 | 2.55 | 2.54 | 2.52 | 2.51 | 2.49 | 2.48 | 2.46 | 2.45 | 2.44 |
| Thermal 3 (initial) | | | | | | | | | | |
| Unit cost (cents/kwhr) | 6.68 | 6.88 | | | | | | | 8.51 | 8.78 |
| Average unit cost | 4.31 | 2.69 | 2.54 | 2.52 | 2.51 | 2.49 | 2.48 | 2.46 | 3.06 | 3.59 |

Table B-14. Detailed results for Nigeria: Scenario #1

| Plant Type | Planning Period | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 |
| Hydro 1 (new) | | | | | | | | | | |
| Capacity (MW) | 198 | 66 | 70 | 75 | 81 | 86 | 98 | 100 | | |
| Unit cost (cents/kwhr) | 3.83 | 3.80 | 3.77 | 3.75 | 3.72 | 3.69 | 3.66 | 3.63 | 3.61 | 3.58 |
| Thermal 2 (initial) | | | | | | | | | | |
| Unit cost (cents/kwhr) | | | | | | | | | 7.81 | 8.53 |
| Hydro 1 (initial) | | | | | | | | | | |
| Unit cost (cents/kwhr) | 2.53 | 2.51 | 2.49 | 2.46 | 2.44 | 2.42 | 2.39 | 2.37 | 2.35 | 2.33 |
| Average Unit Cost | 2.81 | 2.85 | 2.89 | 2.92 | 2.95 | 2.98 | 3.00 | 3.02 | 3.32 | 3.69 |

Table B-15 Detailed results for Nigeria: Scenario #2

| Plant Type | Planning Period | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 |
| Hydro 1 (new) | | | | | | | | | | |
| Capacity (MW) | 168 | 66 | 70 | 75 | 81 | 86 | 98 | 100 | | |
| Unit cost (cents/kwhr) | 3.83 | 3.80 | 3.77 | 3.75 | 3.72 | 3.69 | 3.66 | 3.63 | 3.61 | 3.58 |
| Thermal 1 (initial) | | | | | | | | | | |
| Unit cost (cents/kwhr) | | | | | | | | | 6.68 | |
| Thermal 2 (initial) | | | | | | | | | | |
| Unit cost (cents/kwhr) | | | | | | | | | 8.84 | 8.53 |
| Hydro 1 (initial | | | | | | | | | | |
| Unit cost (cents/kwhr) | 2.53 | 2.51 | 2.49 | 2.46 | 2.44 | 2.42 | 2.39 | 2.37 | 2.35 | 2.33 |
| Average Unit Cost | 2.77 | 2.81 | 2.85 | 2.89 | 2.92 | 2.95 | 2.97 | 2.99 | 3.29 | 3.67 |

Table B-16. Detailed results for Nigeria: Scenario #3

| Plant Type | Planning Period | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 |
| Hydro 1 (new) | | | | | | | | | | |
| Gravity (MW) | 198 | 66 | 70 | 75 | 81 | 86 | 98 | 27 | | |
| Unit cost (cents/kwhr) | 3.83 | 3.80 | 3.77 | 3.75 | 3.72 | 3.69 | 3.66 | 3.63 | 3.61 | 3.59 |
| Thermal 1 (initial) | | | | | | | | | | |
| Unit cost (cents/kwhr) | | | | | | | | 6.54 | 6.68 | 6.82 |
| Thermal 2 (initial) | | | | | | | | | | |
| Unit cost (cents/kwhr) | | | | | | | | 8.63 | 8.84 | 9.07 |
| Hydro 1 (initial) | | | | | | | | | | |
| Unit cost (cents/kwhr) | 2.53 | 2.51 | 2.49 | 2.46 | 2.44 | 2.42 | 2.39 | 2.37 | 2.35 | 2.33 |
| Average Unit Cost | 2.81 | 2.85 | 2.89 | 2.92 | 2.95 | 2.98 | 3.00 | 3.20 | 3.56 | 3.93 |

Table B-17. Detailed results for Togo: Scenario #1

| Plant Type | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 |
|---|---|---|---|---|---|---|---|---|---|---|
| | Planning Period | | | | | | | | | |
| Thermal 3 (initial) | | | | | | | | | | |
| Unit cost (cents/kwhr) | 7.81 | 8.00 | 8.20 | 8.40 | 8.61 | 8.84 | 9.07 | 9.31 | 9.56 | 9.82 |
| Hydro imports | | | | | | | | | | |
| Unit cost (cents/kwhr) | 2.26 | 2.24 | 2.22 | 2.20 | 2.18 | 2.16 | 2.14 | 2.12 | 2.10 | 2.08 |
| Hydro 2 (initial) | | | | | | | | | | |
| Unit cost (cents/kwhr) | 2.26 | 2.24 | 2.22 | 2.20 | 2.18 | 2.16 | 2.14 | 2.12 | 2.19 | 2.08 |
| Average Unit Cost | 4.23 | 4.18 | 4.04 | 4.09 | 4.36 | 4.70 | 4.99 | 5.20 | 5.39 | 5.60 |

Table B-18. Detailed results for Togo: Scenario #2

| Plant Type | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 |
|---|---|---|---|---|---|---|---|---|---|---|
| | Planning Period | | | | | | | | | |
| Thermal 3 (new) | | | | | | | | | | |
| Capacity (KW) | 13890 | | | | | 1595 | 1955 | 1231 | 908 | 1079 |
| Unit cost (cents/kwhr) | 8.84 | 9.03 | 9.47 | 9.67 | 9.71 | 9.86 | 10.09 | 10.32 | 10.57 | 10.83 |
| Thermal 3 (initial) | | | | | | | | | | |
| Unit cost (cents/kwhr) | 7.81 | 8.00 | 8.20 | 8.40 | 8.61 | 8.84 | 9.07 | 9.31 | 9.56 | 9.82 |
| Hydro 2 (initial) | | | | | | | | | | |
| Unit cost (cents/kwhr) | 2.26 | 2.24 | 2.22 | 2.20 | 2.18 | 2.16 | 2.14 | 2.12 | 2.10 | 2.08 |
| Average Unit Cost | 8.05 | 8.24 | 8.44 | 8.64 | 8.83 | 9.07 | 9.34 | 9.59 | 9.85 | 10.12 |

Table B-19. Detailed reports for Upper Volta: Scenario #1

| Plant Type | Planning Period | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 |
| Thermal 3 (new) | | | | | | | | | | |
| Capacity (kw) | | | | | | | | 3174 | 4463 | 5102 |
| Unit cost (cents/kwhr) | | | | | | | | 10.27 | 10.52 | 10.77 |
| Thermal 3 (initial) | | | | | | | | | | |
| Unit cost | 7.81 | 8.00 | 8.20 | 8.40 | 8.61 | 8.84 | 9.07 | 9.31 | 9.56 | 9.82 |
| Average unit cost | 7.81 | 8.00 | 8.20 | 8.40 | 8.61 | 8.84 | 9.07 | 9:41 | 9.77 | 10.12 |

Table B-20. Detailed results for Upper Volta: Scenario #2

| Plant Type | Planning Period 1980 | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 |
|---|---|---|---|---|---|---|---|---|---|---|
| Hydro (new) | | | | | | | | | | |
| Capacity (kw) | 7271 | 7433 | 2105 | 2406 | 2751 | | | | | |
| Unit cost (cents/kwhr) | 5.35 | 5.32 | 5.29 | 5.26 | 5.23 | 5.21 | 5.19 | 5.17 | 5.15 | 5.13 |
| Thermal 3 (initial) | | | | | | | | | | |
| Unit cost (cents/kwhr) | 7.81 | | | | | 8.84 | 9.07 | 9.31 | 9.56 | 9.82 |
| Average unit cost (cents/kwhr) | 6.42 | 5.32 | 5.29 | 5.26 | 5.23 | 5.66 | 5.10 | 6.54 | 6.98 | 7.42 |

