社会開発調査部報告書

REPUBLIC OF KENYA

MINISTRY OF WATER DEVELOPMENT

THE STUDY ON THE NATIONAL WATER MASTER PLAN

SECTORAL REPORT (L)

POWER DEVELOPMENT PLAN

JULY 1992

JAPAN INTERNATIONAL COOPERATION AGENCY

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PREFACE

Interpretation of Report

The original objective of this NWMP Study is to propose a nationwide framework for orderly planning and development of water resources in the country. The Study also deals with the formulation of individual development schemes. However, it should be noted that the plans formulated in this Study remain at a national level and do not provide complete details at local level. Further details should be examined in subsequent studies on each river basin, district, and project basis which are separately recommended in this Study.

Administrative Division of Districts

In this Study, the original 41 districts were considered and various statistical data, particularly socio-economic information, were collected for these districts. During the progress of the Study, six districts were detached from the original ones and established as new districts. In the report, the data on these new districts are grouped together with the corresponding original districts as shown below.

	Original Districts	New Districts	Data included in:
1.	Machakos	Makueni	Machakos/Makueni
2.	Kisii	Nyamira	Kisii/Nyamira
3.	Kakamega	Vihiga	Kakamega/Vihiga
4.	Meru	Tharaka-Nithi	Meru/Tharaka-Nithi
5.	Kericho	Bomet	Kericho/Bomet
6.	South Nyanza	Migori	South Nyanza/Migori

(Note: The last three Districts were established very recently.
The report refers only to the names of the original 41 districts.)

The administrative boundary map used in this Study is the latest complete map set covering the whole country (41 Districts, 233 Divisions and 976 Locations), prepared in 1986 by the Survey of Kenya, Ministry of Land, Housing and Physical Planning.

Data and Information

The data and information contained in the report represent those collected in the 1990-1991 period from various documents and reports made available mostly from central government offices in Nairobi and/or those analyzed in this Study based on the collected data. Some of them may be different from those kept in files at some agencies and regional offices. Such discrepancies if any should be collated and adjusted as required in further detailed studies of the relevant development projects.

Development Cost

The cost and benefit estimate was based on the 1991 price level, and expressed in US$ equivalent according to the exchange rate of US$1 = KShs25.2 prevailing at that time. The same exchange rate was used in calculating the development cost in K£/KShs currency.

THE STUDY ON THE NATIONAL WATER MASTER PLAN

SECTORAL REPORT (L)
POWER DEVELOPMENT PLAN

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L1. INTRODUCTION

1.1 Energy Sector in Kenya

The Ministry of Energy (MOE) of the Government of Kenya is responsible for the Kenyan energy sector including electric power.

In 1987, the overall energy consumption in Kenya was estimated at about 8.4 million tons of oil, equivalent to 380 kg per capita. In relation to neighbouring sub-Saharan countries, this figure is relatively high, but most energy required in Kenya (about 70%) is supplied by traditional energy sources, fuelwood and charcoal, which are mainly used by most of population for cooking, and also for heating in many commercial and industrial processes.

Petroleum products, used primarily for transport and also for some cooling and heating, supply 22% of national energy requirements. Electricity supplies about 7% of the national energy requirements, while coal supplies only 1%.

1.2 Hydropower Development

Hydroelectric power potential in Kenya is roughly estimated to be about 6,000 MW (about 30,000 GWh). However, half of this located on small rivers, and most are uneconomical for development.

The first hydroelectric power station (Ndula station) was constructed on the Thika River, a tributary of the Tana River, in 1925. Since then, many hydropower projects have been continually developed. The total installed capacity of hydroelectric generation at present is 497 MW, accounting for 70% of all generating facilities in Kenya and supplying 87% of electricity energy requirements in 1988/89.

The inventory of hydroelectric resources throughout the country was first prepared by Tippets-Abbett-McCarthy-Stratton (TAMS) in their National Master Water Plan in 1980. They estimated the theoretical maximum power at 2,770 MW (24400 GWh).

In the National Power Development Plan prepared in 1987 (1987 NPDP), hydroelectric power potential has been inventoried in more detail by a review of available studies, and estimated at 1,400 MW (6,000 GWh) excluding the existing and committed hydroelectric power stations.

1.3 Report Content

The structure of the remainder of this sectoral report is as follows:

Chapter 2 : A brief overview of the existing power supply system in Kenya including hydroelectric power stations.

Chapter 3 : A brief overview of the power market in Kenya including energy production, sales and electricity tariffs applied in Kenya.

Chapter 4 : Summary of hydroelectric power potential inventoried in the National Master Water plan (1980) and the 1987 NPDP.

Chapter 5 : A brief explanation of the power development plan established in the 1987 NPDP including power demand projection, system expansion plan, and hydroelectric power schemes.

Chapter 6 : A brief explanation of the results of interim update of the 1987 NPDP.

L2. EXISTING POWER SUPPLY SYSTEM

2.1 Organization of Power Sector in Kenya

Until March 1988, the Ministry of Energy and Regional Development (MOERD) was responsible for the energy sector. Since then, the two functions have been separated and the Ministry of Regional Development (MRD) and the Ministry of Energy (MOE) have been established. The MOE oversees energy policy formulation, electric power, oil and other fossil fuels, and wind, biogas, solar, geothermal, and woodfuel.

The electricity industry of the country is composed of the following six entities:

- The Kenya Power Company Ltd. (KPC),
- The Kenya Power and Lighting Company Ltd. (KPLC), formerly East Africa Power and Lighting Company (EAP&L),
- The Tana River Development Company (TRDC),
- The Tana and Athi Rivers Development Authority (TARDA), formerly Tana River Development Authority (TRDA),
- The Kerio Valley Development Authority (KVDA), and
- The Lake Basin Development Authority (LBDA)

KPC was formed in 1954 to purchase bulk power from Uganda Electricity Board (UEB), and for this purpose it owns a 132 transmission line from the western border of Kenya to Nairobi. In addition to this, KPC owns both the Wanjii and Tana hydroelectric power stations, and the Olkaria geothermal power plant including associated transmission lines. KPC is also responsible for the development of geothermal and hydropower resources.

KPLC, which is a 60% government-owned entity, owns and operates all conventional thermal generating facilities, a number of small hydroelectric power stations, and most of the power transmission facilities. KPLC purchases electric power in bulk from KPC, TRDC, and TARDA (KVDA and LBDA do not yet have generating facilities in operation) imports electric energy from Uganda, and distributes power to their customers. KPLC also operates and manages all generating facilities under agreement with other companies and authorities.

TRDC was initiated in 1964 to coordinate hydroelectric development on the middle Tana River, and now owns the Kamburu, Gitaru and Kindaruma hydroelectric power stations and their associated transmission lines to Nairobi.

