WORLD BANK/UNDP/BILATERAL AID
ENERGY SECTOR MANAGEMENT
ASSISTANCE PROGRAMME (ESMAP)

ANGOLA

POWER REHABILITATION AND TECHNICAL ASSISTANCE

PRESENT SITUATION OF THE ELECTRIC SYSTEM OF ANGOLA

LEAST-COST EXPANSION PLAN OF THE NORTHERN SYSTEM

EXPANSION PLANS OF THE CENTRAL AND SOUTHERN SYSTEMS

Consultant's Report

October 1991

Foreword

This report has been prepared by ESMAP consultant Mr. Carlos Madureira, from Electricidade de Portugal, during an ESMAP mission to Angola from January 23 to February 23, 1990. The mission consisted of Messrs Michel Del Buono, Mission Leader; Kurt F. Schenk, Power Specialist, Deputy Mission Leader; Ms. E. Battaglini, Economist; Messrs. J. Baptista, Power Engineer/Economist; C. Alves da Cruz and C. Ferreira da Silva, Hydro Plant Specialists; C. Madureira, Power Systems Planner; P. Bernardin, Accounting, Organizational and Institutional Expert; L. Rivera, Financial Analysis; G. Selleri, Hydro Plant Planning and Construction Expert; A. Corsini, Thermal Generation and Transmission Line Expert; G. Brambilla and M. Scarfi', Electric Distribution Experts; Ms. M. Kronen, Environmental Expert.

The report analyses the Northern, Central and Southern Electric Power System of Angola. It provides least-cost power development plans including the impact of Capanda. It also evaluates the potential benefits from interconnection of these three separate systems.

The 1990 mission was followed by another ESMAP mission in early June 1991 which reviewed and revised many of the conclusions and recommendations of the 1990 mission in the light of the recent peace agreement of May 1991.

The cooperation by the Government of Angola, particularly the Secretariat of Energy and Water (formerly the Ministry of Energy and Petroleum); the electric utilities ENE, SONEFE, EDEL and CELB (now incorporated within ENE); and GAMEK, in charge of the development of the River Kwanza, is gratefully acknowledged. Funding for this project has been provided by UNDP (United Nations Development Program) and SIDA (Swedish International Development Agency).

The Blue Cover Report entitled: "Angola: Power Rehabilitation and Technical Assistance -Priorities for Investment and Technical Assistance in the Electric Power Sector", was published in October 1991.

I N T R O D U C T I O N

The present report refers to the participation of its author in the Word Bank Mission that visited Angola from JAN.25 to FEB. 24, 1990; according to the Reference Terms from 90.01.19, the main task attributed to the author was that of the establishment of the Least-Cost Expansion Plan for the Northern Electric Generating System of Angola.

With the purpose of identifying the problems and collecting the maximum information, contacts with the Ministry of Energy and Oil (MEP) the electricity utilities ENE, SONEFE and EDEL, besides GAMEK, were established, namely:

MEP

Engº RUI TITO (Gabinete Técnico)

ENE

Engº QUELHAS MOTA (Director-Geral)

Engº JOÃO SIMÃO (Área de Estudos e Projectos)

Engº JOSÉ REIS (Área de Estudos e Projectos)

Engº LUÌS MOURÃO (Area de Exploração e Manutenção)

Engº AMOR BELO MARTINS (Área de Exploração e Manutenção)

Engº VICTOR CORREIA (Área de Exploração e Manutenção)

Engº HORÁCIO SANTOS (R.A.H.L.)

Engª MARIA CAROLINA SANTOS (R.A.H.M.)

SONEFE

Engº PAULO MATOS (Director-Geral)

Engº GUERREIRO COELHO (Direcção Técnica)

Engº HELENO DUARTE (Área de Estudos e Projectos)

Engº JOÃO SANCHES (Área de Exploração e Manutenção)

Engº JOSÉ MARINHO (Área de Exploração e Manutenção)

Engº EDUARDO NELUMBA (Área de Exploração e Manutenção)

Drª DOMINGAS FERREIRA (Depart. de Finanças e Planificação)

EDEL

Engº SILVA NETO (Director-Geral)

Engº LUCAS DA SILVA (Área de Exploração e Manutenção)

Engº VICTOR FONTES (Gabinete de Planificação)

GAMEK

Engº HENRIQUE GUERRA (Chefe do Departamento Técnico)

The report is made up by three chapters:

- the first chapter shows an appraisal of the present situation of the Electric System in Angola;
- in the second chapter, the Least-Cost Expansion Plan of the Northern Electric Generation System of Angola, within the horizon of year 2015, is given, as well as an analysis on the interest in the establishment of the interconnection of the Northern Electric System to the Central and Southern Electric Systems.
- in the third chapter, the expansion plans of the Central and Southern Electric Systems are established, within the horizon of the year 2005, at the hypothesis they will remain isolated, like they are today.

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SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

CHAPTER 1 - The Electric System of Angola is composed, besides several isolated systems, by the Northern System, whose main potential is found in the river Kwanza, the Central System, including the river Catumbela basin, and the Southern System, including the river Cunene basin.

At the beginning of 1990 the Electric System of Angola it was in a situation of generalised rupture:

- Concerning the hydro power stations

  . Mabubas (17.8 MW), at the Northern System, and Lomaum (35 MW), at the Central System, were totally unavailable.

  . Biópio (14.4 MW), at the Central System, and Matala (27.2 MW), at the Southern System, were in precarious conditions.

  . additionally, at the largest power station of Angola, Cambambe (4 x 45 MW), it is necessary to carry out the overhauling and the repair of three of its four units.

- Concerning the thermal units

  . the gas turbine of Biópio (22.8 MW) and three of the four diesel units, with the unitary capacity of 5 MW, of Lobito, at the Central System, were totally unavailable.

  . one of the two diesel units, with unitary capacity of 5.75 MW, of Namibe, at the Southern System, also was unavailable.

So, in relation to the installed capacity are only available 73% at the Northern System, 24% at the Central System and 37% at the Southern System as well as at the whole of the isolated systems; in addition other equipments such as substations and transmission lines were unavailable.

It is recommended with absolute priority to carry out the restoring of all the unavailable generating centres and other equipments above referred, being vital to reckon upon all the units of Cambambe at the end of 1992, in order to meet the demand of energy and capacity at the Northern System.

CHAPTER 2 - The Least-Cost Expansion Plan for the Northern System of Angola was established:

- for the period between 1993 and 2015;
- for two scenarios of the demand evolution: a High Scenario corresponding to the Intermediate Scenario defined by the WB Mission of 1987 only adjusted from the actual value verified in 1989 onwards; a Low Scenario defined in the scope of the present mission;
- based on the fact that it is not possible to realize the heightening of the Cambambe dam and the construction of the second power station before about the year 2010.

So, in view of the advanced condition of the works at the hydro project of Capanda this was considered as the first candidate to the system expansion, although it as been contemplated at six alternatives, resulting of two demand evolution scenarios and the following three situations:

ALTERNATIVE I- (ALT.I) Observance of the construction schedule as it was established by GAMEK, with the conclusion of the dam, with 110 meters of height, till the end of 1992,but installing the first unit only when necessary for the system, what happens at 1996, for the High Scenario (ALT.I.A), and at 1998, for the Low Scenario (ALT.I.B).