# APPENDIX C

## LPCOMB: PROGRAM LISTING

```
      PROGRAM LPCOMB(INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT)
C*******REAL ARRAYS AND VARIABLES IN XMP************************
      COMMON B(640),ROWTYP(640),TMX,HMAX,CJMAX,DELTAT,JMAX,
     1NTHERM,NHYDRO,CJ1,CJ2,CJ3,CH1,CH2,CH3,PJ1,PJ2,LEVEL,
     2PJ3,AJP1,AJP2,AJP3,AHP1,AHP2,AHP3,Y110,Y220,Y330,YG1,
     3YG2,YG3,YR1,YR2,YR3,XJ10,XJ20,XJ30,XH10,XH20,XH30,
     4XMAX(3),R10,R20,R30,DR1,DR2,DR3,BUDO,DBUD,RHO1,RHO2,
     5RHO3,RHO4,INDGOV(21),IGP(21),EMPLN(21),VTOTAL(21),DARCOS(21),
     6NSUBSN(21),RCON(21),DREV(21),CRF,ID,TELEC(14),LBD1,LBD2,
     7GH,GJ,PGJ,PGH,PH1,PH2,PH3,PRH,PRJ,RH,RJ,XMX(3)
      REAL B,BASCB(640),BASLB(640),BASUB(640),BOUND,
     1 CANDA(14,6),CANDCJ(6),CJ,COLA(14),MEMORY(80000),
     2 UZERO(640),XBZERO(640),YQ(640),Z
C******INTEGER ARRAYS AND VARIABLES IN XMP*********************
      INTEGER BNDTYP,COLLEN,COLMAX,FACTOR,
     1 IOERR,IOLOG,ITER1,ITER2,LENMA,LENMI,LENMY,LOOK,M,
     2 MAPA(20),MAPI(20),MAXA,MAXM,MAXN,N,NTYPE2,P,PRINT,
     3 TERMIN,UNBDDQ
      INTEGER BASIS(640),CAND(6),CANDI(14,6),CANDL(6),COLI(14),
     1 ROWTYP,STATUS(1420)
      INTEGER T,TMAX,H,HMAX ,TMX
      REAL INDGOV,NSUBSN,IGP
      READ(5,990)NCOUNT,LEVEL
***************************************************************
*       LEVEL IS THE TYPE OF DEVELOPMENT PATH TO BE           *
*       PURSUED. THERE ARE TWO CHOICES: LEVEL=1               *
*       IMPLIES INDIVIDUAL COUNTRY EFFORTS;                   *
*       LEVEL=2 IMPLIES SOME COOPERATIVE EFFORTS.             *
*        NCOUNT IS THE NUMBER OF INDIVIDUAL COUNTRIES         *
*       OR COUNTRY COMBINATIONS TO BE EXAMINED IN             *
*       THE CURRENT RUN.                                      *
***************************************************************
  990 FORMAT(2I2)
      WRITE(6,1001)
 1001 FORMAT(1H1)
      DO 1000 LK=1,13
```

```
 1000 WRITE(6,1005)
 1005 FORMAT(1H0)
      WRITE(6,1010)
 1010 FORMAT(30X,70H****************************************************
     1******************)
      WRITE(6,1015)
 1015 FORMAT(30X,1H*,29X,11HWEST AFRICA,28X,1H*)
      IF(LEVEL.EQ.1)GO TO 1040
      GO TO 1045
 1040 WRITE(6,1035)
 1035 FORMAT(30X,1H*,27X,14HSINGLE COUNTRY,27X,1H*)
      GO TO 1050
 1045 WRITE(6,1020)
 1020 FORMAT(30X,1H*,28X,13HINTER-COUNTRY,27X,1H*)
 1050 WRITE(6,1025)
 1025 FORMAT(30X,1H*,22X,24HELECTRICITY SUPPLY STUDY,22X,1H*)
      WRITE(6,1010)
      WRITE(6,1001)
      DO 991 ICOUNT=1,NCOUNT
C**********SPECIFY INPUT PARAMETERS TO XMP*******************
      IOERR=6
      IOLOG=6
      MAXA=10850
      MAXM=640
      MAXN=1420
      COLMAX=14
      P=6
      LOOK=200
      FACTOR=50
      LENMY=80000
      PRINT=0
      BNDTYP=1
C******CALL XMP SUBROUTINE***********************************
      CALL XMAPS(BNDTYP,IOERR,LENMA,LENMI,LENMY,MAPA,MAPI,MAXA,
     1 MAXM,MAXN,MEMORY)
C********SET INPUT PARAMETERS LOCAL TO THIS PROGRAM***************:
```

```
C*******CALL SUBROUTINE DBANK OR DBANKS FOR INPUTS**************
      IF(LEVEL.EQ.1)GO TO 1060
      GO TO 1070
 1060 CALL DBANKS
      GO TO 1080
 1070 CALL DBANK
 1080 TMAX=TMX
      DELTAT=8760.00
      Y10=Y110*(3413.00E+06)*DELTAT
      Y20=Y220*(3413.00E+06)*DELTAT
      Y30=Y330*(3413.00E+06)*DELTAT
      E=0.33
      CJMAX=0.217E+10
C******CALCULATE THE NUMBER;OR THE NUMBER OF BASIS VARIABLES ****
      NCOLSA=(JMAX+HMAX)*(5*TMAX+TMAX**2)/2+5*(3*TMAX+TMAX**2)/2
C************DETERMINE THE NUMBER OF ROWS IN THE PROGRAM.THIS IS
C             EQUAL TO THE NUMBER OF CONSTRAINTS(M) PLUS ONE
C             (THE OBJECTIVE FUNCTION ROW)************************
C************FOR THE SAMPLE PROGRAM:**************************
      NTHERM=JMAX*0.5*TMAX*(3+TMAX)
      NHYDRO=HMAX*0.5*TMAX*(3+TMAX)
      M=5*TMAX+2*NTHERM+NHYDRO+HMAX
C*************THEREFORE THE TOTAL NUMER OF ROWS MR IS:***********
C*************HENCE THE COEFFICIENT MATRIX IS DECLARED AS:
C              C(MR,NCOLSA)*************************************
      CALL RHSIDE
C*********N IS THE CURRENT NUMBER OF VARIABLES*************************
      N=0
C***********SET UP OBJECTIVE AND CONSTRAINT COEFFICIENTS UNDER "XJ" VARIABLES****
      L=1
C    ***********THERMAL PLANT AVAILABILITY CONSTRAINT************
      DO 10 J1=1,JMAX
      IF(J1-2)504,505,506
  504 CJ0=CJ1
      AJ=-AJP1
C******THIS REFERS TO THERMAL PLANT 1***********************
```

```
      GO TO 507
  505 CJO=CJ2
      AJ=-AJP2
C******THIS REFERS TO THERMAL PLANT 2************************
      GO TO 507
  506 CJ0=CJ3
      AJ=-AJP3
C******THIS REFERS TO THERMAL PLANT 3************************
  507 J3=0
      J2=1
      LB1=2*TMX+1+(J1-1)*(0.5*TMX*(TMX+1)+TMX)
      LB2=LB1+TMX-J2
      TMAX=J1*TMX
      DO 11 T=L,TMAX
      JX=T
      COLLEN=TMX+2-J2
      IF(J1-1)5,6,7
    5 WRITE(6,8)
    8 FORMAT(20X,37HINFEASIBLE PROBLEM;JMAX LESS THAN ONE)
      GO TO 10
    6 CJ=-CJO*(((1+GJ)**T)/((1+RJ)**T))/CJMAX
      GO TO 16
    7 I=T-(J1-1)*TMX
      CJ=-CJO*(((1+GJ)**I)/((1+RJ)**I))/CJMAX
   16 DO 12 LB=LB1,LB2
      K=LB-LB1+1
C************DEFINE THE ROW NUMBER*************************
      COLI(K)=LB
C************CONSTRAINT MATRIX COEFFICIENT******************
      COLA(K)=AJ
   12 CONTINUE
C************BUDJET CONSTRAINT***************
      LB3=4*TMX+2*NTHERM+NHYDRO+1+J3
      K=K+1
      COLI(K)=LB3
      COLA(K)=-CJ
```

```
      CALL XADDAJ(CJ,COLA,COLI,COLLEN,COLMAX,IOERR,JX,LENMA,LENMY,
     1 MAPA,MEMORY,N)
      LB1=LB2+1
      LB2=LB2+TMX-J2
      J2=J2+1
      J3=J3+1
   11 CONTINUE
      L=TMAX+1
   10 CONTINUE
C******SET UP OBJECTIVE AND CONSTRAINT COEFFICIENTS
C         UNDER "XH" VARIABLES*****************


C******SET UP CONSTRAINT AND OBJECTIVE COEFFICIENTS
C        UNDER "XJ" VARIABLES**********************
C******** USE INPUT PARAMETERS***********************
C         CHO
C         GH
C         RH
C         AH=-AHP
C*****************************************************
C**********DEFINE INPUT PARAMETERS********************************
      JH1=JMAX+1
      JH=JMAX+HMAX
      DO 30 J1=JH1,JH
C************JMAX+2=5 FOR JMAX=3*****************************
      JM=JMAX+2
      IF(J1-JM)500,501,502
  500 CHO=CH1
      AH=-AHP1
C*******THIS REFERS TO HYDRO PLANT 1*************************
      GO TO 503
  501 CHO=CH2
      AH=-AHP2
C*******THIS REFERS TO HYDRO PLANT 2************************
      GO TO 503
```

```
  502 CHO=CH3
      AH=-AHP3
C*******THIS REFERS TO HYDRO PLANT 3*************************
  503 H=J1-JH1+1
C**********DEFINE CONSTRAINT ROW NUMBER RANGE**********************
      J3=0
      J2=0
      LB1=2*TMX+1+NTHERM+(J1-JH1)*(0.5*TMX*(TMX+1)+TMX)
      LB2=LB1+TMX-1-J2
C******************************************************************
      TMAX=J1*TMX
      DO 31 T=L,TMAX
      JX=T
      COLLEN=TMX+2-J2
      I=T-(J1-1)*TMX
      CH=-CHO*(((1+GH)**I)/((1+RH)**I))/CJMAX
      DO 32 LB=LB1,LB2
      K=LB-LB1+1
C************HYDRO PLANTS AVAILABILITY CONSTRAINTS****************
C************DEFINE THE ROW NUMBER*********************************
      COLI(K)=LB
C************CONSTRAINT MATRIX COEFFICIENT*****************
      COLA(K)=AH
   32 CONTINUE
C***********BUDGET CONSTRAINT*************************************
      LB3=4*TMX+2*NTHERM+NHYDRO+1+J3
      K=K+1
      COLI(K)=LB3
      COLA(K)=-CH
C*************HYDRO RESOURCE CONSTRAINT**********************
      LB4=LB3+TMX-J3+J1-JH1
      K=K+1
      COLI(K)=LB4
      COLA(K)=1.0
      CALL XADDAJ(CH,COLA,COLI,COLLEN,COLMAX,IDERR,JX,LENMA,LENMY,
     1 MAPA,MEMORY,N)
```

```
C*****************************************************************
      LB1=LB2+1
      LB2=LB2+TMX-J2-1
      J3=J3+1
      J2=J2+1
   31 CONTINUE
      L=TMAX+1
   30 CONTINUE
C******SET UP OBJECTIVE AND CONSTRAINT COEFFICIENTS
C         UNDER "UJ" VARIABLES**********************

C**********DEFINE INPUT PARAMETERS*****************************
C*********USE INPUT PARAMETERS*********************************
C          PJO
C          PGJ
C          PRJ
C*****************************************************************
      JBLOCK=TMX+1
      LB3=JBLOCK
      LB4=4*TMX+NTHERM+NHYDRO+1
      DO 90 J1=1,JMAX
      IF(J1-2)600,601,602
  600 PJO=PJ1
      GO TO 603
  601 PJO=PJ2
      GO TO 603
  602 PJO=PJ3
  603 DO 85 J5=1,JBLOCK
      J6=J5-2
      IF(J5.GT.2)GO TO 52
      J4=0
      GO TO 54
   52 J4=J5-1
   54 J2=0
      J3=0
      LB1=1
```

```
      IF(J5-2)55,55,60
   55 TMAX=TMAX+TMX
      I=1
      GO TO 65
   60 TMAX=TMAX+TMX+2-J5
      LB1=J4
      I=J4
   65 DO 50 T=L,TMAX
      JX=T
      COLLEN=3
C**********OBJECTIVE FUNCTION COEFFICIENT*******************
      PJ=-PJ0*(((1+PGJ)**I)/((1+PRJ)**I))/CJMAX
C**************************************************************
C **********DEMAND CONSTRAINT*******************************
      K=1
      IF(J5.LE.2)GO TO 72
      NR=J6+J3+1
      GO TO 95
   72 NR=LB1
   95 COLI(K)=NR
      COLA(K)=1.0
C*************THERMAL PLANTS AVAILABILITY CONSTRAINT**********
      K=K+1
      COLI(K)=LB3
      COLA(K)=1.0
C*************TECHNOLOGICAL CONSTRAINTS***********************
      K=K+1
      COLI(K)=LB4
      COLA(K)=1.0
      CALL XADDAJ(PJ,COLA,COLI,COLLEN,COLMAX,IOERR,JX,LENMA,LENMY,
     1 MAPA,MEMORY,N)
C***********RESET ALL THE KOUNTERS****************************
      J3=J3+1
      J2=J2+1
      I=I+1
      LB1=LB1+1
```

```
      LB3=LB3+1
      LB4=LB4+1
   50 CONTINUE
      L=TMAX+1
   85 CONTINUE
   90 CONTINUE
C****SET UP OBJECTIVE AND CONSTRAINT COEFFICIENTS
C      UNDER "UH" VARIABLES**********************
C**********DEFINE INPUT PARAMETERS*****************************
C*******USE INPUT PARAMETERS***********************************
C          PHO
C          PGH
C          PRH
C*****************************************************************
      JBLOCK=TMX+1
      DO 105 H=1,HMAX
      IF(H-2)604,605,606
  604 PHO=PH1
      GO TO 607
  605 PHO=PH2
      GO TO 607
  606 PHO=PH3
  607 DO 110 J5=1,JBLOCK
      J6=J5-2
      IF(J5.GT.2)GO TO 120
      J4=0
      GO TO 125
  120 J4=J5-1
  125 J2=0
      J3=0
      LB1=1
      LB2=TMX+LB1-1
      IF(J5-2)130,130,135
  130 TMAX=TMAX+TMX
      I=1
      GO TO 140
```

```
  135 TMAX=TMAX+TMX+2-J5
      LB1=J4
      I=J4
  140 DO 145 T=L,TMAX
      JX=T
      COLLEN=2
C**********OBJECTIVE FUNCTION COEFFICIENT*******************
      PH=-PHO*(((1+PGH)**I)/((1+PRH)**I))/CJMAX
C*************************************************************
C **********DEMAND CONSTRAINT*******************************
      K=1
      IF(J5.LE.2)GO TO 165
      NR=J6+J3+1
      GO TO 170
  165 NR=LB1
  170 COLI(K)=NR
      COLA(K)=1.0
C***************HYDRO PLANTS AVAILABILITY CONSTRAINT**********
      K=K+1
      COLI(K)=LB3
      COLA(K)=1.0
      CALL XADDAJ(PH,COLA,COLI,COLLEN,COLMAX,IOERR,JX,LENMA,LENMY,
     1 MAPA,MEMORY,N)
C***********RESET ALL THE KOUNTERS*****************************
      J3=J3+1
      J2=J2+1
      I=I+1
      LB1=LB1+1
      LB3=LB3+1
  145 CONTINUE
      L=TMAX+1
  110 CONTINUE
  105 CONTINUE
C******SET UP OBJECTIVE AND COSTRAINT COEFFICIENTS
C        UNDER "N" VARIABLES***************
C**********DEFINE INPUT PARAMETERS*****************************
```

```
C**********USE INPUT PARAMETERS**********************************
C         Y10
C         YG1
C         YR1
C         Y20
C         YG2
C         YR2
C         Y30
C         YG3
C         YR3
C          E
C*****************************************************************
      JBLOCK=TMX+1
C*********JI IS THE NUMBER OF PLANT-FUEL COMBINATIONS********
C*************FOR THE PRESENT FORMULATION************************
      JI=5
      LB412=4*TMX+NTHERM+NHYDRO
      LB43=LB412+(0.5*TMX*(TMX+1)+TMX)
      LB445=LB43
      DO 320 J1=1,JI
      DO 325 J5=1,JBLOCK
      J6=J5-2
      IF(J5.GT.2)GO TO 205
      J4=0
      GO TO 210
  205 J4=J5-1
  210 J2=0
      J3=0
      IF(J5-2)215,215,220
  215 TMAX=TMAX+TMX
      I=1
      GO TO 225
  220 TMAX=TMAX+TMX+2-J5
      I=J4
  225 DO 230 T=L,TMAX
      JX=T
```

```
      COLLEN=2
C**********OBJECTIVE FUNCTION COEFFICIENT*******************
      IF(J1.LE.2)GO TO 235
      GO TO 240
  235 YI=-Y10*(((1+YG1)**I)/((1+YR1)**I))/CJMAX
      GO TO 260
  240 IF(J1.EQ.3)GO TO 245
      GO TO 250
  245 YI=-Y20*(((1+YG2)**I)/((1+YR2)**I))/CJMAX
      GO TO 260
  250 IF(J1.GE.4) GO TO 255
      GO TO 260
  255 YI=-Y30*(((1+YG3)**I)/((1+YR3)**I))/CJMAX
C**************************************************************
C**********RESOURCE AVAILABILITY CONSTRAINT****************
  260 IF(J1.LE.2)GO TO 270
      GO TO 275
  270 LB2=2*TMX+NHYDRO+NTHERM
      IF(J5.LE.2)GO TO 290
      LB3=LB2+2+J3+J6-1-TMX