The other entities, TARDA, KVDA, and LBDA, were created to plan integrated development in each basin. They are responsible for planning, coordinating and monitoring development projects within the basins. TARDA owns the Masinga and Kiambere hydroelectric power stations on the Tana River which have a large reservoir capable of considerable regulation for the purposes of downstream irrigation and water supply as well as hydroelectric power generation. KVDA has been developing the Turkwel multi-purpose project which is scheduled to be completed in early 1991.

The country is divided into five regions in terms of power supply as follows:

- Nairobi region,
- Coast region,
- Rift Valley region,
- Western region and
- Mt. Kenya region.

Note: The country has recently been divided into six regions in terms of the power supply.

Figure L.2.1 shows the supply region boundaries as well as the existing power systems and potential sites of the indigenous energy resources.

2.2 Generating Facilities

Generating facilities in Kenya consist of hydroelectric, conventional thermal, and geothermal power plants. The total installed capacity of these facilities as of January 1991 in the interconnected power system was 705 MW. Composition of generating facilities is summarized as follows:

Plant	Installed Capacity		Effective Output	
	(MW)	(%)	(MW)	(%)
Hydropower	495.3	70.4	476.3	74.4
Conventional thermal	145.9	20.6	112.8	17.6
Geothermal	45.0	6.4	43.0	6.7
Diesel	18.3	2.6	8.0	1.2
Total	704.5	100.0	640.1	100.0

In addition to the above, there are a number of isolated diesel power plants of about 4 MW in total. Some energy is also imported from Uganda.

The Turkwel hydroelectric power project having two generators rated at 53 MW each is under construction in the Rift Valley, and will be completed soon.

Hydroelectric

With the exception of two small hydroelectric power stations located in Western Kenya (Gogo and Selby Falls), all existing hydroelectric power stations are situated in the Tana River basin.

Details of the existing hydroelectric power plants are given in Table L.2.1.

A more detailed explanation of hydropower plants is given in Section 2.5.

Conventional Thermal

Conventional thermal generating facilities play an important role in the operation of the present power system. A peak portion of the daily loads is shared by these facilities throughout the year. The existing facilities are Kipevu and Nairobi South power plants.

In Kipevu, six oil-fired steam units have been installed since 1954, of which only four are presently operational (1991). The present capability of the plant is as follows:

Unit No.	Year in Service	N/Plate Output	Effect. Output
2	1954	5 MW	0
3	1961	5 MW	0
4	1962	12.5 MW	8 MW
5	1964	12.5 MW	6 MW
6	1972	30 MW	30 MW
7	1976	33 MW	25 MW

(Source: KPLC's information in 1991)

In addition to these steam units, a gas turbine unit of 30 MW has operated since 1987.

Nairobi South power station consists of 3 gas turbine units and 8 diesel engine driven generators of 30.5 MW in total.

Geothermal

The Olkaria geothermal field is situated in the central part of the Rift Valley about 120 km northwest of Nairobi and about 10 km south of Lake Naivasha. Three 15 MW units have now been operating for about 10 years. The first unit was commissioned in mid-1981, the second unit in 1982, and the last unit in March 1985. This 45 MW plant is expected to generate energy at approximately 88% plant factor throughout the planning period. The results of the past 4 years operation were as follows:

Year	Energy Production	Plant Factor
1986/87	374 GWh	94.9%
1987/88	348 GWh	88.3%
1988/89	322 GWh	81.7%
1989/90	366 GWh	85.2%
Average	345 GWh	87.5%

The details of existing and committed thermal power plants including isolated diesel power plants are given in Table L.2.2.

2.3 Transmission and Distribution Facilities

Most of the power supply system in Kenya is interconnected, but it is operationally divided into 5 regions as mentioned in Section 2.1.

Transmission Lines

Power transmission system in the country consists of 220 kV, 132 kV, 66 kV, 40 kV, and 33 kV lines.

The geographic location of the lines and substations are illustrated in Figure L.2.1. A single-line diagram of the transmission system is shown in Figure L.2.2. Detailed transmission line length by voltage and by region is given in Table L.2.3.

A greater part of the existing transmission system is operated at 132 kV, with over 1,986 km-cct (see Table L.2.3) of lines at this voltage. There are also five sections of 220 kV line, totaling about 900 km-cct including Turkwel-Lessos line (225 km) and a double-circuit line from Dandora to Embakasi (12 km) which have been recently completed.

The 132 kV system was first employed in 1956 for importing energy generated at the Owen Falls hydroelectric station in Uganda. In 1983, the first 220 kV system was put into operation between the Kamburu hydroelectric station and Nairobi. Voltages of 66 kV and 40 kV are applied only in the Nairobi region.

In order to supply energy to rural areas, 33 kV lines have widely been developed, especially in the Western region. With the progress of the rural electrification program in the country, both 132 kV and 33 kV systems will be further expanded.

Distribution System

Distribution systems in the country consist of 11 kV on the high voltage and 415/230 V on low voltage, and summarized as below:

Region	1976	1983	1988	Growth
11 kV System				
Nairobi	2,220	2,783	3,158	3.1%
Rift Valley	519	683	810	3.9%
Western	914	1,164	1,329	3.3%
Coast	473	593	655	2.9%
Mt. Kenya	627	1,075	1,228	6.0%
Total	4,753	6,298	7,180	3.7%
415/230 V System				
Nairobi\	1,003	1,370	1,639	4.4%
Rift Valley	153	226	376	8.2%
Western	295	427	723	8.1%
Coast	335	413	482	3.2%
Mt. Kenya	196	373	599	10.2%
Total	1,982	2,809	3,819	5.9%

Note: Growth - Average growth rate over 11.5 years from December 1976 to June 1988

The above table shows that the average growth rates of Rift Valley, Western, and Mt. Kenya regions are higher than the others, which imply that rural electrification is steadily being implemented in these regions.

The detailed breakdown of the distribution lines is given in Table L.2.4. Total installed capacity of distribution transformers, 33/0.415 kV and 11/0.415/0.23 kV, has reached the level of 1,380 MVA as of June 1989 with an annual average increase rate of 8.2% since 1979, as detailed in Table L.2.5.

2.4 Substation Facilities

The power supply system has substations operating at 132 kV and 220 kV, including those at major generating stations. Most of the major high-voltage substations have ring-bus arrangements, with the remainder having either double bus, single breaker, or single bus schemes. Many of the small 132/33 kV distribution substations have no circuit breakers on the 132 kV lines and only one transformer. This arrangement allows economic supply to small load centres, but results in frequent outages of long line sections.

Historical information on the system substations is detailed in Table L.2.5.

In 1983, a 220 kV transmission line system was introduced into the country. The step-up transformer capacity which was installed at the generating stations has been expanded with an average annual growth rate of 11% since 1979. As for the distribution substations, the transformer capacity grew with an average annual growth rate of 8% for the same period.