ALTERNATIVE II- (ALT.II) Corresponding to the schedule of GAMEK, having in operation the first unit at the beginning of 1993 and the second unit at the middle of 1993.

ALTERNATIVE III - (ALT.III) Construction of a lower dam, with 91 meters of height, till the end of 1992, but installing the first unit only as referred at Alternative I.

By means of the utilization of the VALORAGUA model (which enables to simulate the optimized operation of a mixed hydro-thermal electric system using a time-series of the inflows to the hydro power stations) the firm generations and capacities of Capanda fitted with one, two, three or four units (with the unitary capacity of 130 MW) were evaluated , being possible in this manner to define the commissioning dates for those units.

Similarly, the opportunity dates for the heightening of the Capanda dam and for the commissioning of the two units of 130 MW each one to be installed in a first phase at the second power station of Cambambe, as well as the opportunity date for the heightening at the Capanda dam at ALTERNATIVE III, were defined.

Thus, several flows concerning the generations of Capanda and of the second power station of Cambambe were established, as well as the flows concerning the corresponding costs.

It was used a constant prices system referred to the end of 1989, the discount rates of 10, 12 and 15% and a period of life of 50 years.

Discounting those flows to the beginning of 1990, the levelized generating costs which are identified as the Long Run Marginal Costs from Capanda, from the second power station of Cambambe and from the set Capanda-Cambambe were computed.

The results point out that the minimum levelized generating costs are found for the ALT.I which is consequently considered the best option for the Expansion Plan for the Northern System; the commissioning dates for the four units of Capanda are from 1996 to 2009, at the High Scenario, and from 1998 to 2017, at the Low Scenario.

So, the heightening of the Cambambe dam and the construction of its second power station results so far that its execution becomes very questionable. Thus, it is recommended the research of better alternatives by means of the achievement prefeasibility studies, with a satisfactory technical and budgetary characterization, concerning some hydro projects whose dimension seems to be more adjusted to the scale of the electric system of Angola, such as:

Middle Kwanza River Basin - Zenzo II

Queve River Basin - Caivole and Cachoeiras do Binga

Longa River Basin - Quissula, Cassongo, Lungo and Murimbo

Lastly, and using again the VALORAGUA model which allows the study of several systems interconnected by a simplified network, it was analized the interest in the establishment of the interconnection of the Northern Electric System to the Central and Southern Systems, by means of a transmission line at 220 kV from Cambambe to Lubango, passing through Gabela and Biópio with a length 570 km. The transit of the surplus of power existing until about 2025 at Northern System to the Central and Southern System enables important savings of fuel consumption besides to postpone large investments at the Central and Southern System, so that the interconnection results justifiable under a strictly economic viewpoint.

However it is recommended the analysis of the problem under a technical point of view, specially concerning its contribution for the reliability of the Northern, Central and Southern Systems operation.

CHAPTER 3 - The Expansion Plans of the Central and Southern Electric Systems at the hypothesis of remaining isolated were established:

- for the High Scenario of the demand evolution, considered at the preceding chapter, for the analysis on the interest of the interconnection, in order to allow a valid comparison of the results;

- for the period between 1995 and 2005, being assumed that at 1995 all the equipments total on partially unavailable at the present should be rehabilitated.

The results point out to the necessity to install two new turbines, eventually burning natural gas, at the area of Benguela - Lobito, with the capacities of 25 MW, at 1997, and 30 MW, at 1998, in order to the utilization of the gas turbines, at the Central System, will remain between 1200 and 1600 hours, within the study period.

In addition to this, and concerning the Central System hydro component, the power station of Lomaum must be uprated with the two pre-existing units with the capacity of 10 MW each one, after complete rehabilitation, from 1996 onwards, and the Cacombo dam must be finished at 1999, although the respective power station (2 x 12 MW) only be necessary at 2003; at the Southern System will be needed to install a power station at the Gove dam (2 x 15 MW) from 1998 onwards and an additional unit of 15 MW at 2002.

For a constant prices system referred to the end of 1989, this program comparatively to the hypothesis with the interconnection signifies an increase of investments, discounted to the beginning of 1995, reaching amounts between 152 and 170 M. USD, at the Central System, and between 33 and 40 M. USD at the Southern System, which points out the interest on the construction of the transmission line for the interconnection of the Northern System to the Central and Southern Systems.

However, if that interconnection will not be technically advisable, it is recommended to study the interconnection of the Central and the Southern Systems, through a transmission line Gove - Huambo due to the short distance between these two places; in such case, and as consequence of the lower potential of the river Catumbela relatively to the river Cunene, it is suggested the study of the integration of the hydro project of Jamba Ia Mina (130 MW; 580 GWh), on the river Cunene, which probably could avoid or differ for many years the construction of the Cacombo dam, on the river Catumbela.

1 - PRESENT SITUATION OF THE POWER SYSTEM IN ANGOLA

1.1- STRUCTURE

Basically the structure of Angola's Power System is composed by the following companies:

- **ENE (Empresa Nacional de Electricidade)**

  It is a State enterprise, established in 1980 with the intention of becoming the only national power utility in charge of generation, transmission and distribution at medium voltage all over the country. Nowadays, however, this enterprise just operates the Central and the Southern Systems, and some isolated systems in several provinces, besides being responsible for the distribution at low voltage all over the country, with the exception of the areas of Luanda and of several local municipal bodies (Comissariados) who are responsible for the distribution at low voltage and may also be owners of small diesel units;

- **SONEFE** (Sociedade **Nacional** de **Estudos** e **Financiamento** de Empreendimentos Ultramarinos)

  It operates the Northern System, the largest in the country, including the area of Luanda and the provinces of Bengo, North and South Kwanza and Malange, being in charge of generation, transmission and the direct supply of about 300 customers at high (60 kV) and medium voltage.

- **EDEL (Empresa de Electricidade de Luanda)**

  It is in charge of distribution at low voltage in the area of Luanda.

- **CELB (Companhia Eléctrica do Lobito e Benguela)**

  It is in charge of distribution in the province of Benguela.

1.2- THE ELECTRIC GENERATING SYSTEM OF ANGOLA (EG.S.A.)