      GO TO 300
  290 LB3=LB2+1+J3-TMX
      GO TO 300
  275 IF(J1.EQ.3) GO TO 280
      GO TO 285
  280 LB2=3*TMX+NTHERM+NHYDRO
      IF(J5.LE.2) GO TO 295
      LB3=LB2+2+J3+J6-1-TMX
      GO TO 300
  295 LB3=LB2+1+J3-TMX
      GO TO 300
C********J1 IS GREATER THAN OR EQUAL TO 4*********************
  285 LB2=4*TMX+NTHERM+NHYDRO
      IF(J5.LE.2) GO TO 305
      LB3=LB2+2+J3+J6-1-TMX
      GO TO 300
```

```
  305 LB3=LB2+1+J3-TMX
  300 K=1
      COLI(K)=LB3
      COLA(K)=1.0
C*************TECHNOLOGICAL CONSTRAINTS************************
      IF(J1.LE.2)GO TO 310
      IF(J1.EQ.3)GO TO 330
      IF(J1.GE.4)GO TO 335
  330 LB43=LB43+1
      LB4=LB43
      GO TO 315
  335 LB445=LB445+1
      LB4=LB445
      GO TO 315
  310 LB412=LB412+1
      LB4=LB412
  315 K=K+1
      COLI(K)=LB4
      COLA(K)=-E
      CALL XADDAJ(YI,COLA,COLI,COLLEN,COLMAX,IOERR,JX,LENMA,LENMY,
     1 MAPA,MEMORY,N)
C***********RESET ALL THE KOUNTERS******************************
      J3=J3+1
      J2=J2+1
      I=I+1
  230 CONTINUE
      L=TMAX+1
  325 CONTINUE
  320 CONTINUE
C*******************CONTINUATION OF XMP*****************************
C*****START ALL OF THE STRUCTURAL VARIABLES AT THEIR LOWER BOUNDS****
      DO 400 J=1,N
  400 STATUS(J)=0
C*******************************************************************
      CALL XSLACK(B,BASCB,BASIS,BASLB,BASUB,BNDTYP,BOUND,COLA,COLI,
     1 COLMAX,IOERR,LENMA,LENMI,LENMY,M,MAPA,MAPI,MAXM,MAXN,
```

```
     2 MEMORY,N,ROWTYP,STATUS,UZERO,XBZERO,Z)
C************************************************************************
      CALL XPRIML(B,BASCB,BASIS,BASLB,BASUB,BNDTYP,BOUND,CAND,CANDA,
     1 CANDCJ,CANDI,CANDL,COLA,COLI,COLMAX,FACTOR,IOERR,IOLOG,ITER1,
     2 ITER2,LENMA,LENMI,LENMY,LOOK,M,MAPA,MAPI,MAXM,MAXN,MEMORY,
     3 N,NTYPE2,P,PRINT,STATUS,TERMIN,UNBDDQ,UZERO,XBZERO,YQ,Z)
C
C
      WRITE(6,450)TERMIN
  450 FORMAT(18H TERMINATION CODE=,I4)
C
C
      CALL YPRINT(BASIS,BNDTYP,BOUND,IOERR,IOLOG,LENMA,LENMY,M,
     1 MAPA,MAXM,MAXN,MEMORY,N,NTYPE2,STATUS,XBZERO,Z,BASCB)
C
C
  991 CONTINUE
C
C
      STOP
C********END OF MAIN PROGRAM*********************************
C
C
C
      END
```

```
      SUBROUTINE RHSIDE
      INTEGER HMAX,TMX,ROWTYP
      REAL IGP,INDGOV,NSUBSN
      COMMON B(640),ROWTYP(640),TMX,HMAX,CJMAX,DELTAT,JMAX,
     1NTHERM,NHYDRO,CJ1,CJ2,CJ3,CH1,CH2,CH3,PJ1,PJ2,LEVEL,
     2PJ3,AJP1,AJP2,AJP3,AHP1,AHP2,AHP3,Y110,Y220,Y330,YG1,
     3YG2,YG3,YR1,YR2,YR3,XJ10,XJ20,XJ30,XH10,XH20,XH30,
     4XMAX(3),R10,R20,R30,DR1,DR2,DR3,BUDO,DBUD,RHO1,RHO2,
     5RHO3,RHO4,INDGOV(21),IGP(21),EMPLN(21),VTOTAL(21),DARCOS(21),
     6NSUBSN(21),RCON(21),DREV(21),CRF,ID,TELEC(14),LBD1,LBD2,
     7GH,GJ,PGJ,PGH,PH1,PH2,PH3,PRH,PRJ,RH,RJ,XMX(3)
      DIMENSION SUM(3),SUMH(3)
C******DEFINE INPUT PARAMETERS******************************
      SUM(1)=AJP1*XJ10*DELTAT
      SUM(2)=AJP2*XJ20*DELTAT
      SUM(3)=AJP3*XJ30*DELTAT
      SUMH(1)=AHP1*XH10*DELTAT
      SUMH(2)=AHP2*XH20*DELTAT
      SUMH(3)=AHP3*XH30*DELTAT
C**********************************************************
C******DEMAND CONSTRAINT*************************************
C  THIS IS DONE BY CALLING FCAST IN DBANKS OR DBANK
C**************************************************************
C*******THERMAL PLANTS AVAILABILITY CONSTRAINT*******************
      NBLOCK=NTHERM/JMAX
      MK=(JMAX+HMAX)*(5*TMX+TMX**2)/2+5*(3*TMX+TMX**2)/2
      LB1=TMX+1
      LB2=2*TMX
      DO 10 J1=1,JMAX
      DO 55 L=LB1,LB2
      B(L)=SUM(J1)
      ROWTYP(L)=+1
   55 CONTINUE
      LB1=LB2+1
      LB2=LB2+NBLOCK-TMX
      DO 60 L=LB1,LB2
```

```
      B(L)=0.
      ROWTYP(L)=+1
   60 CONTINUE
      LB1=LB2+1
      LB2=LB2+TMX
   10 CONTINUE
C*****************************************************************
C********HYDRO PLANTS AVAILABILITY CONSTRAINT**********************
      DO 15 J1=1,HMAX
      DO 65 L=LB1,LB2
      B(L)=SUMH(J1)
      ROWTYP(L)=+1
   65 CONTINUE
      LB1=LB2+1
      LB2=LB2+NBLOCK-TMX
      DO 70 L=LB1,LB2
      B(L)=0.
      ROWTYP(L)=+1
   70 CONTINUE
      LB1=LB2+1
      LB2=LB2+TMX
   15 CONTINUE
C*********************************************************************
C********RESOURCE AVAILABILITY CONSTRAINT*****************************
C***********FUEL TYPE I=1*******************************************
      DO 20 L=LB1,LB2
      I=L-LB1+1
      B(L)=R10*((1+DR1)**I)/(3413.00E+06)
      ROWTYP(L)=+1
   20 CONTINUE
C**********FUEL TYPE I=2*********************************************
      LB1=LB2+1
      LB2=LB2+TMX
      DO 25 L=LB1,LB2
      I=L-LB1+1
      B(L)=R20*((1+DR2)**I)/(3413.00E+06)
```

```
      ROWTYP(L)=+1
   25 CONTINUE
C**********FUEL TYPE I=3******************************************
      LB1=LB2+1
      LB2=LB2+TMX
      DO 30 L=LB1,LB2
      I=L-LB1+1
      B(L)=R30*((1+DR3)**I)/(3413.00E+06)
      ROWTYP(L)=+1
   30 CONTINUE
C***************************************************************
C*******TECHNOLOGICAL CONSTRAINT*********************************
      LB1=LB2+1
      LB2=LB2+NTHERM
      DO 35 L=LB1,LB2
      B(L)=0.
      ROWTYP(L)=+1
   35 CONTINUE
C****************************************************************
C********BUDGET CONSTRAINT***************************************
      LB1=LB2+1
      LB2=LB2+TMX
      LBD1=LB1+MK
      LBD2=LB2+MK
      DO 40 L=LB1,LB2
      I=L-LB1+1
      B(L)=BUD0*((1+DBUD)**I)*DELTAT/CJMAX
      ROWTYP(L)=+1
   40 CONTINUE
C***************************************************************
C********HYDRO RESOURCE CONSTRAINT*******************************
      LB1=LB2+1
      K=LB2
      LB2=LB2+HMAX
      DO 45 L=LB1,LB2
      LK=L-K
```

```
      B(L)=XMAX(LK)*DELTAT
      ROWTYP(L)=+1
   45 CONTINUE
      RETURN
C***********END OF SUBROUTINE RHSIDE*****************************
C
C
C
      END
```

```
      SUBROUTINE FCAST
      COMMON B(640),ROWTYP(640),TMX,HMAX,CJMAX,DELTAT,JMAX,
     1NTHERM,NHYDRO,CJ1,CJ2,CJ3,CH1,CH2,CH3,PJ1,PJ2,LEVEL,
     2PJ3,AJP1,AJP2,AJP3,AHP1,AHP2,AHP3,Y110,Y220,Y330,YG1,
     3YG2,YG3,YR1,YR2,YR3,XJ10,XJ20,XJ30,XH10,XH20,XH30,
     4XMAX(3),R10,R20,R30,DR1,DR2,DR3,BUDO,DBUD,RHO1,RHO2,
     5RHO3,RHO4,INDGOV(21),IGP(21),EMPLN(21),VTOTAL(21),DARCOS(21),
     6NSUBSN(21),RCON(21),DREV(21),CRF,ID,TELEC(14),LBD1,LBD2,
     7GH,GJ,PGJ,PGH,PH1,PH2,PH3,PRH,PRJ,RH,RJ,XMX(3)
      INTEGER ROWTYP,HMAX,TMX
      REAL INDGOV,IGP,IGPST,INDST,NSUBSN,NSUBST
      DIMENSION YEAR(21),BI0(7),BI1(7),BI2(7),BI3(7),BRO(7),
     1                   BR1(7),BR2(7),BR3(7)
      DATA BI0(4),BI1(4),BI2(4),BI3(4),BRO(4),BR1(4),BR2(4),BR3(4)/
     1 -0.851,0.655,-0.752,0.451,-14.744,-1.240,1.236,0.441/
      DATA BI0(5),BI1(5),BI2(5),BI3(5),BRO(5),BR1(5),BR2(5),BR3(5)/
     1 6.489,0.890,-0.679,0.839,2.881,-0.310,0.627,0.285/
      DATA BI0(6),BI1(6),BI2(6),BI3(6),BRO(6),BR1(6),BR2(6),BR3(6)/
     111.434,0.336,-0.701,0.00,-2.503,-1.8577,0.986,0.00/
      DATA BI0(3),BI1(3),BI2(3),BI3(3),BRO(3),BR1(3),BR2(3),BR3(3)/
     1-5.307,0.494,-0.661,1.303,4.487,-0.783,0.279,0.699/
      DATA BI0(2),BI1(2),BI2(2),BI3(2),BRO(2),BR1(2),BR2(2),BR3(2)/
     111.822,0.522,-0.459,0.00,-3.906,-0.195,1.066,0.00/
      DATA BI0(7),BI1(7),BI2(7),BI3(7),BRO(7),BR1(7),BR2(7),BR3(7)/
     1-99.487,4.88246,-0.84988,0.00,8.75892,-0.29105,0.00,0.97287/
C*********INITIALISE DEPENDENT VARIABLES*****************
      DO 5 I=3,21
      RCON(I)=0.0
    5 INDGOV(I)=0.0
      YEAR(1)=1976.
      YEAR(2)=1977.
      DO 10 I=2,19
      M=I+1
      YEAR(M)=YEAR(I)+1
      TIME=YEAR(M)
C*****SUPPLY PROJECTIONS OF INDEPENDENT VARIABLES THRU. SIMPLE
```

```
C     GROWTH RATES OR REGRESSION WITH YEAR*****************
C
C
      Z=ALOG(TIME)
      IF(ID-4)205,200,210
C        NIGER PROJECTIONS
C***********INDUSTRIAL INDEPENDENT VARIABLES**********
  200 X1=-1026.20839+138.51485*Z
      VTOTAL(M)=EXP(X1)
      X2=828.19283-108.79647*Z
      IGP(M)=EXP(X2)
      X3=-1274.05306+169.04703*Z
      EMPLN(M)=EXP(X3)
C*********RESIDENTIAL INDEPENDENT VARIABLES*******************
      IF(TIME-1985.0)40,40,50
   40 DARCOS(M)=2183.207-1.097*YEAR(M)
      GO TO 60
   50 DARCOS(M)=2183.207-1.097*1985.0
   60 X1=-363.443+51.207*Z
      DREV(M)=EXP(X1)
      X2=-1429.386+189.589*Z
      NSUBSN(M)=EXP(X2)
      GO TO 10
  205 IF(ID-2)400,500,600
C        BENIN PROJECTIONS
  400 X1=-1518.49+203.46*Z
      X2=-8.38124+1.02593*X1
      INDGOV(M)=EXP(X2)
C   INDGOV IS THE TOTAL ELECTRICITY CONSUMPTION>********
      RCON(M)=0.0
      GO TO 10
C
C
C        GHANA PROJECTIONS
C*********INDUSTRIAL INDEPENDENT VARIABLES****************
  500 X2=-1442.163+192.716*Z
```

```
      VTOTAL(M)=EXP(X2)
      IGP(M)=IGP(2)
      EMPLN(M)=0.0
C**********RESIDENTIAL INDEPENDENT VARIABLES*************
      X1=-1102.402+148.156*Z
      DREV(M)=EXP(X1)
      DARCOS(M)=DARCOS(2)
      NSUBSN(M)=0.0
C
C
      GO TO 10
C        IVORY COAST PROJECTIONS
C*********INDUSTRIAL INDEPENDENT VARIABLES*****************
  600 IGP(M)=435.574-0.218*TIME
      X1=-1521.681+203.824*Z
      VTOTAL(M)=EXP(X1)
      EMPLN(M)=-5.315E+06+2716.90*TIME
C********RESIDENTIAL SECTOR**********************
      DARCOS(M)=928.127-0.465*TIME
      X1=-2217.577+294.056*Z
      NSUBSN(M)=EXP(X1)
      X2=-944.774+128.017*Z
      DREV(M)=EXP(X2)
C
C
      GO TO 10
  210 IF(ID-6)100,700,800
C       NIGERIA PROJECTIONS
C*********INDUSTRIAL INDEPENDENT VARIABLES**************
  100 EMPLN(M)=-2.082E+07+10666.0*TIME
      X1=-327.532+43.838*Z
      VTOTAL(M)=EXP(X1)
      IF(TIME-1985.0)110,110,105
  110 IGP(M)=IGP(2)
      GO TO 120
  105 IGP(M)=0.99*IGP(2)
```

```
C**********RESIDENTIAL SECTOR INDEPENDENT VARIABLES********
  120 X2=-2463.173+326.152*Z
      NSUBSN(M)=EXP(X2)
      X3=-1228.166+164.8995*Z
      DREV(M)=EXP(X3)
      DARCOS(M)=DARCOS(2)
      GO TO 10
C         TOGO PROJECTIONS
C**********INDUSTRIAL INDEPENDENT VARIABLES********************
  700 X1=-1549.286+207.407*Z
      VTOTAL(M)=EXP(X1)
      IGP(M)=IGP(2)
      EMPLN(M)=0.0
C************RESIDENTIAL INDEPENDENT VARIABLES*********
      DARCOS(M)=DARCOS(2)
      DREV(M)=DREV(I)*1.025
      NSUBSN(M)=0.0
C
C
      GO TO 10
C         UPPER VOLTA PROJECTIONS
C*********INDUSTRIAL INDEPENDENT VARIABLES******************
  800 X1=-270.85841+38.91672*Z
      VTOTAL(M)=EXP(X1)
      IGP(M)=IGP(I)*0.95
      EMPLN(M)=0.0
C*********RESIDENTIAL INDEPENDENT VARIABLES*****************
      DARCOS(M)=0.95*DARCOS(I)
      DREV(M)=0.0
      X2=-1676.13834+222.09950*Z
      NSUBSN(M)=EXP(X2)
      GO TO 10
C
C
C
C    END OF PROJECTIONS OF INDEPENDENT VARIABLES***************
```

```
   10 CONTINUE
C
      IF(ID.EQ.1)GO TO 405
C*********PRUJECT DEPENDENT VARIABLES*************************
      DO 15 I=2,19
      M=I+1
      J=I-1
C
C**********INDUSTRIAL SECTOR DEPENDENT VARIABLE*****************
      VTST=VTOTAL(M)-RHO1*VTOTAL(I)-RHO2*VTOTAL(J)
      IGPST=IGP(M)-RHO1*IGP(I)-RHO2*IGP(J)
      EMPLST=EMPLN(M)-RHO1*EMPLN(I)-RHO2*EMPLN(J)
      IF(ID.EQ.2 .OR. ID.EQ.6 .OR. ID.EQ.7)GO TO 750
      GO TU 760
  750 Y=BIO(ID)+BI1(ID)*ALOG(VTST)+BI2(ID)*ALOG(IGPST)
      GO TO 755
  760 Y=BIO(ID)+BI1(ID)*ALOG(VTST)+BI2(ID)*ALOG(IGPST)
     1      +BI3(ID)*ALOG(EMPLST)
  755 INDST=EXP(Y)
      INDGOV(M)=INDST+RHO1*INDGOV(I)+RHO2*INDGOV(J)
C*********RESIDENTIAL SECTOR DEPENDENT VARIABLE****************
      DARST=DARCOS(M)-RHO3*DARCOS(I)-RHO4*DARCOS(J)
      DREVST=DREV(M)-RHO3*DREV(I)-RHO4*DREV(J)
      NSUBST=NSUBSN(M)-RHO3*NSUBSN(I)-RHO4*NSUBSN(J)
      IF(ID.EQ.2 .OR. ID.EQ.6)GO TO 765
      GO TO 770
  765 Y=BRO(ID)+BR1(ID)*ALOG(DARST)+BR2(ID)*ALOG(DREVST)
      GO TO 775
  770 IF(ID.EQ.7)GO TO 771
      GO TO 772
  771 Y=BRO(ID)+BR1(ID)*ALOG(DARST)+BR3(ID)*ALOG(NSUBST)
      GO TO 775
  772 Y=BRO(ID)+BR1(ID)*ALOG(DARST)+BR2(ID)*ALOG(DREVST)
     1       +BR3(ID)*ALOG(NSUBST)
  775 RCST=EXP(Y)
      RCON(M)=RCST+RHO3*RCON(I)+RHO4*RCON(J)
```

```
   15 CONTINUE
C*********WRITE OUT PROJECTIONS***************************************
  405 WRITE(6,17)ID
   17 FORMAT(1H1,25X,47H**********ELECTRICAL ENERGY STUDY:COUNTRY ID = ,
     1I2,11H **********)
      WRITE(6,803)
  803 FORMAT(1H0,38X,20HFOR THIS SIMULATION:)
      WRITE(6,804)XH10
  804 FORMAT(1H0,44X,10HXH10     = ,E9.3,3H GW)
      DO 801 KH=1,HMAX
  801 WRITE(6,802)KH,XMX(KH)
  802 FORMAT(1H0,44X,5HXMAX(,I1,4H) = ,E9.3,3H GW)
      IF(ID.EQ.1)GO TO 415
      WRITE(6,11)
   11 FORMAT(1H0,40X,34HINDUSTRIAL ELECTRICITY PROJECTIONS)
      WRITE(6,13)
   13 FORMAT(1H0,21X,4HYEAR,4X,9HCONS'TION,7X,6HOUTPUT,9X,5HPRICE,12X,9H
     1EMPL'MENT,3X,7HCHANGE)
      PCHI=0.00
      WRITE(6,25)YEAR(1),INDGOV(1),VTOTAL(1),IGP(1),EMPLN(1),PCHI
      DO 20 I=1,19
      M=I+1
      PCHI=((INDGOV(M)/INDGOV(I))-1.)*100.0