2.5 Existing Hydroelectric Power Plants

Small Hydropower Stations

Between 1925 and 1958, several small hydroelectric projects were developed, Gogo and Selby Falls in the Lake Victoria drainage basin, and Ndula, Mesco, and Sagana Falls in the Tana River catchment. The total installed capacity of these plants is 6.3 MW.

Tana Cascade

Since 1932, the upper Tana River has been harnessed to provide 491 MW in total by developing the following power projects:

– Wanjii power station	7.4 MW
– Tana power station	14.4 MW
– Masinga power station	40.0 MW
– Kamburu power station	94.2 MW
– Gitaru power station	147.0 MW
– Kindaruma power station	44.0 MW
– Kiambere power station	144.0 MW

The water is cascaded from one station to the next taking advantage of the head created by each dam and falls and/or rapids to produce electric power.

In order to provide adequate flow during the dry periods, water is stored at Masinga Reservoir during the rainy season and released during the dry season. The results of the Masinga Reservoir operation since 1981 (reservoir water level) are given in Figure L.2.4.

Figure L.2.3 illustrates how the river's potential has been developed. These projects are described below, progressing from upstream to downstream, and major characteristics of these projects including the Turkwel are given in Table L.2.6.

(1) Wanjii

This plant is a run-of-river type power plant and is located on the Maragua River, an upstream tributary of the Tana River. It consists of four units with a total installed capacity of 7.4 MW, operating at a head of 115 m and sharing the base load portion. The plant is connected to the Tana power station by a 11 kV line.

(2) Tana

This plant is a run-of-river type power plant and it consists of five units totalling an installed capacity of 14.4 MW. Three units (Unit 1, 2, and 3) out of five units are fed from the Maragua River downstream of Wanjii and develop a head of 70 m. The remaining two units, with a capacity of 4 MW each, are fed from the Sagana River, via a 5 km intake tunnel. The design head on these two machines is 54 m.

In 1981, the Masinga was impounded and reduced the effective head at the Tana plant by raising the tail water level by 6m.

(3) Masinga

This plant was completed in 1981 and plays a key role in the operation of the Tana River basin because its reservoir has huge amount of live storage, 1,410 million cubic meters which is equivalent to 65% of the mean annual flow volume at the dam site.

The power house is a surface type and contains two 20 MW units with Kaplan turbines, operating at a rated head of 49 m. There is a maximum drawdown of 25.5 m. The effective output at minimum head is reduced to about 13 MW.

(4) Kamburu

This is an underground plant having three generators rated at 31.4 MW each. The turbines are Francis type. The plant was completed in 1974 and is in excellent condition. The Kamburu reservoir contains a live storage of 135 million cubic meters which is equivalent to 5% of the mean annual flow volume.

This plant is connected to Nairobi through a 132 kV single circuit transmission line via the Kindaruma plant, and two 220 kV single circuit transmission lines.

Kamburu also functioned as the local control centre, from which Masinga, Gitaru and Kindaruma power houses can be operated.

(5) Gitaru

This is an underground plant and is the largest in the system (its plant capacity as well as unit capacity of 73.5 MW), and comprises a total capacity of 147 MW. There is full provision for the addition of a third unit in future, but due to a hydraulic flow limitation of the tailrace tunnel, the maximum plant output would be limited to 200 MW. The reservoir has capacity only sufficient for daily regulation.

For erection and maintenance, two 130/10 tones overhead travelling cranes are provided in the power house cavern and can be coupled together to handle 175 tones generator.

Electric power generated at this plant is transmitted to the Kamburu substation through a 132 kV double circuit transmission line of 8 km. At Kamburu, the voltage is stepped up further to 220 kV for transmitting power to the Dandora substation in Nairobi.

(6) Kindaruma

This power station is the oldest hydropower station in Seven Forks Complex having been commissioned in 1968. The plant comprises two generators driven by Kaplan turbines and rated at 22 MW each, operating at a net head of 32 M. There is provision for the addition of a third 22 MW unit in future.

The dam structure is a rockfill type having a front concrete deck with asphaltic membrane. Apart from the inflows from Gitaru tailrace and spillway, there are several streams discharging their water into the reservoir. The live storage of the reservoir is about 7.5 million cubic meters which is only capable of daily regulation.

(7) Kiambere

This plant is located downstream from all existing hydropower stations on the Tana River and approximately 70 km downstream of Kamburu dam. It is an underground plant and contains two Francis turbine/generator units rated at 72 MW each, 0.85 power factor at voltage 11 kV. The control building is above the service shaft for the power house.

At present, two single-circuit 220 kV lines are provided to connect into the national power grid. One line connects to Kamburu switchyard with 39 km and the other to Rabai sub-station in Mombasa.

Turkwel

The project is under construction and will be completed in early 1991.

The project comprises a 155 m high concrete arch dam at the Turkwel Gorge located at the boundary between the West Pokot and Turkana districts, a 2.5 km long headrace tunnel to the underground power house situated 250 meters below ground level, and a single tailrace tunnel of 1.3 km long. The powerhouse contains two Francis turbine/generator units rated at 53 MW each. The reservoir has a full supply level (FSL) of 1150 meters and minimum drawdown level of 1105 meters, yielding a live storage of 1,480 million cubic meters which is equivalent to 2.64 times the mean annual flow volume (17.8 cubic meter per second).

2.6 Rural Electrification

The Rural Electrification Program (REP) was established in 1973 as a government programme to subsidize the extension of electricity services into sub-economic rural areas.

The institutional setting of the program includes MOE for administration and policies, KPLC responsible for implementation and operation, Rural Electrification Technical

Committee (RETC) for the management, and District Development Committees (DDCs) for identification and bringing up for electrification.

The initial target of the program was to provide all district headquarters in the country with electricity and thus to support decentralization.

In early 1980s, this target had already been achieved except for the Hola district. The present target is to electrify the country's smaller administrative units like divisions, of which to date, about 100 divisions have been connected to the national grid.

The priority of electrification schemes will include:

- Projects raising productivity and efficiency in agriculture with significant employment benefits.
- Agro-industries, with significant employment benefits.
- Expanding market centres, with priority given to the ones identified as Growth Centres.
- Health Centres and schools.
- Industry using large amount of imported diesel fuel.
- Community water projects.

At the end of June, 1989 there were 73 electrification schemes in operation and 66 schemes under construction. The accumulated number of customers connected to the grid in 1989 was 15,132 and total energy sales was 49.3 GWh, which was about 2% of the total energy sales in the country. The Western and Nairobi regions cover most of the program ; almost two-third of the schemes and 70% of the customers.