At the beginning of 1990 the EG.S.A. was basically composed, besides several isolated systems, by three independent systems who supply the principal centers of consumption:

- the Northern System - who supplies the area of Luanda and is operated by SONEFE. It uses the hydro potential of the river Kwanza, where the power station of Cambambe (180 MW) is located, and of the river Dande, where the power station of Mabubas (17.8 MW) is located, and two gas turbines in Luanda (56.8 MW), totalizing an installed capacity of 254.6 MW (Table 1 from ANNEX 1, pag. 1);

- the Central System - who supplies the areas of Benguela, Lobito and Huambo and is operated by ENE. It uses the hydro potential of the river Catumbela, where the power stations of Lomaum (35 MW) and Biópio (14.4 MW) are located, and the thermal units at Biópio, one gas turbine (22.8 MW) and two diesel units (3 MW), at Lobito, four diesel units (20 MW) installed in a railway carriage, and at Huambo, one gas turbine (10 MW) and six diesel units (4.9 MW), totalizing an installed capacity of 110.1 MW (Table 1 from ANNEX 1, pag. 1);

- the Southern System - who supplies the areas of Lubango and Namibe and is operated by ENE. It uses the hydro potential of the river Cunene, where the regulating reservoir of Gove and the power station of Matala (27.2 MW) are located, and the diesel units at Lubango (3.6 MW), Namibe (11.5 MW), Tombwe (1.6 MW), Jamba (5.7 MW) and Saco (2.9 MW), totalizing an installed capacity of 52.5 MW (Table 1 from ANNEX 1, pag. 1);

The main isolated systems are those of Cabinda, Uíge and Bié and in the province of Lunda-Norte the system belonging to the mining company ENDIAMA (Empresa Nacional de Diamantes de Angola) and was mainly used to support diamond mining activities (Table 1 from ANNEX 1, pag. 2).

On the whole the EG.S.A. is in a situation can be considered of generalized rupture, resulting not only because none hydro power station was built after 1974 but mainly due to a long series of sabotage actions over almost all hydro plants, with exception of Cambambe; in this case, however, the sabotage has falling upon the transmission line Cambambe - Luanda, leading to severe periods of interruption of the electricity supply to the capital, forcing the intensive utilisation of the gas turbines of Luanda and consequently its inevitable premature erosion.

Others sabotage actions, falling upon either on substations or on transmission lines, have added to the worsening of the situation of the Angola's Electric System.

From 1980 onwards, an effort was made in order to overcome this situation with the installation of two gas turbines in Luanda, in 1980 and 1985, one in Huambo, in 1981, and several diesel units in Lobito and other important centers. However, due to the deficient maintenance, lack of technical assistance and extra spare parts and the irregularity of fuel supplies, such decisions did not succeed in solving the problem. The gas turbine of Huambo rested unavailable in February 1985, that of Biópio in 1988 and three diesel units of Lobito in 1989. So, in spite of the restoring at operation of the gas turbine of Huambo, in the Central System only 27 MW, of the 110 MW installed, are available, while in the Southern System only 19 MW, of the 53 MW installed, are available. Of the total installed capacity of about 462 MW, in the power stations of ENE and SONEFE, of which:

- 287 MW in hydro units;
- 102 MW in gas turbines;
- 73 MW in diesel units,

only were available about 248 MW, in the beginning of 1990, that is to say, 54% of the total, as the following table shows:

INSTALLED AND AVAILABLE CAPACITY, JAN.90

(MW)

SYSTEM	HYDRO		THERMAL		TOTAL		PEACK AT 1989 (a)
	Instal.	Avail.	Instal.	Avail.	Instal.	Avail.	
NORTHERN	197.8	135.0	56.8	50.0	254.6	185.0	111
CENTRAL	49.4	10.8	60.7	15.8	110.1	26.6	15
SOUTHERN	27.2	13.6	25.3	5.7	52.5	19.3	10
ISOLATED	12.9	1.1	31.7	15.6	44.6	16.7	N.A.
TOTAL	287.3	160.5	174.5	87.1	461.8	247.6	

(a) Related to generation; reflects distinct levels of suppressed demand. The suppressed demand is estimated at about 12% in the Northern System, 30% in the Central System and 25% in the Southern System.
<u>Source:</u> SONEFE, ENE and Table 1 from ANNEX 1.

Hydroelectricity has always been the main source of supply, remaining its contribution between 80-98% of the total generation. In 1989, in spite of the hydro unavailabilities, total at the station of Lomaum and partial at the station of Mabubas, that contribution was of 89.5% (755 GWh of hydro generation to 884 GWh of the total), belonging to the station of Cambambe the largest portion, 662 GWh, which means 87.7% of all hydro generation and 78.4% of the total generation (Table 2 from ANNEX 1, pag. 3).

Luanda, the largest center of consumption, belongs to the Northern System which, having generated 695 GWh in 1989, was the responsible for 82.4% of the total generation (Table 3 from ANNEX 1, pag. 4).

1.3- THE NORTHERN ELECTRIC GENERATION SYSTEM (N.EG.S.)

The N.EG.S. is operated by SONEFE and is composed by the following generating centres:

HYDROELECTRIC POWER PLANTS

- **CAMBAMBE**, on the river Kwanza, whose dam controls a basin with an area of 115,500 km^2, being of 728 m^3/s the average flow of the river on the site of the dam, in the period of 20 years 1953/1972, in which the minimum flow on the river was 130 m^3/s, verified in October. This power station, the largest of Angola, has an installed capacity of 180 MW, fitted with four units, with a nominal capacity of 45 MW and a turbining rated flow of 65 m^3/s each one. It is a run-of-river type power station, with a daily regulating capability. The firm capacity at 100% of the time is 90 MW, resulting then a firm energy of 790 GWh; however, at peak hours, the firm capacity can reach 135 MW.

  Since the initial project, and when the level of the consumption would be justifiable a heightening of 20 meters of the dam was foreseen, in order to increase the installed capacity to 4x65=260 MW, simultaneously with the construction of the inlet works of a second power station to be built later, fitted with four units with a nominal capacity of 110 MW each one.

  Meanwhile, with the construction of the hydroelectric power plant of Capanda, the above mentioned heightening of the dam and the construction of a second power station in Cambambe will be postponed for many years, assuming the possibility of finding a better alternative.

Concerning the present condition of the generating units (units 1 and 2 installed in 1963 and units 3 and 4 installed in 1973), all of them need an urgent overhauling and repair in order to be at perfect operation conditions until the end of 1992; the total rehabilitation, including generating units, power station and substation, is estimated at 9.38 millions of USD.

After the repair of all units, the firm energy will be 1080 GWh, more 100 GWh resulting from the regulation induced by the reservoir of Capanda since the beginning of 1993, and the firm capacity at 100% of the time will be 135 MW.

The power station generated 662 GWh in 1989, which means 87.7% of all hydro generation and 78.4% of total generation in the country.

- **MABUBAS**, on the river Dande, whose dam controls a basin with an area of 7,490 km^2, being of 30.5 m^3/s the average flow of the river on the site of the dam. The power station, located 54 km at northeast of Luanda, was the first hydroelectric power station built to supply electricity to Luanda and it is fitted with four units, two installed in 1953 and the other two in 1959, being the total installed capacity 2x3.0+2x5.9=17.8 MW.

  The power station is out of service since 1986 and all the hydroelectric scheme needs a deep rehabilitation because, due to the fact of being embarrassed the gates of the spillway and the bottom discharge, during flood periods the water already passed over the dam and also was laterally spilled from the channel of deviation to the power station, severally deteriorating its foundation.

  In the second quarter of 1989 the power station generated 1.3 Gwh.