   20 WRITE(6,25)YEAR(M),INDGOV(M),VTOTAL(M),IGP(M),EMPLN(M),PCHI
C********************************************************************

      WRITE(6,12)
   12 FORMAT(1H1,40X,35HRESIDENTIAL ELECTRICITY PROJECTIONS)
      WRITE(6,14)
   14 FORMAT(1H0,21X,4HYEAR,4X,9HCONS'TION,7X,6HINCOME,9X,5HPRICE,13X,6H
     1SUBS.,5X,7HCHANGE)
      PCHR=0.00
      WRITE(6,25)YEAR(1),RCON(1),DREV(1),DARCOS(1),NSUBSN(1),PCHR
      DO 30 I=1,19
      M=I+1
      PCHR=((RCON(M)/RCON(I))-1.)*100.0
```

```
   30 WRITE(6,25)YEAR(M),RCON(M),DREV(M),DARCOS(M),NSUBSN(M),PCHR
   25 FORMAT(1H0,20X,F6.1,2X,E10.4,5X,E10.4,F15.7,F18.2,F8.1)
  415 IF(ID.EQ.1)GO TO 68
      GO TO 420
   68 WRITE(6,425)
  425 FORMAT(1H0,15X,44HTOTAL COUNTRY ELECTRICITY PROJECTIONS:KW-HRS)
      GO TO 430
  420 WRITE(6,66)
   66 FORMAT(1H1,15X,44HTOTAL COUNTRY ELECTRICITY PROJECTIONS:KW-HRS)
  430 DO 65 I=1,14
      ELEC=RCON(I)+INDGOV(I)
      TELEC(I)=TELEC(I)+ELEC
      IF(LEVEL.EQ.1)GO TO 500
      GO TO 80
  500 IF(I.GT.4) GO TO 70
      GO TO 80
   70 K=I-4
C*************CONVERT TOTAL DEMAND INTO GIGAWATT HOURS**************
      B(K)=ELEC*1.0E-06
      ROWTYP(K)=-1
   80 WRITE(6,85)YEAR(I),ELEC
   65 CONTINUE
   85 FORMAT(1H0,20X,F6.1,E20.4)
      WRITE(6,67)
   67 FORMAT(1H1)
      RETURN
C********END OF SUBROUTINE FCAST****************************
C
C
C
      END
```

```
      SUBROUTINE YPRINT(BASIS,BNDTYP,BOUND,IOERR,IOLOG,
     X LENMA,LENMY,M,MAPA,MAXM,MAXN,MEMORY,N,NTYPE2,
     X STATUS,XBZERO,Z,BASCB)
C
C
C
C     *******PARAMETERS
      COMMON B(640),ROWTYP(640),TMX,HMAX,CJMAX,DELTAT,JMAX,
     1NTHERM,NHYDRO,CJ1,CJ2,CJ3,CH1,CH2,CH3,PJ1,PJ2,
     2PJ3,AJP1,AJP2,AJP3,AHP1,AHP2,AHP3,Y110,Y220,Y330,YG1,
     3YG2,YG3,YR1,YR2,YR3,XJ10,XJ20,XJ30,XH10,XH20,XH30,
     4XMAX(3),R10,R20,R30,DR1,DR2,DR3,BUDO,DBUD,RHO1,RHO2,
     5RHO3,RHO4,INDGOV(21),IGP(21),EMPLN(21),VTOTAL(21),DARCOS(21),
     6NSUBSN(21),RCON(21),DREV(21),CRF,ID,LBD1,LBD2,
     7GH,GJ,PGJ,PGH,PH1,PH2,PH3,PRH,PRJ,RH,RJ,NVAR,
     8ATH1(10),ATH2(10),ATH3(10),AHYD1(10),AHYD2(10),AHYD3(10),
     9ENGT1(65),ENGT2(65),ENGT3(65),OPCT1(65),OPCT2(65),OPCT3(65),
     1ENGH1(65),ENGH2(65),ENGH3(65),OPCH1(65),OPCH2(65),OPCH3(65),
     2FC11(65),FC12(65),FC22(65),FC32(65),FC33(65),CAPJ1(10),
     3CAPJ2(10),CAPJ3(10),CAPH1(10),CAPH2(10),CAPH3(10)
      INTEGER TMX,HMAX,JMAX
      INTEGER LENMA,LENMY,MAXM,MAXN
      REAL BOUND,MEMORY(LENMY),XBZERO(MAXM),Z,IGP
      INTEGER BNDTYP,IOERR,IOLOG,M,MAPA(LENMA),N,NTYPE2
      INTEGER BASIS(MAXM),STATUS(MAXN)
      REAL LJ,UJ,VALUE,BASCB(MAXM),INDGOV,NSUBSN
      INTEGER IX,J
C     ******BODY OF PROGRAM*******************************************
      WRITE(IOLOG,901)
  901 FORMAT(1H1,28H   YPRINT...CURRENT SOLUTION)
      WRITE(IOLOG,902)M,N
  902 FORMAT(1H0,I6,20H LINEAR CONSTRAINTS,,5X,I6,
     X 10H VARIABLES)
      WRITE(IOLOG,903)
  903 FORMAT(1H0,25H  AN SB FOLLOWING STATUS ,
     X 32HINDICATES A SUPER-BASIC VARIABLE)
```

```
C
C
C
C     PRINT OUT THE VALUES OF ALL THE BASIC VARIABLES
C     AND ALL OF THE NON-BASIC VARIABLES THAT ARE AT NON-ZERO
C     BOUNDS.
C     FIRST DEFINE PARAMETERS LOCAL TO THIS PROGRAM
C******DEFINE A CAPITAL RECOVERY FACTOR***************
C
C
      NVAR=TMX+0.5*TMX*(TMX+1)
      NVAR1=TMX*JMAX
      NVAR2=TMX*HMAX
      L1=NVAR1
      L11=L1+1
      L2=L1+NVAR2
      L22=L2+1
      L3=L2+JMAX*NVAR
      L33=L3+1
      L4=L3+HMAX*NVAR
      L44=L4+1
      L5=L4+2*NVAR
      L55=L5+1
      L6=L5+NVAR
      L66=L6+1
      L7=L6+2*NVAR
      L77=L7+1
C*********************************************************************
      DO 280 J=1,N
      VALUE=0.0
      IF(STATUS(J))200,250,260
  200 IF(STATUS(J).EQ.-2 .OR. STATUS(J).EQ.-3)GO TO 230
      IF(STATUS(J).EQ.-4)GO TO 250
C
C     HERE FOR NON-BASIC VARIABLES AT THEIR UPPER BOUNDS.
      IF(BNDTYP.LT.3) GO TO 210
```

```
      CALL XGETUB(BNDTYP,IOERR,J,LENMA,LENMY,LJ,MAPA,MEMORY,UJ)
      VALUE=UJ
      GO TO 290
  210 IF(BNDTYP.LT.2)GO TO 220
      IF(J.GT.NTYPE2)GO TO 220
      VALUE=BOUND
      GO TO 290
  220 WRITE(IOLOG,905) J
  905 FORMAT(16H ERROR: VARIABLE,I6,16H IS AT ITS UPPER,
     X 20H BOUND OF +INFINITY.)
      GO TO 280
C
C
C     HERE FOR FREE AND ARTIFICIAL VARIABLES.
  230 DO 240 I=1,M
      IF(BASIS(I) .NE. J)GO TO 240
      VALUE=XBZERO(I)
      GO TO 290
  240 CONTINUE
      GO TO 280
C
C     HERE FOR NON-BASIC VARIABLES AT THEIR LOWER BOUNDS.
  250 IF(BNDTYP .NE. 4) GO TO 270
      CALL XGETUB(BNDTYP,IOERR,J,LENMA,LENMY,LJ,MAPA,MEMORY,UJ)
      IF(LJ .EQ. 0.0)GO TO 280
      VALUE=LJ
      GO TO 290
C
C     HERE FOR THE BASIC VARIABLES (EXCEPT FREE AND ARTIFICIALS)
  260 IX=STATUS(J)
      VALUE=XBZERO(IX)
      IF(IX .LE. M)GO TO 270
C
C     HERE FOR SUPER-BASIC VARIABLES.
      WRITE(IOLOG,908)J,STATUS(J),VALUE
  908 FORMAT(1X,I10,5X,I10,1X,2HSB,2X,E15.8)
```

```
      GO TO 280
C
C
  270 IF(J.LE.L1)GO TO 500
      IF(J.GT.L1 .AND. J.LE.L2)GO TO 550
      IF(J.GT.L2 .AND. J.LE.L3)GO TO 600
      IF(J.GT.L3 .AND. J.LE.L4)GO TO 650
      IF(J.GT.L4 .AND. J.LE.L5)GO TO 700
      IF(J.GT.L5 .AND. J.LE.L6)GO TO 750
      IF(J.GT.L6 .AND. J.LE.L7)GO TO 800
      IF(J.GT.L7)GO TO 950
  500 IF(J.EQ.1)GO TO 510
      GO TO 505
  510 WRITE(6,618)
      WRITE(6,515)
      WRITE(6,516)
  515 FORMAT(1H0,6X,8HVARIABLE,5X,6HSTATUS,6X,8HLP.VALUE,8X,17HCAPACITY
     1OF PLANT,5X,13HCOST OF PLANT,6X,14HANNUAL PAYMENT)
  516 FORMAT(53X,4H(MW),14X,9H(DOLLARS),10X,9H(DOLLARS))
  505 XJ=(VALUE/DELTAT)*1.0E+03
      CC=-(VALUE/DELTAT)*BASCB(IX)*CJMAX
      ANPAY=CRF*CC
      K2=TMX*2
      IF(J-K2)5,10,15
    5 IF(J-TMX)20,20,10
   20 K=J
      ATH1(K)=ANPAY
      CAPJ1(K)=XJ
      GO TO 25
   10 K=J-TMX
      ATH2(K)=ANPAY
      CAPJ2(K)=XJ
      GO TO 25
   15 K=J-K2
      ATH3(K)=ANPAY
      CAPJ3(K)=XJ
```

```
 25 IF(VALUE.EQ.0.0)GO TO 280
    WRITE(6,506)J,STATUS(J),VALUE,XJ,CC,ANPAY
    GO TO 280
550 IF(J.EQ.L11)GO TO 555
    GO TO 565
555 WRITE(6,560)
    WRITE(6,515)
    WRITE(6,516)
560 FORMAT(1H1,38H*****HYDRO PLANTS CHARACTERISTICS*****)
565 IF(NVAR2.EQ.0)GO TO 280
    XH=(VALUE/DELTAT)*1.0E+03
    CC=-(VALUE/DELTAT)*BASCB(IX)*CJMAX
    ANPAY=CRF*CC
    K3=L1+TMX
    K4=K3+TMX
    IF(J-K4)30,35,40
 30 IF(J-K3)45,45,35
 45 K=J-L1
    AHYD1(K)=ANPAY
    CAPH1(K)=XH
    GO TO 55
 35 K=J-K3
    AHYD2(K)=ANPAY
    CAPH2(K)=XH
    GO TO 55
 40 K=J-K4
    AHYD3(K)=ANPAY
    CAPH3(K)=XH
 55 IF(VALUE.EQ.0.0)GO TO 280
    WRITE(6,506)J,STATUS(J),VALUE,XH,CC,ANPAY
    GO TO 280
506 FORMAT(1H0,8X,I4,8X,I4,4X,E14.8,6X,E14.8,6X,E14.8,6X,E14.8)
600 IF(J.EQ.L22)GO TO 605
    GO TO 610
605 WRITE(6,618)
    WRITE(6,615)
```

```
      WRITE(6,616)
  615 FORMAT(1H0,3X,8HVARIABLE,2X,6HSTATUS,5X,8HLP.VALUE,3X,15HENERGY PR
     1ODUCED,3X,17HCAP.OF PLANT USED,3X,14HOPERATING COST,5X,11HENERGY C
     2OST)
  616 FORMAT(38X,8H(KW-HRS),13X,4H(MW),12X,9H(DOLLARS),8X,13H(CENTS/KW-H
     1R))

  618 FORMAT(1H1,40H*****THERMAL PLANTS CHARACTERISTICS*****)
  610 ENERGY=VALUE*1.0E+06
      UJU=(VALUE/DELTAT)*1.0E+03
      CC=-(VALUE/DELTAT)*BASCB(IX)*CJMAX
      L2J1=L2+NVAR
      L2J2=L2J1+NVAR
      IF(J.LE.L2J1)GO TO 60
      IF(J.GT.L2J1 .AND. J.LE.L2J2)GO TO 65
      IF(J.GT.L2J2)GO TO 70
   60 K=J-L2
      ENGT1(K)=ENERGY
      OPCT1(K)=CC
      GO TO 75
   65 K=J-L2J1
      ENGT2(K)=ENERGY
      OPCT2(K)=CC
      GO TO 75
   70 K=J-L2J2
      ENGT3(K)=ENERGY
      OPCT3(K)=CC
   75 IF(VALUE.EQ.0.0)GO TO 280
      UCOST=(CC/ENERGY)*100.0
      WRITE(6,612)J,STATUS(J),VALUE,ENERGY,UJU,CC,UCOST
      GO TO 280
  612 FORMAT(1H0,5X,I4,5X,I4,2X,E14.8,1X,E14.8,5X,E14.8,5X,E14.8,6X,F6.2
     1)
  650 IF(J.EQ.L33)GO TO 655
      GO TO 660
  655 WRITE(6,560)
```

```
      WRITE(6,615)
      WRITE(6,616)
  660 ENERGY=VALUE*1.0E+06
      UHU=(VALUE/DELTAT)*1.0E+03
      CC=-(VALUE/DELTAT)*BASCB(IX)*CJMAX
      L3H1=L3+NVAR
      L3H2=L3H1+NVAR
      IF(J.LE.L3H1)GO TO 80
      IF(J.GT.L3H1 .AND. J.LE.L3H2)GO TO 90
      IF(J.GT.L3H2)GO TO 95
   80 K=J-L3
      ENGH1(K)=ENERGY
      OPCH1(K)=CC
      GO TO 85
   90 K=J-L3H1
      ENGH2(K)=ENERGY
      OPCH2(K)=CC
      GO TO 85
   95 K=J-L3H2
      ENGH3(K)=ENERGY
      OPCH3(K)=CC
   85 IF(VALUE.EQ.0.0)GO TO 280
      UCOST=(CC/ENERGY)*100.0
      WRITE(6,612)J,STATUS(J),VALUE,ENERGY,UHU,CC,UCOST
      GO TO 280
  700 IF(J.EQ.L44)GO TO 705
      GO TO 710
  705 WRITE(6,715)
      WRITE(6,716)
  715 FORMAT(1H1,39H******NATURAL GAS CHARACTERISTICS******)
      WRITE(6,717)
  716 FORMAT(1H0,6X,8HVARIABLE,6X,6HSTATUS,4X,8HLP.VALUE,7X,9HFUEL USED,
     14X,12HCOST OF FUEL,2X,9HUNIT COST)
  717 FORMAT(45X,11H(CU.METRES),5X,9H(DOLLARS),3X,9H(DOLLARS))
  710 FUEL=VALUE*(3413.00E+06)*23.8/(1.035E+06)
      COST=-(VALUE/DELTAT)*BASCB(IX)*CJMAX
```

```
      L4N1=L4+NVAR
      IF(J.LE.L4N1)GO TO 100
      K=J-L4N1
      FC12(K)=COST
      GO TO 105
  100 K=J-L4
      FC11(K)=COST
  105 IF(VALUE.EQ.0.0)GO TO 280
      UCOST=COST/FUEL
      WRITE(6,711)J,STATUS(J),VALUE,FUEL,COST,UCOST
      GO TO 280
  711 FORMAT(1H0,8X,I4,9X,I4,2X,E14.8,1X,E14.8,1X,E14.8,2X,F7.3)
  750 IF(J.EQ.L55)GO TO 755
      GO TO 760
  755 WRITE(6,756)
      WRITE(6,716)
      WRITE(6,757)
  756 FORMAT(1H1,40H**********COAL CHARACTERISTICS**********)
  757 FORMAT(46X,8H(TONNES),6X,9H(DOLLARS))
  760 FUEL=VALUE*(3413.00E+06)/(2.80E+07)
      COST=-(VALUE/DELTAT)*BASCB(IX)*CJMAX
      K=J-L5
      FC22(K)=COST
      IF(VALUE.EQ.0.0)GO TO 280
      UCOST=COST/FUEL
      WRITE(6,711)J,STATUS(J),VALUE,FUEL,COST,UCOST
      GO TO 280
  800 IF(J.EQ.L66)GO TO 805
      GO TO 810
  805 WRITE(6,806)
      WRITE(6,716)
      WRITE(6,807)
  806 FORMAT(1H1,40H***********OIL CHARACTERISTICS**********)
  807 FORMAT(46X,9H(BARRELS),5X,9H(DOLLARS))
  810 FUEL=VALUE*(3413.00E+06)/(5.80E+06)
      COST=-(VALUE/DELTAT)*BASCB(IX)*CJMAX
```

```
      L6N3=L6+NVAR
      IF(J.LE.L6N3)GO TO 110
      K=J-L6N3
      FC33(K)=COST
      GO TO 115
  110 K=J-L6
      FC32(K)=COST
  115 IF(VALUE.EQ.0.0)GO TO 280
      UCOST=COST/FUEL
      WRITE(6,711)J,STATUS(J),VALUE,FUEL,COST,UCOST
      GO TO 280
  950 IF(J.EQ.L77)GO TO 951
      GO TO 987
  951 WRITE(6,953)
      WRITE(6,954)
  953 FORMAT(1H1,20X,36H***********OTHER VARIABLES**********)
  954 FORMAT(1H0,6X,8HVARIABLE,7X,6HSTATUS,11X,5HVALUE)
      GO TO 952
  987 IF(J.GE.LBD1 .AND. J.LE.LBD2)GO TO 985
      GO TO 952
  985 VALUE=(VALUE/DELTAT)*CJMAX
      IF(J.EQ.LBD1)GO TO 980
      GO TO 952
  980 WRITE(6,981)
  981 FORMAT(1H0,8X,48H********SLACK BUDGET CONSTRAINT VARIABLES*******)
      GO TO 952
  952 WRITE(6,955)J,STATUS(J),VALUE
      IF(J.EQ.LBD2)GO TO 982
      GO TO 280
  982 WRITE(6,986)
  986 FORMAT(8X,50H*****END OF SLACK BUDGET CONSTRAINT VARIABLES*****)
  955 FORMAT(8X,I4,10X,I4,6X,E14.8)
      GO TO 280
C*********************************************************************
C
  290 IF(VALUE.EQ.0.0)GO TO 280
```

```
      WRITE(IOLOG,906)J,STATUS(J),VALUE
  906 FORMAT(1H0,1X,I10,5X,I10,5X,E15.8)
C
C
  280 CONTINUE
C
C
C      PRINT THE OBJECTIVE FUNCTION VALUE
      OBJF=-(Z/DELTAT)*CJMAX
      WRITE(6,900)
  900 FORMAT(1H0,14X,12HLP OBJECTIVE,9X,14HTRUE OBJECTIVE)
      WRITE(6,970)Z,OBJF
  970 FORMAT(13X,E14.8,8X,E14.8)
      WRITE(6,971)
  971 FORMAT(1H1)
C*********************************************************************
C
C
      RETURN
C**********************LAST CARD OF YPRINT****************
      END
```

```
 SUBROUTINE DBANK
 COMMON B(640),ROWTYP(640),TMX,HMAX,CJMAX,DELTAT,JMAX,
1NTHERM,NHYDRO,CJ1,CJ2,CJ3,CH1,CH2,CH3,PJ1,PJ2,LEVEL,
2PJ3,AJP1,AJP2,AJP3,AHP1,AHP2,AHP3,Y110,Y220,Y330,YG1,
3YG2,YG3,YR1,YR2,YR3,XJ10,XJ20,XJ30,XH10,XH20,XH30,
4XMAX(3),R10,R20,R30,DR1,DR2,DR3,BUD0,DBUD,RHO1,RHO2,
5RHO3,RHO4,INDGOV(21),IGP(21),EMPLN(21),VTOTAL(21),DARCOS(21),
6NSUBSN(21),RCON(21),DREV(21),CRF,ID,TELEC(14),LBD1,LBD2,
7GH,GJ,PGJ,PGH,PH1,PH2,PH3,PRH,PRJ,RH,RJ,XMX(3)
 DIMENSION COSTJ(7,3),COSTH(7,3),COSPJ(7,3),COSPH(7,3),
1HMX(7),FAJP(7,3),FAHP(7,3),Y(7,3),YG(7,3),XJI(7,3),XHI(7,3),
2RI(7,3),DR(7,3),BUDJ(7),DBUI(7),RHO(7,4),CONIND(7,2),
3PRIND(7,2),EMPL(7,2),OUTPUT(7,2),PRIRES(7,2),INCOME(7,2),
4SUBS(7,2),RESCON(7,2),CR(7),YR(7,3),THZ(7)
 INTEGER HMAX,TMX,HMX,THZ,ROWTYP
 REAL INDGOV,IGP,NSUBSN,INCOME
 DATA THZ(4),JMX,HMX(4),(COSTJ(4,J),J=1,3),(COSTH(4,J),J=1,3),
1GJJ,GHH,RJJ,RHH,(COSPJ(4,J),J=1,3),(COSPH(4,J),J=1,3),PGJJ,PGHH,
2PRJJ,PRHH,(FAJP(4,J),J=1,3),(FAHP(4,J),J=1,3),(Y(4,J),J=1,3),
3(YG(4,J),J=1,3),(YR(4,J),J=1,3),(XJI(4,J),J=1,3),(XHI(4,J),J=2,3),
4(RI(4,J),J=1,3),(DR(4,J),J=1,3),BUDJ(4),DBUI(4),
5(RHO(4,K),K=1,4),(CONIND(4,L),L=1,2),(PRIND(4,L),L=1,2),
6(EMPL(4,L),L=1,2),(OUTPUT(4,L),L=1,2),(PRIRES(4,L),L=1,2),
7(INCOME(4,L),L=1,2),(SUBS(4,L),L=1,2),(RESCON(4,L),L=1,2),CR(4)/
810,3,2,1500.00E+06,1500.00E+06,1500.00E+06,1303.00E+06,