L3. POWER MARKET

3.1 Historical Power Supply

(1) Generation in the Country

At present, hydroelectric generation plays a major role in supply of power and energy in the country. The second is geothermal. Historical records of generation by plant type are outlined below:

	1979	1984	1988/89	Growth
Supply (GWh)				
Hydro	1,288	1,471	2,508	6.6%
Geothermal	–	233	336	–
Oil Thermal	205	174	97	–
Diesel & G.T.	2	1	12	–
Import	160	215	174	–
Adjustment	0	0	9	–
Total Supply	1,655	2,094	3,136	6.3%
Station Use	22	28	33	
Net Supply	1,633	2,066	3,103	6.3%
System Loses	220	276	456	7.2%

Note: Growth - 10.5 years from 1979 to 1989/90

As seen in the above table, generation by hydroelectric power plants was 86% of total generation as of the fiscal year 1989/90. Energy imports from UEB were 4% (1988/89) to 18% (1980) of total supply, a still considerable amount of share. Average annual growth rate of total supply was of 6.3% in the past 10 years, although some variations were recorded. The historical power and energy balance including the detailed energy production by plant and losses are given in Table L.3.1.

Monthly energy production including energy imports from UEB by plant type for the last 10 years is shown in Figure L.3.1.

(2) Energy Production by Each Plant

Energy production records of major power stations are summarized below:

Plant	Installed Cap. (MW)	Period (year)	Production / Year (GWh)		
			Max.	Min.	Aver.
Masinga Hydro	40.0	82-89	215.4	45.0	134.1
Kamburu Hydro	94.2	78-89	447.0	277.0	371.8
Gitaru Hydro	147.0	79-89	862.0	515.0	708.1
Kindaruma Hydro	44.0	78-89	219.4	128.9	187.3
Kiambere Hydro	144.0	89	-	-	716.2
Olkaria Geo	45.0	85-89	369.3	315.9	340.6
Kipevu Steam	98.0	78-89	332.8	32.0	181.7

Monthly operation records in the period 1980 - 1989 of hydroelectric power stations on the Tana River, which have a reservoir and/or regulating poundage, are shown in Figures L.3.2 and L.3.3. These figures show that the cascaded power schemes on the Tana River have been operated well in the hydro dominant power system which requires to maximize firm energy.

Historical outage rates of hydropower plants for the period between 1981 and 1985 are given in Table L.3.2.

3.2 Historical Power Demand

(1) Category of Customers

The customers in the country have been classified into 11 categories and 5 groups since 1979. Accounting year of KPLC has also been changed from "January 1 to December 31" to "July 1 to June 30" since 1986.

According to the "Method of Charge (KPLC) Bylaws 1990, 11 electric tariff categories are specified as follows:

(a) Method A0 : Ordinary domestic customers whose consumption does not exceed 7,000 kWh/month.

(b) Method A1 : Ordinary small non-domestic customers whose consumption does not exceed 7,000 kWh/month.

Method B : Ordinary customers whose consumption exceed 7,000 kWh/month but does not exceed 100,000 kWh/month.

(c) Method BO : Irrigation pumping loads at 240 V single - phase 2-wire or 415 V, 3-phase 4-wire.

(d) Method B1 : Customers at 240 V single-phase 2-wire or 415 V, 3-phase 4-wire.

(e) Method B2 : Customers at 11 kV or 33 kV.

(f) Method B3 : Customer at 66 kV or 132 kV.

Method C : Ordinary customer whose consumption exceeds 100,000 kWh/month

(g) Method C1 : Customers at 415V, 3-phase 4-wire.

(h) Method C2 : Customers at 11 kV or 33 kV.

(i) Method C3 : Customers at 66 kV or 132 kV.

(j) Method D0 : Interruptible off-peak supplies of electrical energy to ordinary customers.

(k) Method E : Public and local authorities for supplies of electrical energy for public lamps (Street Lighting).

Besides these categories, a category "F" will be defined for demand analysis and forecast. Category F is for energy consumption by KPLC's staff.

Method D (off-peak sales) is applied primarily for domestic hot water heating, and is regulated with a ripple control system which switches these loads off during peak period hours and on again during off peak hours of the day. The attraction to customers of off-peak supply (Tariff D) is that it is less costly than other tariffs (see Section 3.4), and the attraction to KPLC is that it reduces the peak load on the integrated power system.

(2) Energy Demand

Total energy sales in the whole of KPLC's network was 2,412 GWh in 1988/89, of which sales in the Nairobi region was 1,270 GWh, followed by the Coastal region of 564 GWh, are the western region of 340 GWh. This implies that more than 53% of KPLC's energy was consumed in the Nairobi region. As for the demand sectors, energy sales of tariff category C (large commercial and industrial) was 1,041 GWh (43%), and followed by tariff category A (domestic and small non-domestic) of 729 GWh (30%).

In order to analyze the historical tendency of energy consumption, tariff categories are grouped into 3 customer groups:

(a) Domestic/small non-domestic : Domestic and non-domestic use less than 7,000 kWh/month, street lighting and KPLC's staff consumption (Method A0, A1, E and F).

(b) Commercial/	Lighting and power, and industries of Industrial more than 7,000 kWh/month (Method B0, B1, B2, B3, C1, C2 and C3)
(c) Off-peak	Interruptible off-peak supply (Method D)

Historical energy sales by region and by customer group are summarized as follows:

(GWh)

Region	Group	1979	1984	1988/89	Growth
Nairobi	Domestic	252.5	331.0	458.6	6.5
	Commercial	428.3	550.4	707.7	5.4
	Off-peak	110.0	104.0	104.1	–
	Sub-total	790.8	985.4	1,270.4	5.1
Coast	Domestic	69.3	88.7	127.6	6.6
	Commercial	270.0	317.8	433.8	5.1
	Off-peak	4.5	4.3	3.0	–
	Sub-total	348.9	410.8	564.4	5.2
Rift Valley	Domestic	23.5	33.1	41.2	6.1
	Commercial	44.8	56.1	89.5	7.6
	Off-peak	2.5	2.6	1.9	–
	Sub-total	70.8	91.8	132.6	6.8
Western	Domestic	36.4	45.2	71.5	7.4
	Commercial	127.4	171.9	264.9	8.0
	Off-peak	3.9	3.3	3.0	–
	Sub-total	167.7	220.4	339.4	7.7
Mt. Kenya	Domestic	16.9	24.7	38.7	9.1
	Commercial	17.5	39.6	60.6	14.0
	Off-peak	1.7	2.1	2.1	–
	Sub-total	36.2	66.3	101.4	11.5
National Total	Domestic	398.7	522.7	737.6	6.7
	Commercial	880.1	1,135.8	1,556.4	6.2
	Off-peak	122.6	116.2	114.1	–
	Sub-total	1,409.4	1,774.7	2,408.2	5.8

Note: Growth - Average growth rate in % for 9.5 years from 1979 to 1988/89.

The detailed energy sales by tariff category and by region are given in Table L.3.3. Figure L.3.4 shows annual energy sales by customer group from 1979 to 1988/89.

The average annual growth rate for energy sales in the country was 5.8% in the period of 1979 to 1988/89.