THERMAL POWER STATION OF LUANDA

With an installed capacity of 56.8 MW, it is fitted with two gas turbines burning Jet B fuel, the first having been installed in 1980 and the second in 1985, with respectively 25.6 and 31.2 MW of nominal capacity. At the present condition the values of 20 and 30 MW, respectively, must be considered as firm capacity.

The generation of the power station in 1989 was 32.1 GWh.

On the whole, the N.EG.S. generated 695 GWh in 1989, that is, 82.4% of the total electricity generation of Angola (Table 3 from ANNEX 1, page 4), having the maximum peak related to the generation reached 111 MW.

1.4- THE CENTRAL ELECTRIC GENERATING SYSTEM (C.EG.S.)

The C.EG.S. is operated by ENE, into which after the independence was incorporated HEAD (Hidro Eléctrica do Alto Catumbela, who was in charge of generation and transmission), being CELB the responsible for the distribution in the province of Benguela. The system supplies the two most important regions of Angola after Luanda, concerning population and industrial development, with the transmission lines running approximately parallel to the railway of Benguela, and it is composed by the following generating centres:

HYDROELECTRIC PLANTS

Both located on the river Catumbela are the following:

- **LOMAUM**, whose dam controls a basin with an area of 8,296 km^2, being the average flow of the river on the site of the dam of 86.3 m^3/s, in the period of 20 years 1953/1972, and the dryness flow with 95% of probability of 8m^3/s. The power station has an installed capacity of 35 MW, being fitted with two units, installed in 1964, with a nominal capacity of 10 MW each one, and one unit, installed in 1972, with a nominal capacity of 15 MW.

  The power station, of the run-of-river type and only with a daily regulating capability, is out of operation since 1983, period wherein was target of sabotage (as well as the substation of Alto Catumbela), their penstocks having been destroyed which caused the flood of the power station and the destruction of the control and protection systems.

  Before the refitting of the three units already installed in the power station, it is foreseen with priority the installation of two new units with a nominal capacity of 15 MW each one, in order to be ready to start operating until the end of 1992; the total rehabilitation of the penstocks and the power station is estimated at 62.3 millions of USD, being the cost of the new generating units estimated at 5.3 millions of DM.

  The restoring of the three former units requiring repair will be made latter in a proper time.

- **BIOPIO**, downstream of Lomaum, whose dam controls a basin with an area of 15,550 km^2, being the average flow of the river on the site of the dam of 117.3 m^3/s, in the period of 20 years 1953/1972, and the dryness flow with 95% of probability of 20 m^3/s. The power station has an installed capacity of 14.4 MW , being fitted with four units, installed in 1957, with a nominal capacity of 3.6 MW each one. The power station, of the run-of-river type and only with a daily regulating capability, has nowadays only three units in operation, having generated

42 Gwh in 1989 , that is, 51% of the total generating of C.EG.S. (83 GWh, including the power stations of the provinces of Bié and Moxico: Table 3 from ANNEX 1, pag.4).

In view of the antiquity of the four units, more than thirty years, and their present condition, their replacement by four new units with the same nominal capacity of those is foreseen as very likely, as well as the total rehabilitation of the power station, what is essential to assure until the end of 1994, being its cost estimated at 13.65 millions of USD.

THERMAL POWER STATIONS

- **BIÔPIO**, where, in 1974, was installed a turbine burning gasoil, with a capacity of 22.8 MW and, in 1982, two diesel units with a nominal capacity of 1.5 MW each one. At this moment all these units are out of operation.

- **HUAMBO**, where, in 1981, was installed a turbine burning gasoil, with a nominal capacity of 13.5 MW that, however, due to the altitude where it is located (1800 m), has an output of only 10 MW. It rested out of operation in 1985, having been restored recently. There are still four diesel units of 0.8 MW each one, installed in 1953, and two new units, installed in 1986, with a nominal capacity of 0.85 MW, each one. Presently, only one of the units of 0.8 MW is available.

- **LOBITO**, where, in 1986, were installed four diesel units of 5 MW each one; however at this moment only one of the units is available.

As result of the unavailabilities of the gas turbine of Biópio and of the three diesel units of Lobito, the generation of C.EG.S., who had reached 108.5 GWh in 1987 (including 5.0 GWh of the power station of the province of Bié and 0.5 GWh of Moxico) fell down to 104.1 GWh in 1988 and 83.0 GWh in 1989, meaning now only 9.8% of the total generation of Angola; in 1989 the peak of the system, related to generation, was around 15 MW, due to the present situation of suppressed demand estimated at 30%.

1.5- THE SOUTHERN ELECTRIC GENERATING SYSTEM (S.EG.S.)

The S.EG.S. is operated by ENE and is composed by the following generating centers:

HYDROELECTRIC POWER PLANTS

- **MATALA**, on the river Cunene, whose dam controls a basin with an area of 28,037 km^2, being the average flow of the river on the site of the dam of 147.2 m^3/s in the period of 20 years 1953/1972. The power station has as an installed capacity of 27.2 MW since 1959, being fitted with two units with a nominal capacity of 13.6 MW each one, but since 1984 it works with one unit out of operation. The power station suffered seriously during several fires and, in consequence, the generators, the control-room and the power cables are damaged. So, it needs an urgent rehabilitation for which a program already exists, going on at this moment the installation of a new unit with the same nominal capacity of the older ones, and then the repair of the two older units. The power station is the most important power plant of the S.EG.S., having generated, in 1989, 43.2 GWh, that is, 88.3% of the total generation of this system (Table 3 from ANNEXE 1, pag. 4).

  Upstream of Matala is located the Gove dam, of the earth-fill type, also on the river Cunene, belonging to the Ministry of Construction, controlling a basin with an area of 4,811 km^2, being the average flow of the river on the site of the dam 56.1 m^3/s, in the period of 20 years 1953/1972. Concluded in 1974, it was built to irrigate an area of 93000 ha and above all to assure a regulated flow of 80 m^3/s at Matala; however, this duty has not been satisfactorily carried out yet, due to the irregular working of the existing discharge. In the future, when the level of consumption is justifiable, the scheme will be completed with a power station, fitted with three generating units with a nominal capacity of 15 MW each one, remaining one unit as a reserve.

  Both Matala and Gove have serious problems concerning safety. The 29 gates of the spillway of the Matala dam cannot be open because they are embarrassed due to the shiftings ocurred in the structure; the same happens to the three gates of the spillway of Gove dam, as a result of sabotage in 1986. Furthermore serious percolation problems remain at the Gove dam.

  It is urgent to open the spillway gates of the Gove dam in order to avoid, in the occurrence of a serious flood, not only the risk of the water pass over the dam and consequently its destruction, but also disastrous damages at the dam and power station of Matala; this could endanger the supply of energy to the all Southern System and put the life of the population living downstream in serious risk.

Consequently it is vital and urgent that ENE put the needful solutions for these serious problems affecting the dams of Matala and Gove in practice, at the presupposition that the last one could be under its responsibility and administration, which is justifiable once it is intended to build a power station there in the future, as it was mentioned above.