91500.00E+06,1500.00E+06,0.10,0.10,0,06,0.06,100.00E+06,100.00E+06,
1100.00E+06,90.00E+06,90.00E+06,90.00E+06,0.10,0.10,0.06,0.06,
20.90,0.85,0.80,0.69,0.31,0.00,3.00E-06,4.5E-06,5.172E-06,
30.10,0.10,0.10,0.06,0.06,0.06,0.00,0.00,37.410E-03,
40.00,0.00,0.00,0.00,
51.00E+13,0.00,0.00,0.00,2.00E+07,0.03,0.627,0.00,0.559,-0.757,
60.4169E+08,0.5399E+08,12.6832,9.66265,6742.00,7344.00,0.7020E11,
70.7604E11,15.7734,10.4750,0.7472E+11,0.657609E+11,11805.00,
812993.00,0.2669E+08,0.337E+08,0.0726489/
 DATA THZ(5),JMX,HMX(5),(COSTJ(5,J),J=1,3),(COSTH(5,J),J=1,3),
1GJJ,GHH,RJJ,RHH,(COSPJ(5,J),J=1,3),(COSPH(5,J),J=1,3),PGJJ,PGHH,
```

```
2PRJJ,PRHH,(FAJP(5,J),J=1,3),(FAHP(5,J),J=1,3),(Y(5,J),J=1,3),
3(YG(5,J),J=1,3),(YR(5,J),J=1,3),(XJI(5,J),J=1,3),(XHI(5,J),J=2,3),
4(RI(5,J),J=1,3),(DR(5,J),J=1,3),BUDJ(5),DBUI(5),
5(RHO(5,K),K=1,4),(CONIND(5,L),L=1,2),(PRIND(5,L),L=1,2),
6(EMPL(5,L),L=1,2),(OUTPUT(5,L),L=1,2),(PRIRES(5,L),L=1,2),
7(INCOME(5,L),L=1,2),(SUBS(5,L),L=1,2),(RESCON(5,L),L=1,2),CR(5)/
810,3,3,800.00E06,700.00E06,1000.00E06,900.00E06,970.00E06,
91000.00E06,0.10,0.10,0.06,0.06,224.00E06,224.00E06,224.00E06,
1224.00E06,224.00E06,224.00E06,0.10,0.10,0.06,0.06,0.83,
20.71,0.50,0.57,0.57,0.50,3.00E-06,4.5E-06,5.172E-06,0.10,0.10,
30.10,0.06,0.06,0.06,536.00E-03,355.00E-03,18.00E-03,
40.00,0.00,1.712E+12,
510.00E+12,10.00E+12,0.05,0.05,0.05,200.00E+06,0.05,
60.00,0.00,0.012,0.00,1.82235E+09,2.23636E+09,1.11236,0.916624,
7262484.00,280746.00,147.316,134.486,1.11236,0.916629,
81.49833E+10,1.73872E+10,137100.00,142100.00,1.13674E+09,
91.50215E+09,0.0726489/
 DATA THZ(6),JMX,HMX(6),(COSTJ(6,J),J=1,3),(COSTH(6,J),J=1,3),
1GJJ,GHH,RJJ,RHH,(COSPJ(6,J),J=1,3),(COSPH(6,J),J=1,3),PGJJ,PGHH,
2PRJJ,PRHH,(FAJP(6,J),J=1,3),(FAHP(6,J),J=1,3),(Y(6,J),J=1,3),
3(YG(6,J),J=1,3),(YR(6,J),J=1,3),(XJI(6,J),J=1,3),(XHI(6,J),J=2,3),
4(RI(6,J),J=1,3),(DR(6,J),J=1,3),BUDJ(6),DBUI(6),
5(RHO(6,K),K=1,4),(CONIND(6,L),L=1,2),(PRIND(6,L),L=1,2),
6(EMPL(6,L),L=1,2),(OUTPUT(6,L),L=1,2),(PRIRES(6,L),L=1,2),
7(INCOME(6,L),L=1,2),(SUBS(6,L),L=1,2),(RESCON(6,L),L=1,2),CR(6)/
810,3,2,1000.00E+06,1000.00E+06,1000.00E+06,1000.00E+06,
91000.00E+06,1000.00E+06,0.10,0.10,0.06,0.06,200.00E+06,
1200.00E+06,200.00E+06,200.00E06,200.00E+06,200.00E+06,0.10,
20.10,0.06,0.06,0.83,0.71,0.80,0.73,0.40,0.00,3.00E-06,4.50E-06,
35.172E-06,0.10,0.10,0.10,0.06,0.06,0.06,0.00,0.00,22.00E-03,
42.00E-03,0.00,0.00,0.00,2.00E+14,0.00,0.00,0.00,20.00E+06,0.03,
50.860,-0.575,0.00,0.00,0.78436E+08,0.100699E+09,7.38035,6.52263,
60.00,0.00,0.486624E+11,0.660418E+11,10.9018,9.05350,0.584383E+11,
70.453016E+11,0.00,0.00,0.3916E+08,0.4612E+08,0.0726489/
 DATA THZ(3),JMX,HMX(3),(COSTJ(3,J),J=1,3),(COSTH(3,J),J=1,3),
1GJJ,GHH,RJJ,RHH,(COSPJ(3,J),J=1,3),(COSPH(3,J),J=1,3),PGJJ,PGHH,
```

```
2PRJJ,PRHH,(FAJP(3,J),J=1,3),(FAHP(3,J),J=1,3),(Y(3,J),J=1,3),
3(YG(3,J),J=1,3),(YR(3,J),J=1,3),(XJI(3,J),J=1,3),(XHI(3,J),J=2,3),
4(RI(3,J),J=1,3),(DR(3,J),J=1,3),BUDJ(3),DBUI(3),
5(RHO(3,K),K=1,4),(CONIND(3,L),L=1,2),(PRIND(3,L),L=1,2),
6(EMPL(3,L),L=1,2),(OUTPUT(3,L),L=1,2),(PRIRES(3,L),L=1,2),
7(INCOME(3,L),L=1,2),(SUBS(3,L),L=1,2),(RESCON(3,L),L=1,2),CR(3)/
810,3,1,800.00E+06,700.00E+06,1000.00E+06,1000.00E+06,1000.00E+06,
91000.00E+06,0.10,0.10,0.06,0.06,150.00E+06,150.00E+06,150.00E+06,
1150.00E+06,150.00E+06,150.00E+06,0.10,0.10,
20.06,0.06,0.83,0.71,0.51,0.40,0.00,0.00,3.00E-06,
34.50E-06,5.172E-06,0.10,0.10,0.10,0.06,0.06,0.06,
40.00,0.00,278.00E-03,0.00,0.00,0.00,0.00,2.00E+14,
50.00,0.00,0.00,300.00E+06,0.05,0.726,0.00,0.00,0.00,
60.5127E+09,0.59656E+09,7.30211,5.82629,57915.0,63005.0,
70.7777E+11,0.599545E+11,12.1218,9.84385,0.388786E+12,
80.35011E+12,0.11512E+07,0.12025E+07,375.18E+06,435.33E+06,
90.0726489/
 DATA THZ(2),JMX,HMX(2),(COSTJ(2,J),J=1,3),(COSTH(2,J),J=1,3),
1GJJ,GHH,RJJ,RHH,(COSPJ(2,J),J=1,3),(COSPH(2,J),J=1,3),PGJJ,PGHH,
2PRJJ,PRHH,(FAJP(2,J),J=1,3),(FAHP(2,J),J=1,3),(Y(2,J),J=1,3),
3(YG(2,J),J=1,3),(YR(2,J),J=1,3),(XJI(2,J),J=1,3),(XHI(2,J),J=2,3),
4(RI(2,J),J=1,3),(DR(2,J),J=1,3),BUDJ(2),DBUI(2),
5(RHO(2,K),K=1,4),(CONIND(2,L),L=1,2),(PRIND(2,L),L=1,2),
6(EMPL(2,L),L=1,2),(OUTPUT(2,L),L=1,2),(PRIRES(2,L),L=1,2),
7(INCOME(2,L),L=1,2),(SUBS(2,L),L=1,2),(RESCON(2,L),L=1,2),CR(2)/
810,3,3,800.00E+06,700.00E+06,1000.00E+06,1757.00E+06,
92037.00E+06,2508.00E+06,0.10,0.10,0.06,0.06,150.00E+06,
1150.00E+06,150.00E+06,150.00E+06,150.00E+06,150.00E+06,
20.10,0.10,0.06,0.06,0.83,0.71,0.51,0.725,1.00,1.00,
33.00E-06,4.50E-06,5.172E-06,0.10,0.10,0.10,0.06,0.06,0.06,
40.00,0.00,0.00,0.00,0.00,0.00,0.00,2.00E+14,0.00,0.00,0.00,
5300.00E+06,0.03,0.430,0.00,0.383,0.00,0.365837E+10,
60.382661E+10,2.26190,2.13244,0.00,0.00,0.672E+09,
70.741E+09,1.30952,1.23457,0.3346E+10,0.36065E+10,0.00,0.00,
80.273E+09,0.3063E+09,0.0726489/
 DATA THZ(7),JMX,HMX(7),(COSTJ(7,J),J=1,3),(COSTH(7,J),J=1,3),
```

```
     1GJJ,GHH,RJJ,RHH,(COSPJ(7,J),J=1,3),(COSPH(7,J),J=1,3),PGJJ,PGHH,
     2PRJJ,PRHH,(FAJP(7,J),J=1,3),(FAHP(7,J),J=1,3),(Y(7,J),J=1,3),
     3(YG(7,J),J=1,3),(YR(7,J),J=1,3),(XJI(7,J),J=1,3),(XHI(7,J),J=2,3),
     4(RI(7,J),J=1,3),(DR(7,J),J=1,3),BUDJ(7),DBUI(7),
     5(RHO(7,K),K=1,4),(CONIND(7,L),L=1,2),(PRIND(7,L),L=1,2),
     6(EMPL(7,L),L=1,2),(OUTPUT(7,L),L=1,2),(PRIRES(7,L),L=1,2),
     7(INCOME(7,L),L=1,2),(SUBS(7,L),L=1,2),(RESCON(7,L),L=1,2),CR(7)/
     810,3,1,1000.00E+06,1000.00E+06,1000.00E+06,2860.00E+06,
     92860.00E+06,2860.00E+06,0.10,0.10,0.06,0.06,200.00E+06,
     1200.00E+06,200.00E+06,200.00E+06,200.00E+06,200.00E+06,
     20.10,0.10,0.06,0.06,0.75,0.70,0.80,0.76,0.00,0.00,3.00E-06,
     34.50E-06,5.172E-06,0.10,0.10,0.10,0.06,0.06,0.06,0.00,
     40.00,28.00E-03,0.00,0.00,0.00,0.00,2.00E+14,
     50.00,0.00,0.00,20.00E+06,0.03,0.00,0.00,0.00,0.00,
     60.32633E08,0.37975E08,32.2677,24.6343,0.00,0.00,0.434590E11,
     70.433380E11,47.9066,36.0606,0.00,0.00,11705.0,13177.0,
     80.19293E08,0.23401E08,0.0726489/
      DATA THZ(1),JMX,HMX(1),(COSTJ(1,J),J=1,3),(COSTH(1,J),J=1,3),
     1GJJ,GHH,RJJ,RHH,(COSPJ(1,J),J=1,3),(COSPH(1,J),J=1,3),PGJJ,PGHH,
     2PRJJ,PRHH,(FAJP(1,J),J=1,3),(FAHP(1,J),J=1,3),(Y(1,J),J=1,3),
     3(YG(1,J),J=1,3),(YR(1,J),J=1,3),(XJI(1,J),J=1,3),(XHI(1,J),J=2,3),
     4(RI(1,J),J=1,3),(DR(1,J),J=1,3),BUDJ(1),DBUI(1),
     5(CONIND(1,L),L=1,2),(RESCON(1,L),L=1,2),CR(1)/
     610,3,2,1000.00E06,1000.00E06,1000.00E06,1250.00E06,
     71250.00E06,1250.00E06,0.10,0.10,0.06,0.06,200.00E06,
     8200.00E06,200.00E06,200.00E06,200.00E06,200.00E06,
     90.10,0.10,0.06,0.06,0.83,0.71,0.80,0.571,0.73,0.00,
     13.00E-06,4.50E-06,5.172E-06,0.10,0.10,0.10,0.06,
     20.06,0.06,0.00,0.00,15.00E-03,0.00,0.00,0.00,0.00,
     32.00E+14,0.00,0.00,0.00,20.00E+06,0.03,0.54073E+08,
     40.660610E+08,0.00,0.00,0.0726489/
C     INITIALISE BASE PARAMETERS
      DO 1 I=1,14
    1 TELEC(I)=0.0
      XJ10=0.0
      XJ20=0.0
```

```
      XJ30=0.0
      XH1=0.0
      XH20=0.0
      XH30=0.0
      X1=0.0
      X2=0.0
      X3=0.0
      R1=0.0
      R2=0.0
      R3=0.0
      BUDGET=0.0
      PDBUD=0.0
      PDR1=0.0
      PDR2=0.0
      PDR3=0.0
      AJ1=0.0
      AJ2=0.0
      AJ3=0.0
      AH1=0.0
      READ(5,45)IDC,NCOOP
*************************************************************
*       IDC IS THE IDENTITY OF THE PARTICULAR COUNTRY-      *
*         COMBINATION.                                      *
*      NCOOP IS THE NUMBER OF COUNTRIES IN COMMON           *
*         DEVELPOPMENT PROGRAM.                             *
*************************************************************
   45 FORMAT(2I2)
      DO 30 K=1,NCOOP
      READ(5,992)ID,XH10,(XMX(J),J=1,3)
  992 FORMAT(I2,4E12.2)
      IF(IDC-11)100,200,102
***********************************************************
*        THIS SECTION IS COUNTRY-COMBINATION SPECIFIC     *
*        FOR GHANA/UPPER VOLTA COMBINATION:IDC=11.        *
***********************************************************
  200 IF(ID.EQ.2)GO TO 205
```

```
      GO TO 210
  205 X1=X1+XMX(1)
      X2=X2+XMX(2)
      X3=X3+XMX(3)
      CJ1=COSTJ(ID,1)
      CJ2=COSTJ(ID,2)
      CJ3=COSTJ(ID,3)
      CH1=0.85*COSTH(ID,1)
      CH2=0.85*COSTH(ID,2)
      CH3=0.85*COSTH(ID,3)
      PJ1=COSPJ(ID,1)
      PJ2=COSPJ(ID,2)
      PJ3=COSPJ(ID,3)
      PH1=COSPH(ID,1)
      PH2=COSPH(ID,2)
      PH3=COSPH(ID,3)
      AHP1=FAHP(ID,1)
      AHP2=FAHP(ID,2)
      AHP3=FAHP(ID,3)
      GO TO 210
*********************************************************
*         END OF SPECIFIC SECTION FOR GHANA/            *
*         UPPER VOLTA.                                  *
*********************************************************
  100 IF(IDC-9)400,300,500
**********************************************************
*         THIS SECTION IS COUNTRY-COMBINATION SPECIFIC   *
*         FOR TOGO/BENIN COMBINATION:IDC=9               *
**********************************************************
  300 IF(ID.EQ.1)GO TO 305
      GO TO 210
  305 X1=X1+XMX(1)
      X2=X2+15.00E-03
      X3=X3+XMX(3)
      AHP1=FAHP(ID,1)
      AHP2=0.372
```

```
      AHP3=0.00
      CH1=0.85*COSTH(ID,1)
      CH2=0.85*COSTH(ID,2)
      CH3=0.85*COSTH(ID,3)
      CJ1=COSTJ(ID,1)
      CJ2=COSTJ(ID,2)
      CJ3=COSTJ(ID,3)
      PH1=COSPH(ID,1)
      PH2=COSPH(ID,2)
      PH3=COSPH(ID,3)
      PJ1=COSPJ(ID,1)
      PJ2=COSPJ(ID,2)
      PJ3=COSPJ(ID,3)
      GO TO 210
******************************************************
*         END OF SPECIFIC SECTION FOR TOGO/BENIN     *
*         COMBINATION.                               *
******************************************************
*  THIS SECTION IS COUNTRY-COMBINATION SPECIFIC      *
*     FOR NIGER/NIGERIA COMBINATION:IDC=8            *
******************************************************
  400 IF(ID.EQ.5)GO TO 35
      GO TO 40
   35 CJ1=COSTJ(ID,1)
      CJ2=COSTJ(ID,2)
      CJ3=COSTJ(ID,3)
      CH1=0.85*COSTH(ID,1)
      CH2=0.85*COSTH(ID,2)
      CH3=0.85*COSTH(ID,3)
      PJ1=COSPJ(ID,1)
      PJ2=COSPJ(ID,2)
      PJ3=COSPJ(ID,3)
      PH1=COSPH(ID,1)
      PH2=COSPH(ID,2)
      PH3=COSPH(ID,3)
      AHP2=FAHP(ID,2)
```

```
      AHP3=FAHP(ID,3)
C******INPUT PARAMETERS FOR SUBROUTINE RHSIDE*****************
   40 X1=X1+XMX(1)
      X2=X2+XMX(2)
      X3=X3+XMX(3)
      AH1=AH1+FAHP(ID,1)/2.
      GO TO 210
*********************************************************
*        END OF SPECIFIC SECTION FOR NIGERIA/NIGER      *
*        COMBINATION *****************************      *
*********************************************************
*        THIS SECTION IS COUNTRY-COMBINATION SPECIFIC   *
*        FOR GHANA/IVORY COAST/UPPER VOLTA              *
*        COMBINATION=IDC=10                             *
*********************************************************
  500 IF(ID.EQ.3)GO TO 505
      GO TO 510
  505 X1=X1+XMX(1)
      AHP1=FAHP(ID,1)
      CH1=0.65*COSTH(ID,1)
  510 IF(ID.EQ.2)GO TO 515
      GO TO 210
  515 X2=X2+XMX(2)
      X3=X3+XMX(3)
      AHP2=FAHP(ID,2)
      AHP3=FAHP(ID,3)
      CH2=0.85*COSTH(ID,2)
      CH3=0.85*COSTH(ID,3)
      CJ1=COSTJ(ID,1)
      CJ2=COSTJ(ID,2)
      CJ3=COSTJ(ID,3)
      PH1=COSPH(ID,1)
      PH2=COSPH(ID,2)
      PH3=COSPH(ID,3)
      PJ1=COSPJ(ID,1)
      PJ2=COSPJ(ID,2)
```

```
      PJ3=COSPJ(ID,3)
      GO TO 210
*****************************************************************
*     END OF SPECIFIC SECTION FOR GHANA/IVORY COAST/         *
*     UPPER VOLTA COMBINATION.                                *
*****************************************************************
  102 IF(IDC-13)600,700,800
*****************************************************************
*          THIS SECTION IS COUNTRY COMBINATION                *
*  SPECIFIC FOR GHANA/IVORY COAST/TOGO/BENIN/                 *
*            UPPER VOLTA:IDC=12                               *
* ***************************************************************
  600 IF(ID.EQ.1)GO TO 605
      GO TO 610
  605 X1=X1+XMX(1)+115.0CE-03
      CH1=0.65*COSTH(ID,1)
      AHP1=(FAHP(ID,1)+0.372)/2.
      PH1=COSPH(ID,1)
  610 IF(ID.EQ.3)GO TO 615
      GO TO 620
  615 X2=X2+XMX(1)
      AHP2=FAHP(ID,1)
      CH2=0.75*COSTH(ID,1)
      PH2=COSPH(ID,2)
  620 IF(ID.EQ.2)GO TO 625
      GO TO 210
  625 DO 630 KG=1,3
  630 X3=X3+XMX(KG)
      CH3=0.85*COSTH(ID,1)
      PH3=COSPH(ID,3)
      PJ1=COSPJ(ID,1)
      PJ2=COSPJ(ID,2)
      PJ3=COSPJ(ID,3)
      AHP3=FAHP(ID,3)
      GO TO 210
*****************************************************************
```

```
*    END OF SPECIFIC SECTION FOR GHANA/IVORY COAST      *
*    TOGO/BENIN/UPPER VOLTA COMBINATION.                 *
**********************************************************
*     THIS SECTION IS COUNTRY-COMBINATION SPECIFIC       *