The domestic and small customers group in the country was 31% in 1988/89, and increased with the highest growth rate of 6.7% per annum. The share of off-peak sales has declined steadily since 1979.

The Nairobi region, the largest demand centre in the country, has always consumed 54 to 56% of energy consumption in the country, and followed by the Coast region of 22%. The Rift Valley, Western and Mt. Kenya regions are developing areas in terms of electric energy consumption, showing high growth rates in comparison with that of the Nairobi and Coast regions.

(3) Number of Customers

Number of customers of KPLC system are summarized below:

Tariff	1980 *1	1985 *1	1990 *2	Growth *3
A	120,096	164,004	240,023	7.6%
B	1,146	1,505	1,989	6.0%
C	112	178	275	11.0%
D	907	950	1,295	3.8%
E	76	61	91	8.0%
F	1,460	1,737	2,673	6.6%
Total	123,797	168,435	246,346	7.5%

Note: *1 As of 31st December
*2 As of 30th June
*3 Average growth rate for 9.5 years from December 1980 to June 1990.

Domestic (Tariff AO) and small non-domestic (Tariff A1) customer groups shares 97.5% of the total number of customers in KPLC system. The number of customers has grown at an average annual rate of 7.8% nationwide since 1980.

Electrification ratio of the country in 1989 is roughly estimated as follows:

Total population (estimate)	23,500,000
Household member	6 persons
Total household	3,917,000
Number of customers (tariff AO + AO/Do)	
KPLC system	186,346
REF system	8,799
Total	195,145
Electrification ratio	4.9%

(4) Rural Electrification

Energy sales to the customers of REF (Rural Electrification Fund) system are summarized below. Table L.3.4 shows annual energy sales of REF system by region in the period from 1982 to 1988/89.

	1982 (MWh)	1989 (MWh)	Growth (%)
Nairobi	1,294	11,748	40.4
Coast	284	1,395	27.4
Rift Valley	1,013	3,699	22.0
Western	4,353	22,108	28.4
Mt. Kenya	1,760	9,785	30.2
Total	8,502	48,736	30.8

Note: Growth - Average growth rate for 6.5 years

As shown above, energy sales of REF system have increased at very high rate, but it shared only about 2% of the total energy sales of the country in 1988/89. The Nairobi and Western regions cover most of the energy sales : almost two-third (69%) of the energy sales.

The number of customers by tariff are shown below:

Method	1982	1989	Growth (%)
A	3,134	14,994	27.2
B	8	62	37.0
C	0	3	–
D	0	3	–
E	0	6	–
F	9	64	35.2
Total	3,151	15,132	27.3

3.3 Load Characteristics

The annual load factors for the integrated power system for the past 10 years are summarized as follows:

Year	Energy Production (GWh)	Peak-load (MW)	Load factor (%)
1979	1,655	269	70.2
1980	1,735	290	68.3
1981	1,879	313	68.5
1982	1,946	317	70.1
1983	2,013	334	68.8
1984	2,094	349	68.5
1985	2,300	387	67.8
1986 (1-6)	1,183	400	68.1
1986/87	2,594	430	68.9
1987/88	2,816	461	69.7
1988/89	2,931	480	69.7
		(Average	69.0)

The above table shows that the annual load factor in Kenya is relatively high and there is no significant change in the last 10 years. There are three main reasons for such a high load factor:

(a) The ripple control system reduces peak loads and increases loads during off-peak hours, especially in mid-night.

(b) A high portion of the KPLC sales is to industrial customers.

(c) There is little seasonal variation in load in Kenya due to climatic changes.

Records of monthly energy production and average loads for the integrated power system from 1980 to 1989 are given in Table L.3.5 and Figure L.3.5.

Figure L.3.5 shows that monthly power requirements are relatively uniform, except for on-going load growth, and they show little consistent seasonal variations.

The typical hourly load curve for March 20, 1990 (Tuesday) and for one week from September 27 to October 3, 1989 are given in Figure L.3.6 and L.3.7, respectively. The peak load on power system occurs in the evening, usually 7.00 to 8.00 p.m. when lighting and electrical cooking loads are at their maximum.

3.4 Electricity Tariffs

The present electricity tariffs effected from June 1st 1990 are shown in Table L.3.6.

Figure L.3.8 shows trends of historical average electricity tariffs by customer group in the country. Those average tariffs are worked out by dividing the total revenue of each customer group including other revenue by total energy sales.

Figure L.3.9 shows trends of historical average tariffs adjusted to constant 1982 price level. For adjustment of average tariffs to 1982 price level, the Nairobi consumer price index deflators were used for domestic and off-peak demand groups and non-agriculture GDP deflators (Table L.3.7) for commercial/industrial and total demands.

The results of detail calculation of average tariffs are shown in Table L.3.8.

Average tariffs have been increasing constantly over the past 10 years, while average tariffs at 1982 price level for domestic customer group have been decreased due to increasing subsidies to domestic customers at the expense of commercial customers, and average tariffs of commercial (Tariff B and C) and off-peak sales (Tariff D) have remained relatively constant at 1982 prices.

L4. HYDROPOWER DEVELOPMENT SCHEMES

4.1 Hydropower Scheme Catalogue

Hydroelectric power potential in Kenya centres around the geographical region of the Kenya Highlands, which are located in the southwestern part of the country. The highlands consist of the volcanic landscapes of the Aberdare Range, Mount Kenya, Mount Elgon, and the Mau Escarpment.

The country is divided into 5 major drainage areas for the preparation of inventory of hydroelectric potentials, which were determined from the viewpoint of topography and flow direction of rivers. The five drainage areas, as shown in Figure L.4.1, are:

- Lake Victoria drainage basin (Area No.1)
- Rift Valley region (Area No.2)
- Athi River basin (Area No.3)
- Tana River basin (Area No.4)
- Ewaso N'giro North River basin (Area No.5)

Hydroelectric potential of the country is roughly estimated to be about 6,000 MW (about 30,000 GWh). However, half of this is located on small rivers, and most are uneconomical because of their topographical conditions and scale for development.

National Master Water Plan (1980)

The inventory of hydroelectric resources throughout the country was first prepared by Tippets-Abbett-McCarthy-Stratton (TAMS) in the National Master Water Plan (1980).

In the above study, the theoretical maximum energy and power by drainage basin were worked out. The following shows its summary and details are given in Table L.4.1.

No.	Drainage Basin	Power (MW)	Energy (GWh)
1.	Lake Victoria	707	6,176
2.	Rift Valley	303	2,836
3.	Athi/Sabaki River	281	2,462
4.	Tana River	1,351	11,837
5.	Ewaso N'giro N. River	130	1,133
	National Total	2,772	24,443

The theoretical maximum power for any river reach was calculated on the basis of the following assumptions:

(a) Overall hydroelectric station efficiency : 82%
(b) Capacity factor : 0.6

Potential hydropower schemes on each major river had also been examined as summarized below and the principal features of identified schemes are given in Table L.4.2.