THERMAL POWER PLANTS

- **NAMIBE**, with an installed capacity of 11.5 MW fitted with two diesel units with the nominal capacity of 5.75 MW each one, installed in 1980, it is the only alternative of supply to the Southern System in the case of Matala's unavailability. Presently only one unit is operating, having generated 3.2 GWh in 1989.

- **Lubango**, with an installed capacity of 3.6 MW in diesel units with three of nominal capacity of 0.4 MW each one and twelve of 0,2 MW each one. Presently all the units are out of operation, the generation having been in 1989 of 2.5 GWh.

On the whole, the S.EG.S. generated only 49 GWh in 1989, which means 5.8% of the total generation of Angola (Table 3 from ANNEX 1, pag. 4); in 1989 the peak of the system, related to generation, was around 10 MW, due to the present situation of suppressed demand estimated at 25%.

2 - LEAST-COST EXPANSION PLAN (L.C.E.P.) OF THE N.EG.S.

2.1- BASIS HYPOTHESIS

The L.C.E.P. of the N.EG.S. was established with base on the following pressuppositions:

A - Plan Horizon: year 2015, starting in 1993

B - Initial composition of the generating system:

- two gas turbines in Luanda with available capacities of 20 and 30 MW, respectively;

- hydro power station of Cambambe, with four generating units totally rehabilitated until the end of 1992, assuring from this date onwards a capacity of 3x45=135MW at 100% of the time, remaining one unit as reserve;

- hydro power station of Mabubas unavailable.

C - Projects candidates to the system expansion:

- **the hydroelectric project of Capanda**: in view of the present phase of its construction, on the river Kwanza upstream of Cambambe, even though under a economical viewpoint, its integration on the system is away from the optimal path of its expansion, this project was considered as unavoidable; however it has been considered in different alternative hypothesis, namely concerning the schedule of the commissioning dates of the four units with a nominal capacity of 130 MW each one, totalizing an installed capacity of 520 MW;

- **the heightening of Cambambe dam**: around 20 metres, as had always been foreseen, the installed capacity increasing from 4x45=180 MW to 4x65=260 MW; however, this work, for which is expected a time of five years, requires a previous observation campaign about the present condition and the behaviour of the structure that forces the installation of equipments of measure, during a record period of time with statistical meaning which is estimated at three or four years; so it is not possible to consider the heightening of the dam finished before 8 or 9 years, at least, and this if an immediate decision is taken. Therefore this action is only considered feasible after the construction of Capanda;

- **the construction of a second power station at Cambambe**, fitted with generating units with 130 MW of nominal capacity;

- due to its small dimension and the kind of problems that affect all the scheme, the reintegration of the hydro power station of Mabubas in the N.E.GS. was not considered.

D - Characterisation of the hydroelectric power plants:

On Tables 1 and 2 from ANNEX 2, the monthly inflows to the hydroelectric power plants of Capanda and Cambambe, during a period of 20 years from 1953 to 1972, are shown; equally, the inflows to the rest of the hydro power plants that will be cited in the present report (Cacombo, Lomaum, Biópio, Gove and Matala) are given on Tables 3, 4, 5, 6 and 7 from the same ANNEX 2.

On Tables 8, 9 and 10 the characterisation of the reservoirs, the corresponding heights of evaporation and the characterisation of the power stations are respectively shown.

E - Scenarios of the demand evolution:

On the contacts established with the administrations of the enterprises responsible for the operation of the Northern System (SONEFE) and the Central and Southern Systems (ENE) the fact was emphasised that at the present context of living in Angola it is practically impossible to carry out medium and long range expansion plans, due essentially to the following factors:

- conscience of the existence of a suppressed demand of an unknown but significant magnitude,
- inexistence of a credible census of the population,
- inexistence of statistics about the economic activity in the country.

Consequently, the estimates concerning the evolution of consumption are done only for the short range (1 or 2 years) and they are just based on sensibility criterions.

Basically, the existing plans about to be carried out concern the rehabilitation of the existing equipments which are at inadequate condition of operation.

So, more than the incertitude of the installation of a stable peace on the country in a near future, to establish scenarios of the electricity demand evolution at any range becomes extremely vulnerable.

Anyhow, and for the study purposes, two scenarios of electricity demand evolution, at the level of generation, were considerea:

.the HIGH SCENARIO- equivalent to the Intermediate Scenario of the mission of 1987, adjusted from the actual value verified in 1989 (695.2 GWh) until 2000; from this year onwards the growth rates of 7,0% until 2005, 6,0% until 2010 and 5,0% until 2015 were assumed;

.the LOW SCENARIO - the Intermediate Scenario defined in the scope of the present mission.

DEMAND EVOLUTION SCENARIOS a)

(GWh)

YEAR	HIGH	LOW
1989	695	695
1990	730	729
1995	1091	959
2000	1789	1302
2005	2509	1791
2010	3358	2292
2015	4285	2914

a) Table 11 from ANNEX 2

These two scenarios were subsequently extended in order to allow a better analysis of the allocated generations by Cambambe and Capanda till the limit of their generating capabilities, which at the High Scenario occurs in the year 2024 for a generation level of 6600 GWh, while at the Low Scenario such situation it is only reached about the year 2030.

F - Relatively to the hydro power project of Capanda the following alternative hypothesis were considered.

Alternative I- (ALT.I) Observance of the construction schedule as it was established by GAMEK (Gabinete do Médio Kwanza) with the conclusion of the dam* with the total height as defined at the project, "HIGH CAPANDA", until the end of 1992, but without the installation of any generating unit; the corresponding cost estimate is shown on Table 12 from ANNEX 2.

* Height of the dam about 110 meters.

Alternative II - (ALT.II) Corresponding to the schedule of GAMEK in which the Unit 1, at the beginning of 1993, and the Unit 2 in, the middle of the same year, are considered in operation; the corresponding cost estimate is shown on Table 13 from ANNEX 2.

Alternative III- (ALT.III) Construction of a lower dam with the spillway at the elevation of 920.0,* "LOW CAPANDA", until the end of 1992 but without the installation of any generating unit; the corresponding cost estimate is on Table 14 from ANNEX 2.

* Height of the dam about 91 meters.

Each one of this alternatives was considered at the high and low scenarios above mentioned, resulting in the total six alternatives which were studied for the long range expansion of the N.EG.S., characterised as follows:

			UNITS U1 and U2 in 1993
ALT.I.A -	High Capanda	; High Scenario	no
ALT.I.B -	" "	; Low "	no
ALT.II.A -	" "	; High "	yes
ALT.II.B -	" "	; Low "	yes
ALT.III.A -	Low Capanda	; High "	no
ALT.III.B -	" "	; Low "	no

2.2- ESTABLISHMENT OF THE L.C.E.P.

2.2.1- METHODOLOGY

The establishment of the L.C.E.P. was based on the following methodology :

A - Utilisation of the "VALORAGUA" model for the simulation of the optimized operation of a mixed hydro-thermal electricity generating system. The model is of the static type, that is to say, is employed each time to one only configuration of the system, corresponding to a certain stage (year) of the system evolution (ANNEX 2A).