*     FOR NIGERIA/NIGER/TOGO/BENIN COMBINATION:          *
*               IDC=13                                   *
**********************************************************
  700 IF(ID.EQ.4)GO TO 705
      GO TO 710
  705 X1=X1+XMX(1)
      AH1=AH1+FAHP(ID,1)/2.
  710 IF(ID.EQ.1)GO TO 715
      GO TO 720
  715 X2=X2+XMX(1)
      AHP2=FAHP(ID,1)
      CH2=0.65*COSTH(ID,1)
  720 IF(ID.EQ.5)GO TO 725
      GO TO 210
  725 X1=X1+XMX(1)
      X3=X3+XMX(2)
      CH1=0.65*COSTH(ID,1)
      CH3=0.65*COSTH(ID,2)
      CJ1=COSTJ(ID,1)
      CJ2=COSTJ(ID,2)
      CJ3=COSTJ(ID,3)
      PH1=COSPH(ID,1)
      PH2=COSPH(ID,2)
      PH3=COSPH(ID,3)
      PJ1=COSPJ(ID,1)
      PJ2=COSPJ(ID,2)
      PJ3=COSPJ(ID,3)
      GO TO 210
*********************************************************
*        END OF SPECIFIC SECTION FOR NIGERIA/           *
*        NIGER/TOGO/BENIN COMBINATION.                  *
*********************************************************
```

```
*       THIS SECTION IS COUNTRY-COMBINATION              *
*       SPECIFIC FOR GHANA/IVORY COAST COMBINATION:      *
*                  IDC=14                                *
**********************************************************
  800 IF(ID.EQ.3)GO TO 805
      GO TO 810
  805 X1=X1+XMX(1)
      AHP1=FAHP(ID,1)
      CH1=0.85*COSTH(ID,1)
      GO TO 210
  810 X2=X2+XMX(1)
      X3=X3+XMX(2)
      CH2=0.85*COSTH(ID,1)
      CH3=0.85*COSTH(ID,2)
      CJ1=COSTJ(ID,1)
      CJ2=COSTJ(ID,2)
      CJ3=COSTJ(ID,3)
      PH1=COSPH(ID,1)
      PH2=COSPH(ID,2)
      PH3=COSPH(ID,3)
      PJ1=COSPJ(ID,1)
      PJ2=COSPJ(ID,2)
      PJ3=COSPJ(ID,3)
      AHP2=FAHP(ID,1)
      AHP3=FAHP(ID,2)
**********************************************************
*       END OF SPECIFIC SECTION FOR GHANA/               *
*       IVORY COAST COMBINATION.                         *
**********************************************************
  210 HMAX=HMX(ID)
      XH1=XH1+XH10
      XH20=XH20+XHI(ID,2)
      XH30=XH30+XHI(ID,3)
      PDBUB=PDBUB+DBUI(ID)/NCOOP
      PDR1=PDR1+DR(ID,1)/NCOOP
      PDR2=PDR2+DR(ID,2)/NCOOP
```

```
      PDR3=PDR3+DR(ID,3)/NCOOP
      AJ1=AJ1+FAJP(ID,1)/NCOOP
      AJ2=AJ2+FAJP(ID,2)/NCOOP
      AJ3=AJ3+FAJP(ID,3)/NCOOP
      XJ10=XJ10+XJI(ID,1)
      XJ20=XJ20+XJI(ID,2)
      XJ30=XJ30+XJI(ID,3)
      R1=R1+RI(ID,1)
      R2=R2+RI(ID,2)
      R3=R3+RI(ID,3)
      BUDGET=BUDGET+BUDJ(ID)
C      INPUT PARAMETERS FOR SUBROUTINE FCAST
      RHO1=RHO(ID,1)
      RHO2=RHO(ID,2)
      RHO3=RHO(ID,3)
      RHO4=RHO(ID,4)
      DO 998 I=1,2
      INDGOV(I)=CONIND(ID,I)
      RCON(I)=RESCON(ID,I)
      IF(ID.EQ.1)GO TO 998
      IGP(I)=PRIND(ID,I)
      EMPLN(I)=EMPL(ID,I)
      VTOTAL(I)=OUTPUT(ID,I)
      DARCOS(I)=PRIRES(ID,I)
      DREV(I)=INCOME(ID,I)
      NSUBSN(I)=SUBS(ID,I)
  998 CONTINUE
      CALL FCAST
   30 CONTINUE
****************************************************************
*      THE FOLLOWING SECTION OF THE PROGRAM IS GENERAL.        *
*   IT NEEDS TO BE ASSIGNED ONLY ONCE FOR THE                  *
*        COOPERATIVE STUDY.                                    *
****************************************************************
      TMX=THZ(ID)
      Y110=Y(ID,1)
```

```
      Y220=Y(ID,2)
      Y330=Y(ID,3)
      YG1=YG(ID,1)
      YG2=YG(ID,2)
      YG3=YG(ID,3)
      YR1=YR(ID,1)
      YR2=YR(ID,2)
      YR3=YR(ID,3)
      GJ=GJJ
      GH=GHH
      PGJ=PGJJ
      PGH=PGHH
      PRH=PRHH
      PRJ=PRJJ
      RH=RHH
      RJ=RJJ
      CRF=CR(ID)
      JMAX=JMX
***************************************************************
*           END OF GENERAL SECTION.                           *
***************************************************************
      XH10=XH1
      XMAX(1)=X1
      XMAX(2)=X2
      XMAX(3)=X3
      R10=R1
      R20=R2
      R30=R3
      BUD0=BUDGET
      DBUD=PDBUD
      DR1=PDR1
      DR2=PDR2
      DR3=PDR3
      AJP1=AJ1
      AJP2=AJ2
      AJP3=AJ3
```

```
      IF(IDC.EQ.8 .OR. IDC.EQ.13)GO TO 50
      GO TO 55
   50 AHP1=AH1
C******SET UP RIGHT HAND SIDE CONSTRAINT COEFFICIENTS**********
   55 TIME=1979.
      WRITE(6,2)
    2 FORMAT(1H1,19X,34HTOTAL INTER-COUNTRY DEMAND: GW-HRS)
      WRITE(6,3)
    3 FORMAT(1H0,24X,4HYEAR,11X,6HDEMAND)
      DO 20 I=5,14
      K=I-4
C*****TOTAL DEMAND IN GIGAWATT-HOURS********************
      B(K)=TELEC(I)*1.0E-06
      ROWTYP(K)=-1
      TIME=TIME+1.
   20 WRITE(6,25)TIME,B(K)
   25 FORMAT(1H0,23X,F6.1,E18.5)
      WRITE(6,60)IDC
   60 FORMAT(1H1,25X,49H****INTER-COUNTRY ELECTRICITY SUPPLY STUDY: IDC=
     1 ,I2,4H****)
      WRITE(6,65)XH10,CH1,CH2,CH3
   65 FORMAT(1H0,15X,5HXH10=,E9.3,3H GW,5X,4HCH1=,E12.2,10HDOLLARS/GW,5X
     1,4HCH2=,E12.2,10HDOLLARS/GW,5X,4HCH3=,E12.2,10HDOLLARS/GW)
      WRITE(6,66)(XMAX(J),J=1,3)
   66 FORMAT(1H0,15X,8HXMAX(1)=,E9.3,3H GW,5X,8HXMAX(2)=,E9.3,3H GW,5X,8
     1HXMAX(3)=,E9.3,3H GW)
      WRITE(6,67)AHP1,AHP2,AHP3,BUDO,DBUD
   67 FORMAT(1H0,15X,5HAHP1=,F5.3,5X,5HAHP2=,F5.3,5X,5HAHP3=,F5.3,5X,5HB
     1UDO=,E12.2,7HDOLLARS,5X,5HDBUD=,F4.2)
      WRITE(6,4)
    4 FORMAT(1H1)
      RETURN
C******LAST CARD OF DBANK****************************************
      END
```

```
 SUBROUTINE DBANKS
 COMMON B(640),ROWTYP(640),TMX,HMAX,CJMAX,DELTAT,JMAX,
1NTHERM,NHYDRO,CJ1,CJ2,CJ3,CH1,CH2,CH3,PJ1,PJ2,LEVEL,
2PJ3,AJP1,AJP2,AJP3,AHP1,AHP2,AHP3,Y110,Y220,Y330,YG1,
3YG2,YG3,YR1,YR2,YR3,XJ10,XJ20,XJ30,XH10,XH20,XH30,
4XMAX(3),R10,R20,R30,DR1,DR2,DR3,BUD0,DBUD,RHO1,RHO2,
5RHO3,RHO4,INDGOV(21),IGP(21),EMPLN(21),VTOTAL(21),DARCOS(21),
6NSUBSN(21),RCON(21),DREV(21),CRF,ID,TELEC(14),LBD1,LBD2,
7GH,GJ,PGJ,PGH,PH1,PH2,PH3,PRH,PRJ,RH,RJ,XMX(3)
 DIMENSION COSTJ(7,3),COSTH(7,3),COSPJ(7,3),COSPH(7,3),
1HMX(7),FAJP(7,3),FAHP(7,3),Y(7,3),YG(7,3),XJI(7,3),XHI(7,3),
2XMX(3),RI(7,3),DR(7,3),BUDJ(7),DBUI(7),RHO(7,4),CONIND(7,2),
3PRIND(7,2),EMPL(7,2),OUTPUT(7,2),PRIRES(7,2),INCOME(7,2),
4SUBS(7,2),RESCON(7,2),CR(7),YR(7,3),THZ(7)
 INTEGER HMAX,TMX,HMX,THZ,ROWTYP
 REAL INDGOV,IGP,NSUBSN,INCOME
 DATA THZ(4),JMX,HMX(4),(COSTJ(4,J),J=1,3),(COSTH(4,J),J=1,3),
1GJJ,GHH,RJJ,RHH,(COSPJ(4,J),J=1,3),(COSPH(4,J),J=1,3),PGJJ,PGHH,
2PRJJ,PRHH,(FAJP(4,J),J=1,3),(FAHP(4,J),J=1,3),(Y(4,J),J=1,3),
3(YG(4,J),J=1,3),(YR(4,J),J=1,3),(XJI(4,J),J=1,3),(XHI(4,J),J=2,3),
4(RI(4,J),J=1,3),(DR(4,J),J=1,3),BUDJ(4),DBUI(4),
5(RHO(4,K),K=1,4),(CONIND(4,L),L=1,2),(PRIND(4,L),L=1,2),
6(EMPL(4,L),L=1,2),(OUTPUT(4,L),L=1,2),(PRIRES(4,L),L=1,2),
7(INCOME(4,L),L=1,2),(SUBS(4,L),L=1,2),(RESCON(4,L),L=1,2),CR(4)/
810,3,2,1500.00E+06,1500.00E+06,1500.00E+06,1303.00E+06,
91500.00E+06,1500.00E+06,0.10,0.10,0.06,0.06,100.00E+06,100.00E+06,
1100.00E+06,90.00E+06,90.00E+06,90.00E+06,0.10,0.10,0.06,0.06,
20.90,0.85,0.80,0.69,0.31,0.00,3.00E-06,4.5E-06,5.172E-06,
30.10,0.10,0.10,0.06,0.06,0.06,0.00,0.00,37.410E-03,
40.00,0.00,0.00,0.00,
51.00E+13,0.00,0.00,0.00,2.00E+07,0.03,0.627,0.00,0.559,-0.757,
60.4169E+08,0.5399E+08,12.6832,9.66265,6742.00,7344.00,0.7020E11,
70.7604E11,15.7734,10.4750,0.7472E+11,0.657609E+11,11805.00,
812993.00,0.2669E+08,0.337E+08,0.0726489/
 DATA THZ(5),JMX,HMX(5),(COSTJ(5,J),J=1,3),(COSTH(5,J),J=1,3),
1GJJ,GHH,RJJ,RHH,(COSPJ(5,J),J=1,3),(COSPH(5,J),J=1,3),PGJJ,PGHH,
```

```
2PRJJ,PRHH,(FAJP(5,J),J=1,3),(FAHP(5,J),J=1,3),(Y(5,J),J=1,3),
3(YG(5,J),J=1,3),(YR(5,J),J=1,3),(XJI(5,J),J=1,3),(XHI(5,J),J=2,3),
4(RI(5,J),J=1,3),(DR(5,J),J=1,3),BUDJ(5),DBUI(5),
5(RHO(5,K),K=1,4),(CONIND(5,L),L=1,2),(PRIND(5,L),L=1,2),
6(EMPL(5,L),L=1,2),(OUTPUT(5,L),L=1,2),(PRIRES(5,L),L=1,2),
7(INCOME(5,L),L=1,2),(SUBS(5,L),L=1,2),(RESCON(5,L),L=1,2),CR(5)/
810,3,3,800.00E06,700.00E06,1000.00E06,900.00E06,970.00E06,
91000.00E06,0.10,0.10,0.06,0.06,224.00E06,224.00E06,224.00E06,
1224.00E06,224.00E06,224.00E06,0.10,0.10,0.06,0.06,0.83,
20.71,0.50,0.57,0.57,0.50,3.00E-06,4.5E-06,5.172E-06,0.10,0.10,
30.10,0.06,0.06,0.06,536.00E-03,355.00E-03,18.00E-03,
40.00,0.00,1.712E+12,
510.00E+12,10.00E+12,0.05,0.05,0.05,200.00E+06,0.05,
60.00,0.00,0.012,0.00,1.82235E+09,2.23636E+09,1.11236,0.916624,
7262484.00,280746.00,147.316,134.486,1.11236,0.916629,
81.49833E+10,1.73872E+10,137100.00,142100.00,1.13674E+09,
91.50215E+09,0.0726489/
 DATA THZ(6),JMX,HMX(6),(COSTJ(6,J),J=1,3),(COSTH(6,J),J=1,3),
1GJJ,GHH,RJJ,RHH,(COSPJ(6,J),J=1,3),(COSPH(6,J),J=1,3),PGJJ,PGHH,
2PRJJ,PRHH,(FAJP(6,J),J=1,3),(FAHP(6,J),J=1,3),(Y(6,J),J=1,3),
3(YG(6,J),J=1,3),(YR(6,J),J=1,3),(XJI(6,J),J=1,3),(XHI(6,J),J=2,3),
4(RI(6,J),J=1,3),(DR(6,J),J=1,3),BUDJ(6),DBUI(6),
5(RHO(6,K),K=1,4),(CONIND(6,L),L=1,2),(PRIND(6,L),L=1,2),
6(EMPL(6,L),L=1,2),(OUTPUT(6,L),L=1,2),(PRIRES(6,L),L=1,2),
7(INCOME(6,L),L=1,2),(SUBS(6,L),L=1,2),(RESCON(6,L),L=1,2),CR(6)/
810,3,2,1000.00E+06,1000.00E+06,1000.00E+06,1000.00E+06,
91000.00E+06,1000.00E+06,0.10,0.10,0.06,0.06,200.00E+06,
1200.00E+06,200.00E+06,200.00E06,200.00E+06,200.00E+06,0.10,
20.10,0.06,0.06,0.83,0.71,0.80,0.73,0.40,0.00,3.00E-06,4.50E-06,
35.172E-06,0.10,0.10,0.10,0.06,0.06,0.06,0.00,0.00,22.00E-03,
42.00E-03,0.00,0.00,0.00,2.00E+14,0.00,0.00,0.00,20.00E+06,0.03,
50.860,-0.575,0.00,0.00,0.78436E+08,0.100699E+09,7.38035,6.52263,
60.00,0.00,0.486624E+11,0.660418E+11,10.9018,9.05350,0.584383E+11,
70.453016E+11,0.00,0.00,0.3916E+08,0.4612E+08,0.0726489/
 DATA THZ(3),JMX,HMX(3),(COSTJ(3,J),J=1,3),(COSTH(3,J),J=1,3),
1GJJ,GHH,RJJ,RHH,(COSPJ(3,J),J=1,3),(COSPH(3,J),J=1,3),PGJJ,PGHH,
```

```
2PRJJ,PRHH,(FAJP(3,J),J=1,3),(FAHP(3,J),J=1,3),(Y(3,J),J=1,3),
3(YG(3,J),J=1,3),(YR(3,J),J=1,3),(XJI(3,J),J=1,3),(XHI(3,J),J=2,3),
4(RI(3,J),J=1,3),(DR(3,J),J=1,3),BUDJ(3),DBUI(3),
5(RHO(3,K),K=1,4),(CONIND(3,L),L=1,2),(PRIND(3,L),L=1,2),
6(EMPL(3,L),L=1,2),(OUTPUT(3,L),L=1,2),(PRIRES(3,L),L=1,2),
7(INCOME(3,L),L=1,2),(SUBS(3,L),L=1,2),(RESCON(3,L),L=1,2),CR(3)/
810,3,1,800.00E+06,700.00E+06,1000.00E+06,1000.00E+06,1000.00E+06,
91000.00E+06,0.10,0.10,0.06,0.06,150.00E+06,150.00E+06,150.00E+06,
1150.00E+06,150.00E+06,150.00E+06,0.10,0.10,
20.06,0.06,0.83,0.71,0.51,0.40,0.00,0.00,3.00E-06,
34.50E-06,5.172E-06,0.10,0.10,0.10,0.06,0.06,0.06,
40.00,0.00,278.00E-03,0.00,0.00,0.00,0.00,2.00E+14,
50.00,0.00,0.00,300.00E+06,0.05,0.726,0.00,0.00,0.00,
60.5127E+09,0.59656E+09,7.30211,5.82629,57915.0,63005.0,
70.7777E+11,0.599545E+11,12.1218,9.84385,0.388786E+12,
80.35011E+12,0.11512E+07,0.12025E+07,375.18E+06,435.33E+06,
90.0726489/
 DATA THZ(2),JMX,HMX(2),(COSTJ(2,J),J=1,3),(COSTH(2,J),J=1,3),
1GJJ,GHH,RJJ,RHH,(COSPJ(2,J),J=1,3),(COSPH(2,J),J=1,3),PGJJ,PGHH,
2PRJJ,PRHH,(FAJP(2,J),J=1,3),(FAHP(2,J),J=1,3),(Y(2,J),J=1,3),
3(YG(2,J),J=1,3),(YR(2,J),J=1,3),(XJI(2,J),J=1,3),(XHI(2,J),J=2,3),
4(RI(2,J),J=1,3),(DR(2,J),J=1,3),BUDJ(2),DBUI(2),
5(RHO(2,K),K=1,4),(CONIND(2,L),L=1,2),(PRIND(2,L),L=1,2),
6(EMPL(2,L),L=1,2),(OUTPUT(2,L),L=1,2),(PRIRES(2,L),L=1,2),
7(INCOME(2,L),L=1,2),(SUBS(2,L),L=1,2),(RESCON(2,L),L=1,2),CR(2)/
810,3,3,800.00E+06,700.00E+06,1000.00E+06,1757.00E+06,
92037.00E+06,2508.00E+06,0.10,0.10,0.06,0.06,150.00E+06,
1150.00E+06,150.00E+06,150.00E+06,150.00E+06,150.00E+06,
20.10,0.10,0.06,0.06,0.83,0.71,0.51,0.725,1.00,1.00,
33.00E-06,4.50E-06,5.172E-06,0.10,0.10,0.10,0.06,0.06,0.06,
40.00,0.00,0.00,0.00,0.00,0.00,0.00,2.00E+14,0.00,0.00,0.00,
5300.00E+06,0.03,0.430,0.00,0.383,0.00,0.365837E+10,
60.382661E+10,2.26190,2.13244,0.00,0.00,0.672E+09,
70.741E+09,1.30952,1.23457,0.3346E+10,0.36065E+10,0.00,0.00,
80.273E+09,0.3063E+09,0.0726489/
 DATA THZ(7),JMX,HMX(7),(COSTJ(7,J),J=1,3),(COSTH(7,J),J=1,3),
```

```
      1GJJ,GHH,RJJ,RHH,(COSPJ(7,J),J=1,3),(COSPH(7,J),J=1,3),PGJJ,PGHH,
      2PRJJ,PRHH,(FAJP(7,J),J=1,3),(FAHP(7,J),J=1,3),(Y(7,J),J=1,3),
      3(YG(7,J),J=1,3),(YR(7,J),J=1,3),(XJI(7,J),J=1,3),(XHI(7,J),J=2,3),
      4(RI(7,J),J=1,3),(DR(7,J),J=1,3),BUDJ(7),DBUI(7),
      5(RHO(7,K),K=1,4),(CONIND(7,L),L=1,2),(PRIND(7,L),L=1,2),
      6(EMPL(7,L),L=1,2),(OUTPUT(7,L),L=1,2),(PRIRES(7,L),L=1,2),
      7(INCOME(7,L),L=1,2),(SUBS(7,L),L=1,2),(RESCON(7,L),L=1,2),CR(7)/
      810,3,1,1000.00E+06,1000.00E+06,1000.00E+06,2860.00E+06,
      92860.00E+06,2860.00E+06,0.10,0.10,0.06,0.06,200.00E+06,
      1200.00E+06,200.00E+06,200.00E+06,200.00E+06,200.00E+06,
      20.10,0.10,0.06,0.06,0.75,0.70,0.80,0.76,0.00,0.00,3.00E-06,
      34.50E-06,5.172E-06,0.10,0.10,0.10,0.06,0.06,0.06,0.00,
      40.00,28.00E-03,0.00,0.00,0.00,0.00,2.00E+14,
      50.00,0.00,0.00,20.00E+06,0.03,0.00,0.00,0.00,0.00,
      60.32633E08,0.37975E08,32.2677,24.6343,0.00,0.00,0.434590E11,
      70.433380E11,47.9066,36.0606,0.00,0.00,11705.0,13177.0,
      80.19293E08,0.23401E08,0.0726489/
       DATA THZ(1),JMX,HMX(1),(COSTJ(1,J),J=1,3),(COSTH(1,J),J=1,3),
      1GJJ,GHH,RJJ,RHH,(COSPJ(1,J),J=1,3),(COSPH(1,J),J=1,3),PGJJ,PGHH,
      2PRJJ,PRHH,(FAJP(1,J),J=1,3),(FAHP(1,J),J=1,3),(Y(1,J),J=1,3),
      3(YG(1,J),J=1,3),(YR(1,J),J=1,3),(XJI(1,J),J=1,3),(XHI(1,J),J=2,3),