No.	Drainage Basin	Power (MW)	Energy (GWh)
1.	Lake Victoria	496	2,393
2.	Rift Valley	254	1,359
3.	Athi/Sabaki River	67	335
4.	Tana River	665	2,736
5.	Ewaso N'giro N. River	Nil	Nil
	Total	1,482	6,823

The existing hydropower schemes, except for the Kiambere project (144 MW) completed in early 1988 and the Turkwel project (106 MW) under construction, are excluded from the above potentials.

1987 NPDP

Following the above study, several studies have been conducted in 1980s.

In 1986, as a part of study for establishing a power development plan in Kenya, hydroelectric potential has been inventoried by a review of available studies and classified on the same geographical regions as TAMS study, in the 1987 NPDP prepared by Acres International Limited (Acres).

Overall identified potential is summarized below and its details are given in Table L.4.3. The major identified potential sites are also shown in Figure L.4.1.

No.	Drainage Basin	Power (MW)	Energy (GWh)
1.	Lake Victoria	355	1,680
2.	Rift Valley	245	739
3.	Athi/Sabaki River	84	463
4.	Tana River	583	2,560
5.	Ewaso N'giro N. River	155	675
	Total	1,422	6,117

The existing hydroelectric power stations including the Turkwel project (106 MW) under construction are not included in the above figures.

In addition to the identification of hydroelectric potential, hydropower sites on the Tana, Ewaso N'giro North, Ewaso N'giro South and Sondu rivers were examined in some detail. Principal features of the additional projects examined in the National Power Development Plan are given in Table L.4.4.

However, economic evaluation of proposed projects on a multi-benefit basis was not possible because of shortage of existing studies on water supply, irrigation, and other benefits. Therefore, a further study is proposed to evaluate the remaining promising hydroelectric potential sites through multipurpose benefit analysis. The study may bring additional hydroelectric generation into the least cost development plan in place of thermal combustion and/or coal-fired steam plants proposed in the National Power Development Plan.

4.2 Role of Hydropower in Future Power Supply System

To support the continuing growth of the nation's economic development and enhance the social well-being of her people, stable and reliable electric power supply is a very important factor to be attained. In fact, the GDP elasticity for electricity was high, 1.5 on average from 1979 to 1989.

At present, hydroelectric generation plays a key role in supply of electric power in the country. As of June 1989, the share of hydropower stations is 70% in terms of the installed capacity and 87% in energy supply including energy import from Uganda.

One of the major objectives of the energy policy of the country is to continue the rapid development of hydro and geothermal potential for electricity generation. As a result, power generation of the country will take an exceptionally important position compared to that of other countries, in terms that a significant portion of the base load supply will be geothermal and hydroelectric power.

In the 1987 NPDP, the following generating facilities were recommended to be developed after the Kiambere project (completed in early 1988) up to 2005.

- 155 MW of hydroelectric plants (Turkwel and Miriu)
- 280 MW of geothermal plants
- 150 MW of thermal combustion plants
- 240 MW of coal-fired steam plants

As a result of the above expansion of the power generating facilities, the share of power plants by type by 2005 will be as follows:

Power Plant	1989	2005
Hydropower	72.2%	45.5%
Geothermal	6.6%	22.8%
Combustion thermal	21.1%	14.9%
Coal-fired steam	–	16.8%
Total	100%	100%

In the above table, retirement of existing oil-fired steam plants and gas turbines was taken into account.

The above table shows that the share of hydropower plants in 2005 will still be the highest, even though much base load power plants such as geothermal and coal-fired thermal plants are developed. Thus, the present hydro-dominated power supply system will be kept in future. In such system, the optimum reservoir operating policy is to maximize the firm energy. This is achieved by drawing down the reservoir water level only when necessary.

However, the role of hydroelectric generation changes with the hydrologic conditions. In a dry season or year, hydroelectric generation is stacked at the peak of the load duration curve, constrained by available energy (water) to maximize utilization of capacity. In a wet season or year, it covers a part of the base load to ensure full utilization of seasonal energy that cannot be stored.

I.5. POWER DEVELOPMENT PLAN

5.1 Power Demand Projection by KPLC

Electric power and energy demand in Kenya were forecasted up to the year 2005 by Acres in their "National Power Development Plan" prepared in 1987. The forecast was amended by Ewbank Preece Limited (EPL) in December 1989 in their "Feasibility Study for A Geothermal Power Station at North East Olkaria."

In this section, the methodologies and the results of these demand forecasts are outlined.

1987 NPDP

The forecast made by Acres was based on a combination of detailed disaggregate forecasts in short term (1986 - 1990), and on economic models of total power sales in the longer term after 1990.

The short term disaggregate forecast of sales to large commercial and industrial customers is based on specific new industrial development that were identified, plus an allowance for unspecified growth. For the long term, sales are based on historic trends and expected future changes in these trends as identified by the econometric models of power demands.

Domestic/small commercial demands were analyzed with both econometric models and with disaggregated models. Off-peak sales (Tariff D) were also considered.

Econometric models of power demands were developed for both the domestic and commercial/industrial sales groups. These models correlate sales on a national bases against national economic performance and electricity tariffs. Independent variables considered in these models included total monetary gross domestic product (GDP), sectoral GDPs for manufacturing, agriculture, and other activities, tariff level for separate customer group, alternative fuel prices, and national population statistics.

Three load forecasts were prepared, namely, median forecast, a high forecast, and a low forecast. The median forecast anticipated an improvement in the performance of the Kenyan economy due to greater efficiency of new capital investment, and higher growth in the agricultural and industrial sectors than experienced. The low forecast after 1990 is largely a continuation of historic growth rates in Kenya since 1979. The high forecast is based on the Government of Kenya's official target growth rates. The forecasts of economic growth rates are given below:

		Total	Agric.	Manufac.	Service
(a)	Low forecast				
	1985 - 1990	4.3	3.7	4.7	4.7
	1990 - 2005	3.6	3.0	4.0	4.0
(b)	Median forecast				
	1985 - 1990	4.9	4.5	5.5	5.0
	1990 - 2005	4.5	4.1	5.1	4.6
(b)	High forecast				
	1985 - 1986	5.1	4.5	6.5	5.1
	1986 - 1987	5.4	4.5	7.0	5.5
	1987 - 1988	5.7	5.0	7.5	5.6
	1988 - 2005	5.9	5.3	7.5	5.8

These three forecasts are summarized in Table L.5.1. The median forecast shows an average annual growth rate of 6.0% in energy generation from 1985 to 1990, and then 5.3% from 1990 to 2000. The load forecast on a fiscal year basis is also given in Table L.5.2. The detailed results of the medium forecast on a national and regional basis are shown in Table L.5.3.