B - With base on simulations carried out with the VALORAGUA model using a series of monthly inflows to the hydro power plants for a period of 20 years from 1953 to 1982, for stages around the years 1995, 2000, 2005, 2010 and 2015, it was possible to evaluate the firm capacities and generations(*) by Capanda with one, two, three or four installed units, the corresponding increments due to the heightening of the Cambambe dam and the corresponding values imputable to the new units (U5 and U6) to be installed at the new power station of Cambambe.

In the next table these values are shown:

	FIRM GENERATION (GWh)				FIRMED CAPACITY (MW)
Capanda					
Unit 1	1195 (795)				125 (95)
Unit 2	2170 (1450)				250 (180)
Unit 3	2350				365
Unit 4	2450	2492**	2935**	2790**	445
Cambambe					
4 Units	1080				135
heightning		1385			195
Unit 5			1955		325
Unit 6				2440	455

(**) The increments respecting the value 2450 GWh are those verified in the power station of Cambambe but imputable to the regulation induced by the Capanda reservoir; they were computed from simulations with Cambambe without Capanda upstream, wich led to the values of firm generations of Cambambe shown on this table.

(...) Values for the ALT.'s III.A and III.B before the heightening of the Capanda dam.

(*) In this study firm generation energy and firm capacity are defined as:
Firm generation - the producible energy in critical year, that is, the year with 95% of probability to the overpassed (in the present case, the year 1958);

Firm capacity - the available capacity at the month of the critical year with higher load (in the present case, December 1958).

C - Starting with ALT.'S I.A and I.B, and by comparing the firm generation and the firm capacity of Cambambe and Capanda with the demand of generation and capacity from 1993 onwards, the opportunity times of the commissioning dates for the four generating units of Capanda, of the heightening of the Cambambe dam and of the new generating units of a second power station to be built in Cambambe, were defined.

It was fixed the following criterion: from the commissioning date of the first unit of Capanda onwards, to assure the peak only with the firm hydro capacity, being assumed however, a deficit till the limit of 10%. Nevertheless it was always kept, within the study's horizon, a capacity of 50 MW installed in gas turbines in Luanda as emergence reserve, which eventually could contribute to shorter those deficits. This will lead to the replacement, in a convenient date, of the present turbines by two new ones of 25 MW each, burning gasoil or natural gas.

The ALT.'s II.A and II.B differ from de former just because they consider in operation the units 1 and 2 of Capanda in 1993, in spite of the firm generation and firm capacity of these units being only considered when necessary for the system, as founded in ALT.'s I.A and I.B. The system expansion is similar to the former alternatives from the commissioning date of Unit 3 of Capanda onwards.

At ALT.'s III.A and III.B the opportunity times of the commissioning dates for the Units 1 and 2 of Capanda, of the heightening of Cambambe dam and the commissioning date for the Unit 3 of Capanda, were searched, being the expansion from this date onwards similar to the former alternatives.

D - On Tables 15, 16, 17, 18, 19 and 20 of ANNEX 2 the system expansion is presented in accordance with its foreseen evolution, for the six considered alternatives, as it is shown on the two sets of five columns having the titles, respectively, GWh and MW.

In the set of three columns with the title "GENERATION (GWh)/ /WITHOUT INTERCONNECTION", the generations allocated on the Northern System network by the power stations of Capanda and Cambambe are shown, which, when higher than the respective firm generation, are the generations at the average of the twenty hydrological regimes simulated.

2.2.2- ANALYSIS OF THE RESULTS

From the analysis of the Tables 15, 16, 17, 18, 19 and 20 of ANNEX 2 it is verified that is the following the long range expansion in order to meet the demands of capacity and generation (except for ALT.II in which was considered the commissioning date for the units U1 and U2 of Capanda in 1993, accordingly the schedule of GAMEK):

	HIGH SCENARIO			LOW SCENARIO		
	ALT.I.A	ALT.II.A	ALT.III.A	ALT.I.B	ALT.II.B	ALT.III.B
1993		U1, U2			U1, U2	
1996	U1		U1			
1998			U2	U1		U1
1999	U2					
2002			▮			U2
2004				U2		
2005	U3	U3	U3			
2007						▮
2009	U4	U4	U4			
2011	❙	❙	❙	U3	U3	U3
2013	U5	U5	U5			
2017	U6	U6	U6	U4	U4	U4
2019				❙	❙	❙
2021				U5	U5	U5
2025				U6	U6	U6

U1,U2,U3,U4 - Generating units of Capanda
U5,U6 - Generating units of the second power station of Cambambe
❙ - Heightening of Cambambe dam

▮ - Heightening of Capanda dam
See Table 21 from ANNEX 2.

In conclusion:

- from the commissioning date of the U3 of Capanda the three alternatives are similar for the same scenario;

- passing from the High Scenario to the Low Scenario it is verified that:

  . the commissioning date of U1 moves from 1996 to 1998
  . the commissioning date of U2 moves from 1999 to 2004 at the ALT.I, but from 1998 to 2002 at the ALT.III
  . the heightening of Capanda dam at the ALT.III moves from 2002 to 2007.
  . the commissioning date of U3 moves from 2005 to 2011
  . the commissioning date of U4 moves from 2009 to 2017
  . the heightening of Cambambe dam moves from 2011 to 2019
  . the commissioning date of U5 moves from 2013 to 2021
  . the commissioning date of U6 moves from 2017 to 2025

- at the High Scenario new generation centres are required from the year 2020 onwards.

2.2.3- COST ESTIMATES AND INVESTMENT PLANS

The cost estimates concerning the ALT.'s I, II and III considered for the power plant of Capanda,which are shown on Tables 12, 13 and 14 from ANNEX 2, were elaborated for a system of prices referred to the end of 1989, as well as the estimates concerning the heightening of Cambambe dam and the construction of a new power station in this hydro scheme; in a first phase, it will be fitted with two units with the nominal capacity of 130 MW each one, whose cost reach the following amounts in millions of USD (pag. 22 and 23 from ANNEX 2).

Heightening of Cambambe dam			180.0
New power station (1ª phase: 2x130 MW)	- C.C.	151.0	
	- EQ.	177.0	328.0
	TOTAL		508.0 M.USD

C.C. - Civil construction
EQ. - Equipment

On tables 22, 23, 24, 25, 26 and 27 from ANNEX 2, the corresponding investment plans, as well as the corresponding operation and maintenance costs (in accordance with the timing of the commissioning dates of the different generating units and of the heightening of the dams, as they were presented on tables 15, 16, 17, 18, 19 and 20 and summarized on Table 21 of the same annex) are shown in detail.

On the same tables 22 to 27 are also presented the flows of the generations allocated by Capanda and the second power station of Cambambe at the hypothesis without interconnection of the Northern System to the Central and Southern Systems (from tables 15 to 20 of ANNEX 2).

2.2.4- LONG RUN MARGINAL COSTS (L.R.M.C.)