      4(RI(1,J),J=1,3),(DR(1,J),J=1,3),BUDJ(1),DBUI(1),
      5(CONIND(1,L),L=1,2),(RESCON(1,L),L=1,2),CR(1)/
      610,3,1,1000.00E06,1000.00E06,1000.00E06,1250.00E06,
      71250.00E06,1250.00E06,0.10,0.10,0.06,0.06,200.00E06,
      8200.00E06,200.00E06,200.00E06,200.00E06,200.00E06,
      90.10,0.10,0.06,0.06,0.83,0.71,0.80,0.571,0.73,0.00,
      13.00E-06,4.50E-06,5.172E-06,0.10,0.10,0.10,0.06,
      20.06,0.06,0.00,0.00,15.00E-03,0.00,0.00,0.00,0.00,
      32.00E+14,0.00,0.00,0.00,20.00E+06,0.03,0.54073E+08,
      40.660610E+08,0.00,0.00,0.0726489/
       READ(5,992)ID,XH10,(XMX(J),J=1,3)
  992  FORMAT(I2,4E12.2)
       TMX=THZ(ID)
       JMAX=JMX
       HMAX=HMX(ID)
```

```
      CJ1=COSTJ(ID,1)
      CJ2=COSTJ(ID,2)
      CJ3=COSTJ(ID,3)
      CH1=COSTH(ID,1)
      CH2=COSTH(ID,2)
      CH3=COSTH(ID,3)
      PJ1=COSPJ(ID,1)
      PJ2=COSPJ(ID,2)
      PJ3=COSPJ(ID,3)
      PH1=COSPH(ID,1)
      PH2=COSPH(ID,2)
      PH3=COSPH(ID,3)
      AJP1=FAJP(ID,1)
      AJP2=FAJP(ID,2)
      AJP3=FAJP(ID,3)
      AHP1=FAHP(ID,1)
      AHP2=FAHP(ID,2)
      AHP3=FAHP(ID,3)
      Y110=Y(ID,1)
      Y220=Y(ID,2)
      Y330=Y(ID,3)
      YG1=YG(ID,1)
      YG2=YG(ID,2)
      YG3=YG(ID,3)
      YR1=YR(ID,1)
      YR2=YR(ID,2)
      GJ=GJJ
      GH=GHH
      PGJ=PGJJ
      PGH=PGHH
      PRH=PRHH
      PRJ=PRJJ
      RH=RHH
      RJ=RJJ
      YR3=YR(ID,3)
C******INPUT PARAMETERS FOR SUBROUTINE RHSIDE*****************
```

```
      XJ10=XJI(ID,1)
      XJ20=XJI(ID,2)
      XJ30=XJI(ID,3)
      XH20=XHI(ID,2)
      XH30=XHI(ID,3)
      DO 999 J=1,3
  999 XMAX(J)=XMX(J)
      R10=RI(ID,1)
      R20=RI(ID,2)
      R30=RI(ID,3)
      DR1=DR(ID,1)
      DR2=DR(ID,2)
      DR3=DR(ID,3)
      BUDO=BUDJ(ID)
      DBUD=DBUI(ID)
      IF(ID.EQ.1)GO TO 995
C******INPUT PARAMETERS FOR SUBROUTINE FCAST******************
      RHO1=RHO(ID,1)
      RHO2=RHO(ID,2)
      RHO3=RHO(ID,3)
      RHO4=RHO(ID,4)
  995 DO 998 I=1,2
      INDGOV(I)=CONIND(ID,I)
      IF(ID.EQ.1)GO TO 998
      IGP(I)=PRIND(ID,I)
      EMPLN(I)=EMPL(ID,I)
      VTOTAL(I)=OUTPUT(ID,I)
      DARCOS(I)=PRIRES(ID,I)
      DREV(I)=INCOME(ID,I)
      NSUBSN(I)=SUBS(ID,I)
  998 RCON(I)=RESCON(ID,I)
C********INPUT PARAMETER FOR SUBROUTINE YPRINT******************
      CRF=CR(ID)
      RETURN
C******LAST CARD OF DBANKS*****************************************
      END
```

```
      SUBROUTINE REPORT
      COMMON B(640),ROWTYP(640),TMX,HMAX,CJMAX,DELTAT,JMAX,
     1NTHERM,NHYDRO,CJ1,CJ2,CJ3,CH1,CH2,CH3,PJ1,PJ2,
     2PJ3,AJP1,AJP2,AJP3,AHP1,AHP2,AHP3,Y110,Y220,Y330,YG1,
     3YG2,YG3,YR1,YR2,YR3,XJ10,XJ20,XJ30,XH10,XH20,XH30,
     4XMAX(3),R10,R20,R30,DR1,DR2,DR3,BUDO,DBUD,RHO1,RHO2,
     5RHO3,RHO4,INDGOV(21),IGP(21),EMPLN(21),VTOTAL(21),DARCOS(21),
     6NSUBSN(21),RCON(21),DREV(21),CRF,ID,LBD1,LBD2,
     7GH,GJ,PGJ,PGH,PH1,PH2,PH3,PRH,PRJ,RH,RJ,NVAR,
     8ATH1(10),ATH2(10),ATH3(10),AHYD1(10),AHYD2(10),AHYD3(10),
     9ENGT1(65),ENGT2(65),ENGT3(65),OPCT1(65),OPCT2(65),OPCT3(65),
     1ENGH1(65),ENGH2(65),ENGH3(65),OPCH1(65),OPCH2(65),OPCH3(65),
     2FC11(65),FC12(65),FC22(65),FC32(65),FC33(65),CAPJ1(10),
     3CAPJ2(10),CAPJ3(10),CAPH1(10),CAPH2(10),CAPH3(10)
      INTEGER TMX,HMAX,VNT,YEAR,VINGT
      REAL INDGOV,IGP,NSUBSN
      DIMENSION EUJ1(10,10),OPJ1(10,10),EUJ2(10,10),OPJ2(10,10),
     1EUJ3(10,10),OPJ3(10,10),EUH1(10,10),OPH1(10,10),EUH2(10,10),
     2OPH2(10,10),EUH3(10,10),OPH3(10,10),CF11(10,10),CF12(10,10),
     3CF22(10,10),CF32(10,10),CF33(10,10),YEAR(10),VINGT(10)
      DIMENSION TCJ10(10),APJ10(10),TCJ1(10),ANPJ1(10),
     1TENJ1(10),APJ1(10),TKWJ1(10),TCSTJ1(10),AVPJ1(10)
      DIMENSION TCJ20(10),APJ20(10),TCJ2(10),ANPJ2(10),
     1TENJ2(10),APJ2(10),TKWJ2(10),TCSTJ2(10),AVPJ2(10)
      DIMENSION TCJ30(10),APJ30(10),TCJ3(10),ANPJ3(10),
     1TENJ3(10),APJ3(10),TKWJ3(10),TCSTJ3(10),AVPJ3(10)
      DIMENSION APH10(10),ANPH1(10),TCH1(10),TENH1(10),
     1   APH1(10),TKWH1(10),TCSTH1(10),AVPH1(10)
      DIMENSION APH20(10),ANPH2(10),TCH2(10),TENH2(10),
     1   APH2(10),TKWH2(10),TCSTH2(10),AVPH2(10)
      DIMENSION APH30(10),ANPH3(10),TCH3(10),TENH3(10),
     1   APH3(10),TKWH3(10),TCSTH3(10),AVPH3(10)
C*****************************************************************
      DO 50 I=1,TMX
      TCJ10(I)=0.0
      APJ10(I)=0.0
```

```
TCJ1(I)=0.0
ANPJ1(I)=0.0
TENJ1(I)=0.0
APJ1(I)=0.0
TKWJ1(I)=0.0
TCSTJ1(I)=0.0
AVPJ1(I)=0.0
APJ20(I)=0.0
TCJ2(I)=0.0
ANPJ2(I)=0.0
TENJ2(I)=0.0
APJ2(I)=0.0
TKWJ2(I)=0.0
TCSTJ2(I)=0.0
AVPJ2(I)=0.0
APJ30(I)=0.0
TCJ3(I)=0.0
ANPJ3(I)=0.0
TENJ3(I)=0.0
APJ3(I)=0.0
TKWJ3(I)=0.0
TCSTJ3(I)=0.0
AVPJ3(I)=0.0
APH10(I)=0.0
ANPH1(I)=0.0
TCH1(I)=0.0
TENH1(I)=0.0
APH1(I)=0.0
TKWH1(I)=0.0
TCSTH1(I)=0.0
AVPH1(I)=0.0
APH20(I)=0.0
ANPH2(I)=0.0
TCH2(I)=0.0
TENH2(I)=0.0
APH2(I)=0.0
```

```
      TKWH2(I)=0.0
      TCSTH2(I)=0.0
      AVPH2(I)=0.0
      APH30(I)=0.0
      ANPH3(I)=0.0
      TCH3(I)=0.0
      TENH3(I)=0.0
      APH3(I)=0.0
      TKWH3(I)=0.0
      TCSTH3(I)=0.0
      AVPH3(I)=0.0
      DO 55 K=1,TMX
      EUJ1(I,K)=0.0
      OPJ1(I,K)=0.0
      EUJ2(I,K)=0.0
      OPJ2(I,K)=0.0
      EUJ3(I,K)=0.0
      OPJ3(I,K)=0.0
      EUH1(I,K)=0.0
      OPH1(I,K)=0.0
      EUH2(I,K)=0.0
      OPH2(I,K)=0.0
      EUH3(I,K)=0.0
      OPH3(I,K)=0.0
      CF11(I,K)=0.0
      CF12(I,K)=0.0
      CF22(I,K)=0.0
      CF32(I,K)=0.0
      CF33(I,K)=0.0
   55 CONTINUE
   50 CONTINUE
      VNT=0
      IT=1979
      WRITE(6,56)
   56 FORMAT(1H0,13X,34H**********THERMAL PLANTS**********)
      WRITE(6,57)
```

```
   57 FORMAT(1H0,20X,26HCAPACITY INSTALLATIONS: MW)
      WRITE(6,58)
   58 FORMAT(1H0,11X,4HYEAR,9X,9HTHERMAL 1,11X,9HTHERMAL 2,11X,9HTHERMAL
     1 3)
      DO 59 I=1,TMX
      IT=IT+1
      YEAR(I)=IT
      VINGT(I)=I
   59 WRITE(6,54)IT,CAPJ1(I),CAPJ2(I),CAPJ3(I)
   54 FORMAT(1H0,11X,I4,3E20.8)
C***************************************************************
      IF(HMAX.LT.1)GO TO 43
      WRITE(6,15)
      IT=1979
      WRITE(6,51)
   51 FORMAT(1H0,14X,32H**********HYDRO PLANTS**********)
      WRITE(6,57)
      WRITE(6,52)
   52 FORMAT(1H0,11X,4HYEAR,10X,7HHYDRO 1,13X,7HHYDRO 2,13X,7HHYDRO 3)
      DO 53 I=1,TMX
      IT=IT+1
   53 WRITE(6,54)IT,CAPH1(I),CAPH2(I),CAPH3(I)
C********************************************************************
      WRITE(6,15)
   43 WRITE(6,36)
   36 FORMAT(1H0,24X,30HMATRIX OF INSTALLMENT PAYMENTS)
      WRITE(6,37)
   37 FORMAT(1H0,26X,19HFOR THERMAL PLANTS:)
      WRITE(6,38)
   38 FORMAT(1H0,24X,26HATH1(10),ATH2(10),ATH3(10))
      WRITE(6,907)(YEAR(I),I=1,TMX)
      DO 5 J=1,JMAX
      IF(J-2)31,32,33
   31 WRITE(6,70)(ATH1(K),K=1,TMX)
      GO TO 5
   32 WRITE(6,70)(ATH2(K),K=1,TMX)
```

```
      GO TO 5
   33 WRITE(6,70)(ATH3(K),K=1,TMX)
    5 CONTINUE
      IF(HMAX.LT.1)GO TO 16
      WRITE(6,15)
   15 FORMAT(1H1)
      WRITE(6,36)
      WRITE(6,41)
   41 FORMAT(1H0,27X,17HFOR HYDRO PLANTS:)
      WRITE(6,42)
   42 FORMAT(1H0,21X,29HAHYD1(10),AHYD2(10),AHYD3(10))
      WRITE(6,907)(YEAR(I),I=1,TMX)
      DO 20 I=1,HMAX
      IF(I-2)21,22,23
   21 WRITE(6,70)(AHYD1(K),K=1,TMX)
      GO TO 20
   22 WRITE(6,70)(AHYD2(K),K=1,TMX)
      GO TO 20
   23 WRITE(6,70)(AHYD3(K),K=1,TMX)
   20 CONTINUE
C*********************************************************
   16 DO 45 J=1,JMAX
      M=TMX+1
      M1=2*TMX
      IK=M
      J0=0
      DO 9 IL=1,TMX
      DIFF=M1-M
      DO 8 I=M,M1
      I1=I-M+1+J0
      IF(J-2)11,35,40
   11 EUJ1(IL,I1)=ENGT1(IK)
      OPJ1(IL,I1)=OPCT1(IK)
      GO TO 8
   35 EUJ2(IL,I1)=ENGT2(IK)
      OPJ2(IL,I1)=OPCT2(IK)
```

```
      GO TO 8
   40 EUJ3(IL,I1)=ENGT3(IK)
      OPJ3(IL,I1)=OPCT3(IK)
    8 IK=IK+1
      M=M1+1
      M1=M+DIFF-1
      JO=JO+1
    9 CONTINUE
   45 CONTINUE
C*********************************************************
      IF(HMAX.LT.1)GO TO 121
      DO 120 J=1,HMAX
      M=TMX+1
      M1=2*TMX
      IK=M
      JO=0
      DO 145 IL=1,TMX
      DIFF=M1-M
      DO 140 I=M,M1
      I1=I-M+1+JO
      IF(J-2)125,130,135
  125 EUH1(IL,I1)=ENGH1(IK)
      OPH1(IL,I1)=OPCH1(IK)
      GO TO 140
  130 EUH2(IL,I1)=ENGH2(IK)
      OPH2(IL,I1)=OPCH2(IK)
      GO TO 140
  135 EUH3(IL,I1)=ENGH3(IK)
      OPH3(IL,I1)=OPCH3(IK)
  140 IK=IK+1
      M=M1+1
      M1=M+DIFF-1
      JO=JO+1
  145 CONTINUE
  120 CONTINUE
C*********************************************************
```

```
  121 JI=5
C****** JI IS THE  OF PLANT-FUEL COMBINATIONS *************
      DO 150 J=1,JI
      M=TMX+1
      M1=2*TMX
      IK=M
      JO=0
      DO 155 IL=1,TMX
      DIFF=M1-M
      DO 175 I=M,M1
      I1=I-M+1+JO
      IF(J-3)160,165,170
  165 CF22(IL,I1)=FC22(IK)
      GO TO 175
  160 IF(J.GT.1)GO TO 180
      CF11(IL,I1)=FC11(IK)
      GO TO 175
  180 CF12(IL,I1)=FC12(IK)
      GO TO 175
  170 IF(J.GT.4)GO TO 185
      CF32(IL,I1)=FC32(IK)
      GO TO 175
  185 CF33(IL,I1)=FC33(IK)
  175 IK=IK+1
      M=M1+1
      M1=M+DIFF-1
      JO=JO+1
  155 CONTINUE
  150 CONTINUE
C**********************************************************
      DO 65 J=1,JMAX
      WRITE(6,15)
      IF(J-2)75,80,85
   75 DO 90 I=1,TMX
      IF(I.GT.1)GO TO 94
      WRITE(6,91)
```

```
 91 FORMAT(1HO,24X,25HMATRIX OF ENERGY PRODUCED)
    WRITE(6,92)
 92 FORMAT(1HO,20X,33HBY THERMAL PLANT TYPE 1, ANNUALLY)
    WRITE(6,93)
 93 FORMAT(1HO,31X,10HEUJ1(0,10))
    WRITE(6,908)(YEAR(M),M=1,TMX)
    WRITE(6,73)VNT,(ENGT1(K),K=1,TMX)
 94 WRITE(6,73)VINGT(I),(EUJ1(I,K),K=1,TMX)
 90 CONTINUE
    WRITE(6,15)
    DO 95 I=1,TMX
    IF(I.GT.1)GO TO 98
    WRITE(6,96)
 96 FORMAT(1HO,24X,25HMATRIX OF OPERATING COSTS)
    WRITE(6,92)
    WRITE(6,97)
 97 FORMAT(1HO,31X,10HOPJ1(0,10))
    WRITE(6,908)(YEAR(M),M=1,TMX)
    WRITE(6,73)VNT,(OPCT1(K),K=1,TMX)
 98 WRITE(6,73)VINGT(I),(OPJ1(I,K),K=1,TMX)
 95 CONTINUE
    GO TO 65
 80 DO 100 I=1.TMX
    IF(I.GT.1)GO TO 101
    WRITE(6,91)
    WRITE(6,99)
 99 FORMAT(1HO,20X,33HBY THERMAL PLANT TYPE 2, ANNUALLY)
    WRITE(6,60)
 60 FORMAT(1HO,31X,10HEUJ2(0,10))
    WRITE(6,908)(YEAR(M),M=1,TMX)
    WRITE(6,73)VNT,(ENGT2(K),K=1,TMX)
101 WRITE(6,73)VINGT(I),(EUJ2(I,K),K=1,TMX)
100 CONTINUE
    WRITE(6,15)
    DO 105 I=1,TMX
    IF(I.GT.1)GO TO 106
```

```
      WRITE(6,96)
      WRITE(6,99)
      WRITE(6,61)
   61 FORMAT(1H0,31X,10HOPJ2(0,10))
      WRITE(6,908)(YEAR(M),M=1,TMX)
      WRITE(6,73)VNT,(OPCT2(K),K=1,TMX)
  106 WRITE(6,73)VINGT(I),(OPJ2(I,K),K=1,TMX)
  105 CONTINUE
      GO TO 65
   85 DO 110 I=1,TMX
      IF(I.GT.1)GO TO 111
      WRITE(6,91)
      WRITE(6,62)
   62 FORMAT(1H0,20X,33HBY THERMAL PLANT TYPE 3, ANNUALLY)
      WRITE(6,63)
   63 FORMAT(1H0,31X,10HEUJ3(0,10))
      WRITE(6,908)(YEAR(M),M=1,TMX)
      WRITE(6,73)VNT,(ENGT3(K),K=1,TMX)
  111 WRITE(6,73)VINGT(I),(EUJ3(I,K),K=1,TMX)
  110 CONTINUE
      WRITE(6,15)
      DO 115 I=1,TMX
      IF(I.GT.1)GO TO 116
      WRITE(6,96)
      WRITE(6,62)
      WRITE(6,64)
   64 FORMAT(1H0,31X,10HOPJ3(0,10))
      WRITE(6,908)(YEAR(M),M=1,TMX)
      WRITE(6,73)VNT,(OPCT3(K),K=1,TMX)
  116 WRITE(6,73)VINGT(I),(OPJ3(I,K),K=1,TMX)
  115 CONTINUE
   65 CONTINUE
C*************************************************************
      IF(HMAX.LT.1)GO TO 191
      DO 190 J=1,HMAX
      WRITE(6,15)
```

```
      IF(J-2)195,200,205
195   DO 210 I=1,TMX
      IF(I.GT.1)GO TO 213
      WRITE(6,91)
      WRITE(6,211)
211   FORMAT(1H0,21X,31HBY HYDRO PLANT TYPE 1, ANNUALLY)
      WRITE(6,212)
212   FORMAT(1H0,31X,10HEUH1(0,10))
      WRITE(6,908)(YEAR(M),M=1,TMX)
      WRITE(6,73)VNT,(ENGH1(K),K=1,TMX)
213   WRITE(6,73)VINGT(I),(EUH1(I,K),K=1,TMX)
210   CONTINUE
      WRITE(6,15)
      DO 215 I=1,TMX
      IF(I.GT.1)GO TO 217
      WRITE(6,96)
      WRITE(6,211)
      WRITE(6,216)
216   FORMAT(1H0,31X,10HOPH1(0,10))
      WRITE(6,908)(YEAR(M),M=1,TMX)
      WRITE(6,73)VNT,(OPCH1(K),K=1,TMX)
217   WRITE(6,73)VINGT(I),(OPH1(I,K),K=1,TMX)
215   CONTINUE
      GO TO 190
200   DO 220 I=1,TMX
      IF(I.GT.1)GO TO 221
      WRITE(6,91)
      WRITE(6,214)
214   FORMAT(1H0,21X,31HBY HYDRO PLANT TYPE 2, ANNUALLY)
      WRITE(6,218)
218   FORMAT(1H0,31X,10HEUH2(0,10))
      WRITE(6,908)(YEAR(M),M=1,TMX)
      WRITE(6,73)VNT,(ENGH2(K),K=1,TMX)
221   WRITE(6,73)VINGT(I),(EUH2(I,K),K=1,TMX)
220   CONTINUE
      WRITE(6,15)
```

```
      DO 225 I=1,TMX
      IF(I.GT.1)GO TO 226
      WRITE(6,96)
      WRITE(6,214)
      WRITE(6,219)
  219 FORMAT(1H0,31X,10HOPH2(0,10))
      WRITE(6,908)(YEAR(M),M=1,TMX)
      WRITE(6,73)VNT,(OPCH2(K),K=1,TMX)
  226 WRITE(6,73)VINGT(I),(OPH2(I,K),K=1,TMX)
  225 CONTINUE
      GO TO 190
  205 DO 230 I=1,TMX
      IF(I.GT.1)GO TO 231
      WRITE(6,91)
      WRITE(6,232)
  232 FORMAT(1H0,21X,31HBY HYDRO PLANT TYPE 3, ANNUALLY)
      WRITE(6,233)
  233 FORMAT(1H0,31X,10HEUH3(0,10))
      WRITE(6,908)(YEAR(M),M=1,TMX)