The results of forecasts are also illustrated in Figure L.5.1 for net generation requirements and Figure L.5.2 for peak demand.

F/S for North East Olkaria Geothermal Plant

The power and energy demand forecasts made in the National Power Development Plan were updated by EPL in their feasibility study for the North East Olkaria geothemal plant, based on the methodology adopted by Acres.

The principal method of revising the load forecast was to use the actual sales for 1987 as a base, and to assume growth rates for 1968 to 2006 consistent with those of Acres' medium or high forecast.

The results of the revised demand forecasts were converted from calender year to fiscal year, because of changes in KPLC accounting and record-keeping procedures.

The three revised forecasts, median, low, and high forecast, are summarized in Table L.5.4, and details of the median forecast in Table L.5.5 on the regional basis and Table L.5.6 on national basis.
These results are also illustrated in Figure L.5.3 and L.5.4.

5.2 Power System Expansion Plan

The National Power Development Plan (prepared by Acres in 1987) worked out a least cost generation expansion plan.

In order to meet customers requirements on a reliable supply of electricity, the development planning process considered demand forecast over a planning period of 20 years which has been explained in the previous section, available energy resources, and operating characteristics and costs of candidated power plants. The objective of the plan was to meet demands with generation development at a specified level of reliability and in the least-cost manner.

Alternative generation expansion sequences were analyzed by computer simulation models. The timing of plant additions was determined by analysis of monthly load demands and available generating capacity. New plants were added when either system firm monthly energy or capacity was insufficient to meet demand.

The total dependable load-carrying capacity of the power system was determined by using an analysis of the Loss of Load Expectation (LOLE). The allowable LOLE for Kenya was set at 10 days during a 1-year time frame during the critical drought. Over the long term, the corresponding expected (or weighted) LOLE is less than 1 day/year. If this LOLE criteria is not satisfied in a particular year, then additional generating capacity must be scheduled.

In order to determine the most probable operating cost including fuel utilization at thermal stations, operation of each sequence of alternative generation expansion was simulated, month by month for the whole period of analysis, taking into account the probable nature of hydroelectric plant capabilities, i.e. expected annual plant generation on five possible hydrologic conditions, ranging from very wet to very dry year.

Stacking on the monthly load duration curve was made in order of merit to minimize total operating costs. This was achieved by specifying a stacking order which gives first priority to the use of geothermal stations and firm import contracts, followed by hydroelectric, and fossil-fuel thermal generation in the order of increasing fuel and operating costs.

The costs of alternative power supply plans were compared on the basis of their total discounted cash flow. The total annual costs of the power system included the levelized annual capital costs of all projects in service, fixed annual O/M costs plus variable O/M costs, thermal fuel costs and import purchase costs as determined by the power system simulation studies. These annual costs were discounted back to a common date (Jan. 1986) for present value computations.

The least cost development plan recommended in the National Power Development Plan is given in Table L.5.7, and Figure L.5.5 illustrates the relation between the median load forecast and the system capacity for a whole period of analysis.

The least cost generation expansion plan includes one new hydroelectric plant (the Miriu project in 1996), as well as 280 MW of new geothermal generation, 240 MW of coal-fired steam generation and 180 MW of combustion turbines.

5.3 Hydropower Schemes Envisaged Towards the year 2010

(1) Schemes Committed in National Plan

In 1987 NPDP, twelve of the most promising hydroelectric projects were compared in a prescreening analysis. The screening model calculated the expected life-cycle energy costs of the alternative plants. Costs were based on an assumption that each of the plants would come on-line in 1995 which is a realistic earliest possible completion date for each project.

The summary of the preliminary screening results is shown in Table L.5.8, and more detail project features are given in Table L.4.4.

The projects with average energy cost less than 100 US mills are Mid-Miriu (48 mills), Low Miriu (54 mills), Sererwa (65 mills), High Miriu (71 mills), Low Grand Falls (73 mills), Mutonga (85 mills), Adamson's Falls (86 mills), Kora (88 mills), the combined Low Miriu and Magwagwa (89 mills) and Nandi Forest-Kano plain transfer project (99 mills).

Due to its relatively low energy and capacity costs, the Sererwa project is a very attractive site. However, this project was not considered in the detailed planning work because it had been studied only to the reconnaissance level and the data used in the prescreening analysis was, therefore, preliminary.

As a result of the least cost generation expansion analysis (Section 5.2), only one new hydroelectric project, Low Miriu, has been selected after Turkwel and it is scheduled to be commissioned in 1996.

For further evaluation of alternative expansion plans, the plans were grouped to investigate several important topics, such as hydroelectric development, rate and timing of geothermal development which is a least cost candidate for power generation in Kenya, expansion of base-load operated thermal generation and peaking thermal generation. These comparison studies indicated that:

(a) The Low Miriu project is competitive with conventional thermal generation.

(b) Other projects (Mutonga, Low Grand Falls, Sererwa and Nandi Forest) cannot compete economically with coal-fired generation on the basis of power benefits only.

However, some of these projects would have other benefits such as irrigation, water supply, and flood control, that makes them competitive with other options.

For the Low Miriu project, the detailed design work had started in March 1990 and will be finished in October 1991, under OECF financing.

Table L.5.9 shows the major project features studied under the above detailed design work.

(2) Needs of Multipurpose Development

As discussed in the previous sections, potentially economic hydroelectric projects exist such as Sererwa, Nandi Forest, Low Grand Falls, and Mutonga. However, on the basis of power benefit alone, these projects are less economical than other generation candidates such as thermal combustion and coal-fired steam power plants.

For making these projects attractive, a further study should be done to evaluate more exactly these remaining promising hydroelectric potential sites multipurpose benefits analysis. The study may bring additional hydroelectric generation into the least cost development plan in place of thermal combustion and/or coal-fired steam plants.

(3) Present Situations of Studies on Hydroelectric Schemes

The hydroelectric inventory of Kenya should be continually improved in order to assess projects that will be candidates for future power planning studies. Although apparently more expensive than other resources, hydropower could become competitive if other social economic benefits should be identified, geothermal exploration should fail to prove adequate reservoirs, or fossil fuels should greatly increase in price.

For this purpose, the National Power Development Plan in 1987, strongly recommended further studies as follows:

(a) Update of the Miriu feasibility study made by JICA in 1985, and its detailed design.

(b) Feasibility level study of the Nandi Forest-Kano Plain Transfer multipurpose project.

(c) Detailed inventory assessment of the Kerio Valley hydroelectric potential including pre-feasibility level study of one or two schemes.

(d) Feasibility level studies (Mutonga and Low Grand Falls) and reconnaissance level studies (Karura and Usueni) on the Tana River.