The L.R.M.C. from Capanda are defined as the levelized generating costs during its lifetime, which is assumed to be of 50 years from the completion of the dam construction (end of 1992).

So discounting, to the beginning of 1990, the flows presented on tables 22 to 27 from ANNEX 2, using the discount rates of 10, 12 and 15%, it is possible to compute the L.R.M.C. from Capanda, from Cambambe (concerning only the second power station) and from the set Capanda-Cambambe, at the hypothesis without interconnection.

Such values are shown on tables 28, 29, 30, 31, 32 and 33 from ANNEX 2; at the bottom of Table 21 from ANNEX 2 are summarized those values (in cents of USD per kWh) for the set Capanda-Cambambe, jointly with the corresponding total discounted costs (in M.USD), for the six alternatives.

Looking only at the Capanda costs it is verified that the minimum costs correspond to the ALT.III (LOW CAPANDA until 2002 or 2007 according to the scenarios); however, the corresponding generation is lower than that of the ALT.1 resulting for this alternative the minimum levelized generating costs.

Consequently it is considered that the L.C.E.P. for the Northern Electric System corresponds to the ALT.I with the following L.R.M.C. (in cents of USD/kWh):

		DISCOUNT RATE		
		10%	12%	15%
CAPANDA	H	12.59	17.86	28.67
	L	18.10	26.91	46.16
CAMBAMBE	H	5.98	7.68	10.92
	L	5.54	7.11	9.98
CAPANDA + CAMBAMBE	H	11.84	16.96	27.62
	L	16.99	25.68	44.85

H - High Scenario L - Low Scenario

2.2.5- CONCLUSIONS AND RECOMMENDATIONS

The L.C.E.P. for the N.E.G.S. corresponds to the best strategy for the development of the hydro project of Capanda which consists on the ALT.I leading to the minimum generation costs per kWh (between 12.59 cents of USD, for the discount rate of 10% and the High Scenario, and 46.16 cents of USD, for the discount rate of 15% and the Low Scenario).

Capanda hydro project, jointly with the present power station of Cambambe, is enough to meet the demand on the Northern system till 2010, at the High Scenario, or till 2018 at the Low Scenario.

In this context the heightening of Cambambe dam and its second power station are very questionable because they are only put in perspective at the years 2011 or 2019, according the scenarios.

This raise the question of to know if it would be justifiable to realize those works at a moment when the dam is already more then 50 years old and suggest the research of better alternatives.

So, it is recommended the achievement of prefeasibility studies, with a satisfactory technical and budgetary characterization, concerning some hydro projects whose dimension seems to be more adequate to the scale of the electric systems of Angola, such as, for instance:

Middle Kwanza Basin - Zenzo II (150 MW; 670 GWh)

Queve Basin - Caivole (70 MW; 325 GWh) and Cachoeiras do Binga (195MW; 960 GWh)

Longa Basin - Quissula (110 MW; 538 GWh), Cassongo (110 MW, 517 GWh), Lungo (50 MW; 233 GWh) and Murimbo (170 MW; 818 GWh)

2.3- THE INTERCONNECTION OF THE N.EG.S. TO THE C.EG.S. AND S.EG.S.

2.3.1- IMPACT ON THE L.R.M.C. OF THE N.EG.S.

With the hydro power plants of Cambambe and Capanda in operation surplus of generations are verified in the Northern System comparatively to the demand, even in the High Scenario, until the year 2025.

This fact suggests an analysis on the interest of that system interconnection to the Central and Southern Systems which would be materialized by means of a transmission line of 220 kV, from the substation of Cambambe to Lubango, passing through Gabela and Biopio; with a total extension of 570 Km and a period of construction of 4 years its technical cost, at prices of the end of 1989, is estimated at 102.6 millions of USD* (see Map of ANNEX 2).

The study was performed only for the hypothesis of the High Scenario of power demand in the three systems to which corresponds the evolution presented on Table 1 from ANNEX 3; once more the VALORAGUA model was used, which allows the analysis of several mixed hydro-thermal systems, interconnected by a transmission network with a simplified representation (ANNEX 2A), having been analysed the systems stages for the years 1996, 2005 and 2015.

The study was carried out on the presupposition that all the equipment of generation nowadays unavailable, or at precarious conditions of operation, would be rehabilitated in order to get ready, from 1994 onwards:

- all the thermal generation equipment, namely, the gas turbines of Biopio (22.8 MW) and Huambo (10 MW), and the diesel units of Lobito (20.0 MW) and Namibe (11.5 MW);
- the hydroelectric power plant (H.P.P.) of Lomaum fitted with the two new units with the nominal capacity of 15 MW each one and the former one with the same nominal capacity as a reserve;
- the H.P.P. of Biopio fitted with four units with a nominal capacity of 3.6 MW each one, completly rehabilitated, or new ones with the same capacity, remaining one as reserve;
- the H.P.P. of Matala fitted with one new unit of a nominal capacity of 13.6 MW and the two former units, of the same nominal capacity, after rehabilitation, remaining one of these as reserve.
- the Gove dam with its discharge equipments.

(*) Taking as basis 180,000 USD per Km.

At these conditions, the following evolutions arose for the composition of the Central and Southern Systems, within the study horizon (year 2015):

C.EG.S.
- Gas turbine of Biopio with 22.8 MW, available from 1994 onwards
- Gas turbine of Huambo with 10.0 MW, available from 1994 onwards
- Diesel units of Lobito with 20.0 MW, available from 1994 onwards
- H.P.P. of Lomaum, fitted with 45 MW from 1994 onwards and with 65 MW from 2004 onwards by uprating with the two former units with 10 MW of nominal capacity each one, after rehabilitation
- H.P.P. of Biopio fitted with 14.4 MW, from 1994 onwards
- H.P.P. of Cacombo only with regulating purpose from 2009 onwards and fitted with two units of 12 MW each one, from 2014 onwards.

S.EG.S.
- Gas turbine of Namibe with 11.5 MW, available from 1994 onwards
- H.P.P. of Gove only with regulating purpose from 1994 onwards and fitted with two units of 15 MW each one from 2014 onwards
- H.P.P. of Matala fitted with 40,8 MW from 1994 onwards.

On Table 15 from ANNEX 2 on the last set of three columns entitled "GENERATION (GWh) - WITH INTERCONNECTION" and on the right hand side of Table 22 from the same annex are shown the generations of Cambambe (D) and Capanda, at the above mentioned conditions. As previously, discounting these generation flows, supposed to be constant from from 2025 onwards, to the beginning of 1990, and for the rates of 10, 12 and 15%, new values for the L.R.M.C. are obtained which are shown on Table 28 from ANNEX 2.

As consequence of the interconnection it is verified that for ALT.I.A the L.R.M.C. at the N.EG.S. decrease:

. around 6,4% at Capanda, independently of the discount rates

. between 18 and 23% at Cambambe, according to the discount rates

. 7,8% for the set Capanda-Cambambe, independently of the discount rate

2.3.2- ECONOMICAL ANALYSIS

On tables 34, 35 and 36 from ANNEX 2 are shortly shown the results with interest for the analysis in consideration.