      WRITE(6,73)VNT,(ENGH3(K),K=1,TMX)
  231 WRITE(6,73)VINGT(I),(EUH3(I,K),K=1,TMX)
  230 CONTINUE
      WRITE(6,15)
      DO 235 I=1,TMX
      IF(I.GT.1)GO TO 236
      WRITE(6,96)
      WRITE(6,232)
      WRITE(6,234)
  234 FORMAT(1H0,31X,10HOPH3(0,10))
      WRITE(6,908)(YEAR(M),M=1,TMX)
      WRITE(6,73)VNT,(OPCH3(K),K=1,TMX)
  236 WRITE(6,73)VINGT(I),(OPH3(I,K),K=1,TMX)
  235 CONTINUE
  190 CONTINUE
C***********************************************************
  191 DO 240 J=1,JI
```

```
      WRITE(6,15)
      IF(J-3)245,250,255
  250 DO 260 I=1,TMX
      IF(I.GT.1)GO TO 264
      WRITE(6,261)
  261 FORMAT(1H0,24X,25HMATRIX OF ANNUAL COSTS OF)
      WRITE(6,262)
  262 FORMAT(1H0,19X,37HTYPE 2 FUEL CONSUMED BY PLANT TYPE 2:)
      WRITE(6,263)
  263 FORMAT(1H0,31X,10HCF22(0,10))
      WRITE(6,908)(YEAR(M),M=1,TMX)
      WRITE(6,73)VNT,(FC22(K),K=1,TMX)
  264 WRITE(6,73)VINGT(I),(CF22(I,K),K=1,TMX)
  260 CONTINUE
      GO TO 240
  245 IF(J.GT.1)GO TO 265
      DO 270 I=1,TMX
      IF(I.GT.1)GO TO 271
      WRITE(6,261)
      WRITE(6,266)
  266 FORMAT(1H0,19X,37HTYPE 1 FUEL CONSUMED BY PLANT TYPE 1:)
      WRITE(6,267)
  267 FORMAT(1H0,31X,10HCF11(0,10))
      WRITE(6,908)(YEAR(M),M=1,TMX)
      WRITE(6,73)VNT,(FC11(K),K=1,TMX)
  271 WRITE(6,73)VINGT(I),(CF11(I,K),K=1,TMX)
  270 CONTINUE
      GO TO 240
  265 DO 275 I=1,TMX
      IF(I.GT.1)GO TO 276
      WRITE(6,261)
      WRITE(6,269)
  269 FORMAT(1H0,19X,37HTYPE 1 FUEL CONSUMED BY PLANT TYPE 2:)
      WRITE(6,268)
  268 FORMAT(1H0,31X,10HCF12(0,10))
      WRITE(6,908)(YEAR(M),M=1,TMX)
```

```
      WRITE(6,73)VNT,(FC12(K),K=1,TMX)
  276 WRITE(6,73)VINGT(I),(CF12(I,K),K=1,TMX)
  275 CONTINUE
      GO TO 240
  255 IF(J.GT.4)GO TO 280
      DO 285 I=1,TMX
      IF(I.GT.1)GO TO 286
      WRITE(6,261)
      WRITE(6,287)
  287 FORMAT(1H0,19X,37HTYPE 3 FUEL CONSUMED BY PLANT TYPE 2:)
      WRITE(6,289)
  289 FORMAT(1H0,31X,10HCF32(0,10))
      WRITE(6,908)(YEAR(M),M=1,TMX)
      WRITE(6,73)VNT,(FC32(K),K=1,TMX)
  286 WRITE(6,73)VINGT(I),(CF32(I,K),K=1,TMX)
  285 CONTINUE
      GO TO 240
  280 DO 290 I=1,TMX
      IF(I.GT.1)GO TO 291
      WRITE(6,261)
      WRITE(6,292)
  292 FORMAT(1H0,19X,37HTYPE 3 FUEL CONSUMED BY PLANT TYPE 3:)
      WRITE(6,293)
  293 FORMAT(1H0,31X,10HCF33(0,10))
      WRITE(6,908)(YEAR(M),M=1,TMX)
      WRITE(6,73)VNT,(FC33(K),K=1,TMX)
  291 WRITE(6,73)VINGT(I),(CF33(I,K),K=1,TMX)
  290 CONTINUE
  240 CONTINUE
C*************************************************************
   70 FORMAT(1H0,10E13.4)
C**************************************************************
C**************************************************************
C**********THERMAL PLANT 1*************************************
      IT=1979
      KO=0
```

```
      DO 300 I=1,TMX
      IT=IT+1
      TCJ10(I)=OPCT1(I)+FC11(I)
      IF(ENGT1(I).EQ.0.0)GO TO 300
      KO=KO+1
      IF(KO.EQ.1)GO TO 311
      GO TO 312
  311 WRITE(6,15)
      WRITE(6,750)
      WRITE(6,951)
  312 APJ10(I)=(TCJ10(I)/ENGT1(I))*100.00
      WRITE(6,950)IT,TCJ10(I),ENGT1(I),APJ10(I)
  300 CONTINUE
      IT=1979
      KO=0
      DO 305 K=1,TMX
      IT=IT+1
      DO 310 K1=1,K
  310 ANPJ1(K)=ANPJ1(K)+ATH1(K1)
      DO 315 I=1,TMX
      TCJ1(K)=TCJ1(K)+OPJ1(I,K)+CF11(I,K)
  315 TENJ1(K)=TENJ1(K)+EUJ1(I,K)
      TCJ1(K)=TCJ1(K)+ANPJ1(K)
      IF(TENJ1(K).EQ.0.0)GO TO 305
      KO=KO+1
      IF(KO.EQ.1)GO TO 316
      GO TO 317
  316 WRITE(6,15)
      WRITE(6,751)
      WRITE(6,321)
  317 APJ1(K)=(TCJ1(K)/TENJ1(K))*100.00
      WRITE(6,320)IT,ANPJ1(K),TCJ1(K),TENJ1(K),APJ1(K)
  320 FORMAT(1H0,10X,I4,3E20.4,F15.2)
  305 CONTINUE
C*********SUMMARY FOR THERMAL PLANT 1********
      KO=0
```

```
      IT=1979
      DO 306 I=1,TMX
      IT=IT+1
      TKWJ1(I)=TENJ1(I)+ENGT1(I)
      TCSTJ1(I)=TCJ1(I)+TCJ10(I)
      IF(TKWJ1(I).EQ.0.0)GO TO 306
      KO=KO+1
      IF(KO.EQ.1)GO TO 307
      GO TO 308
  307 WRITE(6,15)
      WRITE(6,752)
      WRITE(6,321)
  308 AVPJ1(I)=(TCSTJ1(I)/TKWJ1(I))*100.00
      WRITE(6,320)IT,ANPJ1(I),TCSTJ1(I),TKWJ1(I),AVPJ1(I)
  306 CONTINUE
C***********THERMAL PLANT 2 ******************************
      KO=0
      IT=1979
      DO 400 I=1,TMX
      IT=IT+1
      TCJ20(I)=OPCT2(I)+FC12(I)+FC22(I)+FC32(I)
      IF(ENGT2(I).EQ.0.0)GO TO 400
      KO=KO+1
      IF(KO.EQ.1)GO TO 401
      GO TO 402
  401 WRITE(6,15)
      WRITE(6,753)
      WRITE(6,951)
  402 APJ20(I)=(TCJ20(I)/ENGT2(I))*100.00
      WRITE(6,950)IT,TCJ20(I),ENGT2(I),APJ20(I)
  400 CONTINUE
      KO=0
      IT=1979
      DO 405 K=1,TMX
      IT=IT+1
      DO 410 K1=1,K
```

```
  410 ANPJ2(K)=ANPJ2(K)+ATH2(K1)
      DO 415 I=1,TMX
      TCJ2(K)=TCJ2(K)+OPJ2(I,K)+CF12(I,K)+CF22(I,K)+CF32(I,K)
  415 TENJ2(K)=TENJ2(K)+EUJ2(I,K)
      TCJ2(K)=TCJ2(K)+ANPJ2(K)
      IF(TENJ2(K).EQ.0.0)GO TO 405
      KO=KO+1
      IF(KO.EQ.1)GO TO 903
      GO TO 407
  903 WRITE(6,15)
      WRITE(6,754)
      WRITE(6,321)
  407 APJ2(K)=(TCJ2(K)/TENJ2(K))*100.00
      WRITE(6,320)IT,ANPJ2(K),TCJ2(K),TENJ2(K),APJ2(K)
  405 CONTINUE
C*********SUMMARY FOR THERMAL PLANT 2********
      KO=0
      IT=1979
      DO 406 I=1,TMX
      IT=IT+1
      TKWJ2(I)=TENJ2(I)+ENGT2(I)
      TCSTJ2(I)=TCJ2(I)+TCJ20(I)
      IF(TKWJ2(I).EQ.0.0)GO TO 406
      KO=KO+1
      IF(KO.EQ.1)GO TO 408
      GO TO 409
  408 WRITE(6,15)
      WRITE(6,755)
      WRITE(6,321)
  409 AVPJ2(I)=(TCSTJ2(I)/TKWJ2(I))*100.00
      WRITE(6,320)IT,ANPJ2(I),TCSTJ2(I),TKWJ2(I),AVPJ2(I)
  406 CONTINUE
C***********THERMAL PLANT 3****************************
      KO=0
      IT=1979
      DO 500 I=1,TMX
```

```
      IT=IT+1
      TCJ30(I)=OPCT3(I)+FC33(I)
      IF(ENGT3(I).EQ.0.0)GO TO 500
      K0=K0+1
      IF(K0.EQ.1)GO TO 501
      GO TO 502
  501 WRITE(6,15)
      WRITE(6,756)
      WRITE(6,951)
  502 APJ30(I)=(TCJ30(I)/ENGT3(I))*100.00
      WRITE(6,950)IT,TCJ30(I),ENGT3(I),APJ30(I)
  500 CONTINUE
      K0=0
      IT=1979
      DO 505 K=1,TMX
      IT=IT+1
      DO 510 K1=1,K
  510 ANPJ3(K)=ANPJ3(K)+ATH3(K1)
      DO 515 I=1,TMX
      TCJ3(K)=TCJ3(K)+OPJ3(I,K)+CF33(I,K)
  515 TENJ3(K)=TENJ3(K)+EUJ3(I,K)
      TCJ3(K)=TCJ3(K)+ANPJ3(K)
      IF(TENJ3(K).EQ.0.0)GO TO 505
      K0=K0+1
      IF(K0.EQ.1)GO TO 503
      GO TO 504
  503 WRITE(6,15)
      WRITE(6,757)
      WRITE(6,321)
  504 APJ3(K)=(TCJ3(K)/TENJ3(K))*100.00
      WRITE(6,320)IT,ANPJ3(K),TCJ3(K),TENJ3(K),APJ3(K)
  505 CONTINUE
C*********SUMMARY FOR THERMAL PLANT 3********
      K0=0
      IT=1979
      DO 506 I=1,TMX
```

```
      IT=IT+1
      TKWJ3(I)=TENJ3(I)+ENGT3(I)
      TCSTJ3(I)=TCJ3(I)+TCJ30(I)
      IF(TKWJ3(I).EQ.0.0)GO TO 506
      KO=KO+1
      IF(KO.EQ.1)GO TO 71
      GO TO 72
   71 WRITE(6,15)
      WRITE(6,758)
      WRITE(6,321)
   72 AVPJ3(I)=(TCSTJ3(I)/TKWJ3(I))*100.00
      WRITE(6,320)IT,ANPJ3(I),TCSTJ3(I),TKWJ3(I),AVPJ3(I)
  506 CONTINUE
      DO 850 J=1,HMAX
      IF(J-2)852,854,855
C*********HYDRO PLANT 1**********************************
  852 IT=1979
      KO=0
      DO 600 I=1,TMX
      IT=IT+1
      IF(ENGH1(I).EQ.0.0)GO TO 600
      KO=KO+1
      IF(KO.EQ.1)GO TO 601
      GO TO 602
  601 WRITE(6,15)
      WRITE(6,770)
      WRITE(6,951)
  602 APH10(I)=(OPCH1(I)/ENGH1(I))*100.00
      WRITE(6,950)IT,OPCH1(I),ENGH1(I),APH10(I)
  600 CONTINUE
      KO=0
      IT=1979
      DO 605 K=1,TMX
      IT=IT+1
      DO 610 K1=1,K
  610 ANPH1(K)=ANPH1(K)+AHYD1(K1)
```

```
      DO 615 I=1,TMX
      TCH1(K)=TCH1(K)+OPH1(I,K)
  615 TENH1(K)=TENH1(K)+EUH1(I,K)
      TCH1(K)=TCH1(K)+ANPH1(K)
      IF(TENH1(K).EQ.0.0)GO TO 605
      KO=KO+1
      IF(KO.EQ.1)GO TO 904
      GO TO 607
  904 WRITE(6,15)
      WRITE(6,771)
      WRITE(6,321)
  607 APH1(K)=(TCH1(K)/TENH1(K))*100.00
      WRITE(6,320)IT,ANPH1(K),TCH1(K),TENH1(K),APH1(K)
  605 CONTINUE
C*********SUMMARY FOR HYDRO PLANT 1********
      KO=0
      IT=1979
      DO 606 I=1,TMX
      IT=IT+1
      TKWH1(I)=TENH1(I)+ENGH1(I)
      TCSTH1(I)=TCH1(I)+OPCH1(I)
      IF(TKWH1(I).EQ.0.0)GO TO 606
      KO=KO+1
      IF(KO.EQ.1)GO TO 608
      GO TO 609
  608 WRITE(6,15)
      WRITE(6,772)
      WRITE(6,321)
  609 AVPH1(I)=(TCSTH1(I)/TKWH1(I))*100.00
      WRITE(6,320)IT,ANPH1(I),TCSTH1(I),TKWH1(I),AVPH1(I)
  606 CONTINUE
      GO TO 850
C*********HYDRO PLANT 2*********************************
  854 KO=0
      IT=1979
      DO 700 I=1,TMX
```

```
      IT=IT+1
      IF(ENGH2(I).EQ.0.0)GO TO 700
      K0=K0+1
      IF(K0.EQ.1)GO TO 701
      GO TO 702
  701 WRITE(6,15)
      WRITE(6,773)
      WRITE(6,951)
  702 APH20(I)=(OPCH2(I)/ENGH2(I))*100.00
      WRITE(6,950)IT,OPCH2(I),ENGH2(I),APH20(I)
  700 CONTINUE
      K0=0
      IT=1979
      DO 705 K=1,TMX
      IT=IT+1
      DO 710 K1=1,K
  710 ANPH2(K)=ANPH2(K)+AHYD2(K1)
      DO 715 I=1,TMX
      TCH2(K)=TCH2(K)+OPH2(I,K)
  715 TENH2(K)=TENH2(K)+EUH2(I,K)
      TCH2(K)=TCH2(K)+ANPH2(K)
      IF(TENH2(K).EQ.0.0)GO TO 705
      K0=K0+1
      IF(K0.EQ.1)GO TO 905
      GO TO 707
  905 WRITE(6,15)
      WRITE(6,774)
      WRITE(6,321)
  707 APH2(K)=(TCH2(K)/TENH2(K))*100.00
      WRITE(6,320)IT,ANPH2(K),TCH2(K),TENH2(K),APH2(K)
  705 CONTINUE
C*********SUMMARY FOR HYDRO PLANT 2********
      K0=0
      IT=1979
      DO 706 I=1,TMX
      IT=IT+1
```

```
      TKWH2(I)=TENH2(I)+ENGH2(I)
      TCSTH2(I)=TCH2(I)+OPCH2(I)
      IF(TKWH2(I).EQ.0.0)GO TO 706
      KO=KO+1
      IF(KO.EQ.1)GO TO 901
      GO TO 902
  901 WRITE(6,15)
      WRITE(6,775)
      WRITE(6,321)
  902 AVPH2(I)=(TCSTH2(I)/TKWH2(I))*100.00
      WRITE(6,320)IT,ANPH2(I),TCSTH2(I),TKWH2(I),AVPH2(I)
  706 CONTINUE
      GO TO 850
C*********HYDRO PLANT 3*********************************
  855 KO=0
      IT=1979
      DO 800 I=1,TMX
      IT=IT+1
      IF(ENGH3(I).EQ.0.0)GO TO 800
      KO=KO+1
      IF(KO.EQ.1)GO TO 801
      GO TO 802
  801 WRITE(6,15)
      WRITE(6,776)
      WRITE(6,951)
  802 APH3O(I)=(OPCH3(I)/ENGH3(I))*100.00
      WRITE(6,950)IT,OPCH3(I),ENGH3(I),APH3O(I)
  800 CONTINUE
      IT=1979
      KO=0
      DO 805 K=1,TMX
      IT=IT+1
      DO 810 K1=1,K
  810 ANPH3(K)=ANPH3(K)+AHYD3(K1)
      DO 815 I=1,TMX
      TCH3(K)=TCH3(K)+OPH3(I,K)
```

```
  815 TENH3(K)=TENH3(K)+EUH3(I,K)
      TCH3(K)=TCH3(K)+ANPH3(K)
      IF(TENH3(K).EQ.0.0)GO TO 805
      KO=KO+1
      IF(KO.EQ.1)GO TO 803
      GO TO 804
  803 WRITE(6,15)
      WRITE(6,777)
      WRITE(6,321)
  804 APH3(K)=(TCH3(K)/TENH3(K))*100.00
      WRITE(6,320)IT,ANPH3(K),TCH3(K),TENH3(K),APH3(K)
  805 CONTINUE
C*********SUMMARY FOR HYDRO PLANT 3********
      KO=0
      IT=1979
      DO 806 I=1,TMX
      IT=IT+1
      TKWH3(I)=TENH3(I)+ENGH3(I)
      TCSTH3(I)=TCH3(I)+OPCH3(I)
      IF(TKWH3(I).EQ.0.0)GO TO 806
      KO=KO+1
      IF(KO.EQ.1)GO TO 807
      GO TO 808
  807 WRITE(6,15)
      WRITE(6,778)
      WRITE(6,321)
  808 AVPH3(I)=(TCSTH3(I)/TKWH3(I))*100.00
      WRITE(6,320)IT,ANPH3(I),TCSTH3(I),TKWH3(I),AVPH3(I)
  806 CONTINUE
  850 CONTINUE
      WRITE(6,15)
      WRITE(6,952)
      WRITE(6,760)
C**********GENERAL SUMMARY************************************
      IT=1979
      DO 900 I=1,TMX
```

```
      IT=IT+1
      TENGY=TKWJ1(I)+TKWJ2(I)+TKWJ3(I)+TKWH1(I)
     1       +TKWH2(I)+TKWH3(I)
      TCOST=TCSTJ1(I)+TCSTJ2(I)+TCSTJ3(I)
     1       +TCSTH1(I)+TCSTH2(I)+TCSTH3(I)
      APRICE=(TCOST/TENGY)*100.00
      WRITE(6,950)IT,TCOST,TENGY,APRICE
  900 CONTINUE
  952 FORMAT(1H0,30X,36H**********GENERAL  SUMMARY**********)
  950 FORMAT(1H0,10X,I4,2E20.4,F15.2)
  908 FORMAT(1H0,1X,7HVINTAGE,I11,9I12)
  907 FORMAT(1H0,I11,9I13)
  321 FORMAT(1H0,10X,4HYEAR,8X,14HCUM.ANNUAL PMT,5X,17HTOTAL ANNUAL COST
     1,5X,13HELEC.PRODUCED,5X,12HAV.UNIT COST)
   73 FORMAT(1H0,I5,4X,10E12.4)
  951 FORMAT(1H0,10X,4HYEAR,12X,8HOP. COST,9X,12HENERGY PROD.,6X,12HAV.U
     1NIT COST)
  760 FORMAT(1H0,10X,4HYEAR,10X,10HTOTAL COST,9X,12HENERGY PROD.,6X,12HA
     1V.UNIT COST)
  750 FORMAT(1H0,30X,17HTHERMAL 1 INITIAL)
  751 FORMAT(1H0,30X,13HTHERMAL 1 NEW)
  752 FORMAT(1H0,25X,21HSUMMARY FOR THERMAL 1)
  753 FORMAT(1H0,30X,17HTHERMAL 2 INITIAL)
  754 FORMAT(1H0,30X,13HTHERMAL 2 NEW)
  755 FORMAT(1H0,25X,21HSUMMARY FOR THERMAL 2)
  756 FORMAT(1H0,30X,17HTHERMAL 3 INITIAL)
  757 FORMAT(1H0,30X,13HTHERMAL 3 NEW)
  758 FORMAT(1H0,25X,21HSUMMARY FOR THERMAL 3)
  770 FORMAT(1H0,35X,15HHYDRO 1 INITIAL)
  771 FORMAT(1H0,35X,11HHYDRO 1 NEW)
  772 FORMAT(1H0,25X,19HSUMMARY FOR HYDRO 1)
  773 FORMAT(1H0,35X,15HHYDRO 2 INITIAL)
  774 FORMAT(1H0,35X,11HHYDRO 2 NEW)
  775 FORMAT(1H0,25X,19HSUMMARY FOR HYDRO 2)
  776 FORMAT(1H0,35X,15HHYDRO 3 INITIAL)
  777 FORMAT(1H0,35X,11HHYDRO 3 NEW)
```

```
  778 FORMAT(1H0,25X,19HSUMMARY FOR HYDRO 3)
C***********END OF SUBROUTINE REPORT **********************
      RETURN
      END
```

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