(e) Reconnaissance level studies of the following:

- Redevelopment of Gogo Falls on the Kuja River,
- Hemsted Bridge and Webuye Falls projects on the Nzoia River,

- Hydroelectric potential on the Mara River,
- Munyu multipurpose dam project, the Fourteen Falls complex and Yatta project on the Athi River (prefeasibility level),
- Ewaso N'giro North River, and
- Ewaso N'giro South hydroelectric projects

As of January 1991, the following studies are currently or have been done since the National Power Development Plan in 1987:

(a) Pre-feasibility study of the Nzoia-Kerio Water Transfer (Hemsted Bridge or Ugari)
: Completed (1989). Subsequently, an idea of double transfer (Nzoia-Swam and Nzoia-Kerio) has also been identified.

(b) Feasibility study on the integrated development of the Arror River basin (Sererwa project)
: Completed (1990)

(c) Detailed design and preparation of tender documents for Sondu/Miriu hydropower project
: Under design

(d) Feasibility study of the Magwagwa hydroelectric power development project
: Under study

(e) Pre-feasibility study of the Ewaso N'giro South multipurpose projects
: Completed

(f) Feasibility study on of the Ewaso N'giro South multipurpose projects (Leshota and Oldorko)
: Under study

(g) Feasibility study on the Munyu multipurpose dam project
: Under study

(h) Pre-feasibility study of 13 hydroelectric projects, and feasibility study on the top ranked 5 projects
: To be started soon.

In addition to the above, a new water transfer project from the Amala River in the Mara River basin to the Ewaso N'giro South River basin (Narok) has been proposed. The details will be examined further.

L6. UPDATE OF NATIONAL POWER DEVELOPMENT PLAN

6.1 General

The 1987 NPDP has recently been updated by the same consultant (Acres) taking into account the changed circumstances and more comprehensive database available since the previous power sector study was prepared, and the results of the study are reported in the draft final report titled "1990 Interim Update of National Power Development Plan 1991 to 2010" in April 1991 (Update NPDP).

In this chapter, the results of the study integrated in the draft report will be briefly overviewed.

6.2 Power Demand Projection

For the long-term forecast, the general structure of the original forecast models developed in the previous study is unchanged in the update, except for individual coefficients within the models, which were recalculated to incorporate the actual sales energy, average tariffs, and GDP values since 1985. The short-term forecasts (1990/91 to 1994/95) were worked out on the basis of projected the number of customers and average consumption per customer.

The load forecasts were prepared in this update study; namely, reference forecast, high forecast, and low forecast, based on the three alternative economic forecasts. The forecasts of future economic growth are summarized below:

	Total	Agric.	Manuf.	Service
(a) Low Scenario				
1990/91	2.6%	3.0%	4.0%	2.0%
Long term	4.3%	4.6%	3.0%	4.6%
(b) Reference Scenario				
1990/91	2.6%	3.0%	4.0%	2.0%
Long term	5.2%	4.0%	5.6%	5.7%
(b) High Scenario				
1990/91	2.6%	3.0%	4.0%	2.0%
Long term	6.0%	5.3%	7.5%	6.1%

These three forecasts are summarized in Table L.6.1. The reference forecast shows an average annual growth rate of 3.8% in energy generation in 1990/91, 4.0% in 1991/92, 6.3% in 1992/93, and then about 6.0% per year until the planning horizon in 2010.

The following table summarizes the projected demand in the previous 1987 NPDP (medium) and the Update NPDP (reference).

	NPDP 1987		Update NPDP	
	Peak (MW)	Generation (GWh)	Peak (MW)	Generation (GWh)
1989/90	496	2,958	520	3,103
1994/95	644	3,822	710	3,963
1999/00	837	4,943	959	5,321
2004/05	1,089	6,410	1,290	7,127
2009/10	–	–	1,727	9,501

6.3 Generation Resources

(1) Hydroelectric Resources

As explained in the previous chapter, several studies have been conducted which have made improvements to the hydropower inventory for future development.

In Update NPDP, hydroelectric cost estimates of eights projects, namely, Miriu, Magwagwa, Leshota, Oldorko, Arrow, Low Grand Falls, Mutonga, and High Grand Falls, have been reviewed on the basis of cost estimates in the study reports for the respective projects made by other consultants.

The main features, cost estimates, and results of preliminary screening are summarized in Table L.6.2.

(2) Geothermal Resources

The present geothermal development utilizes 15 MW units, and the next development, Olkaria Northeast, will utilize 32 MW units. Unit capacity of candidate geothermal plant is 32 MW, the standard unit which is planned to be adopted for the plant at Olkaria West, since that unit is more compatible with system size and growth rates.

The results of preliminary screening are given below:

	2 x 32 MW	2 x 55 MW
Capacity (MW)		
- Installed	64.0	110.0
- Net sent out	61.4	105.6
Averaged annual energy (GWh)	472.0	812.0
Capital cost ($ x 106)	125.2	210.7
IDC factor	1.216	1.256
Average cost of energy ($/kWh)	0.0386	0.0379

(3) Conventional Thermal Generating Plant

As an alternative candidate power plant, a number of different thermal plants were considered, including coal- and oil-fired steam plants, combustion turbines, combined cycle plants, medium- and low-speed diesels.

The generation unit cost of each plant is summarized in Table L.6.3.

6.4 Generation Expansion Plan

The same planning activities and methodologies with 1987 NPDP were applied for this update study.

The recommended optimum development plan was selected through planning principal activities, i.e. preliminary screening, preparation generation expansion sequences, evaluation of alternative expansion sequences, and sensitivity analysis.

The recommended plan includes four new hydroelectric developments after Turkwel, with a total installed capacity of 312 MW plus an additional unit at the existing Gitaru power station. Geothermal generation takes the most prominent role in the generation expansion throughout study horizon, with a total installed capacity of 394 MW of new developments. In addition, 400 MW of conventional thermal, 90 MW of medium speed diesel sets and 60 MW of peaking gas turbines are planned. The details of the recommended plan is given in Table L.6.4.

Magwagwa hydropower development project was left out of the development plan for the reason that it will probably be developed following full implementation of the Miriu irrigation scheme which will be late in the planning period (Update NPDP).

Installed capacity of generating plants by type at the end of the planning horizon will be:

	1989		2010	
Hydropower	495.3 MW	(71.3%)	879.3 MW	(47.1%)
Geothermal	45.0 MW	(6.5%)	439.0 MW	(23.5%)
Steam plant	88.0 MW	(12.7%)	0.0 MW	(0.0%)
Low speed diesel	0.0 MW	(0.0%)	400.0 MW	(21.4%)
Medium speed diesel	18.3 MW	(2.6%)	90.0 MW	(4.8%)
Gas turbine	47.9 MW	(6.9%)	60.0 MW	(3.2%)
Total	694.5 MW	(100.0%)	1,868.3 MW	(100.0%)

Note: All existing steam plants, diesel sets and gas turbines are planned to be retired by 2010.