The obtained results show clearly that the N.EG.S., although beginning in 1996 with a discreet contribution for the C.EG.S. and S.EG.S., can assure very important power transfers for these systems, mainly between 2000 and 2023 year in which such support will finish due to the saturation of the generation of the set Capanda/Cambambe to fulfil the requirements of the Northern System supply.

For instance, for the C.EG.S. in the year 2015 (and for a discount rate of 10%) the situation is the following:

	Thermal Generation in average year (GWh)	Fuel consumption(*) (M. USD)
without interconnection	414.2	41.43
with interconnection	80.0	8.01

	Required capacity in G.T. besides the existent, at critical period (DEZ.58) (MW)	Correspondent annual charge(**) (M. USD)
without interconnection	140.8	8.87
with interconnection	56.1	3.53

So, for the C.EG.S., at the year 2015 and to the discount rate of 10%, the existence of the interconnection enables a saving of about 39 millions of USD.

It results that, globally, the worth of the interconnection is, in M.USD:

	DISCOUNT RATE 10%	12%	15%
. in 1996	1.89	1.89	1.89
. in 2005	23.86	24.65	25.91
. in 2015	47.66	48.65	50.25

(*) For the gas turbines it was assumed a variable cost between 9.0 and 10.7 cents of USD per kWh.

(**) Annual fixed charge of 63, 73 and 89 USD per kW, respectively, for the rates of 10, 12, and 15%.

As it can be seen on Table 15 from ANNEX 2 the values for 2015 correspond to a transit of about 600 GWh from the Northern System to Central and Southern Systems. On the same table it can be observed that this situation goes on until the year 2022, decreasing to 300 GWh in 2023 and to zero in 2024, year in which the generation demand at the Northern System (6600 GWh) saturates the average annual generation of Cambambe and Capanda.

So, considering the value of 2015 valid up to 2022, half of that value for 2023 and zero to 2024, and interpolating linearly between the values obtained for 1996, 2005 and 2015, a flow is defined which, discounted for the rates 10, 12 and 15% to the beginning of 1996, gives the following values for the worth of the interconnection:

RATE	
10%	196.0 M. USD
12%	159.7 M. USD
15%	121.7 M. USD

On the other hand, and as it was already said, the cost of the line is estimated in 102.6 USD, being foreseen a construction period of 4 years. So, its total cost, discounted to the beginning of 1996, results approximately equal to:

RATE	
10%	102.6 x 1.20 = 123.1 M.USD
12%	102.6 x 1.24 = 127.2 M.USD
15%	102.6 x 1.30 = 133.4 M.UDS

Considering the annual charges with the transmission line maintenance of about 3% of its cost, that is, 0.03x102.6=3.78 M.USD, the corresponding discounted total values to the beginning of 1996, and for a period of 28 years (from 1996 up to 2023), are the following:

RATE	
10%	9.76081 x 3.078 = 30.0 M.USD
12%	8.44992 x 3.078 = 26.0 M.USD
15%	7.00641 x 3.078 = 21.6 M.USD

So, the discounted net values of the worth of the interconnection are:

RATE							
10%	196.0	-	123.1	-	30.0	=	42.9 M.USD
12%	159.7	-	127.2	-	26.0	=	6.5 M.USD
15%	121.7	-	133.4	-	21.6	=	-33.3 M.USD

It follows that the interconnection of the Northern System to the Central and Southern System, at the considered scenario, is interesting under a strictly economic viewpoint, for the discount rates of 10 and 12%, but not justifiable for the rate of 15%. Additionally, such interconnection enables to postpone large investments at the Central and Southern Systems for several years, as it is analysed on Chapter 3.

However, that interconnection can be subject to some technical restraints which must be carefully analysed as, for instance, its contribution for the reliability of the Northern, Central and Southern Systems operation.

3 - EXPANSION PLANS OF THE C.EG.S. AND S.EG.S. AS ISOLATED SYSTEMS

On chapter 2.3 was defined the evolution of the composition of the C.EG.S. and S.EG.S., between 1995 and 2015, assuming the interconnection of the Northern System to the Central and Southern Systems.

However, in case of such interconnection not being clearly advisable under a technical point of view, it is important to analyse the expansion of these two systems, although for a shorter horizon, 1995-2005, at the hypothesis of remaining isolated, as it happens nowadays.

For this purpose only the High Scenario of the demand evolution, presented on Table 1 from ANNEX 3, was considered. This scenario corresponds to the Intermediate Scenario assumed at the Mission of 1987 as already mentioned, only rectified from the values actually verified in 1987 at the Central and Southern Systems. In consequence of failures of several equipments occurred in 1988 and 1989, the generation values of these years cannot be used as a basis for a demand forecast because they correspond to a situation in which the demand has not been met.

It was assumed that in 1995 the composition of the C.EG.S. and the S.EG.S. were exactly the same of those defined on chapter 2.3.

The simulations carried out for the years 1995, 2000 and 2005, by means of the utilization of VALORAGUA model, led to the results shortly presented on Tables 2 and 3 from ANNEX 3, whose analysis suggests the following remarks:

- At the C.EG.S, the dam of CACOMBO only with the regulation purpose is needed in 2000 and its power station, fitted with 2x12 MW, in 2003, while, in the case of interconnection to the Northern System, those dates were, respectively, 2010 and 2015 (Table 2 from ANNEX 3 and Table 34 from ANNEX 2).

  In addition to this, in view of the magnitude of the shortage of energy in dry year (1958) between 1997 and 1999 and at the year 2005, it is essential to install two new gas turbines, one with the nominal capacity of 25 MW, in 1997, and the other with 30 MW, in 1998, so that the utilization of the thermal units in that dry year will be around 1200 and 1600 hours.

- At the S.EG.S., the power station to be installed at the H.P.P. of GOVE is needful at 1999 fitted with 2x15 MW, and at 2003 with 3x15 MW while in case of interconnection to the Northern System it would only be required in 2015 (Table 3 from ANNEX 3 and Table 34 from ANNEX 2).

This means that, in case of the Central and Southern System remaining isolated, it will be needed to anticipate investments that are estimated as follows:

CACOMBO -	Dam	150.0	M.USD
	Power station (3x12 MW) ...	48.0	M.USD
	Gas turbine (25 MW)	11.0*	M.USD
	Gas turbine (30 MW)	13.2*	M.USD
GOVE -	Power Station (3x15 MW) ..	60.0	M.USD

Taking into account the respective investment plans at the hypothesis with and without interconnection, it is verified that, for discounted values to the beginning of 1995, the sustenance of the C.EG.S. and S.EG.S. isolated "versus" the hypothesis with interconnection means the following increment of costs concerning the investments until the year 2003:

RATE	C.EG.S.	S.EG.S.	TOTAL
10%	169.9	39.9	209.8 M.USD
12%	162.3	37.1	199.4 M.USD
15%	152.1	33.4	185.5 M.USD

as it follows from Table 4 of ANNEX 3; this figures added to the corresponding ones concerning the worth of the interconnection (see nº 2.3.2) are big enough to justifie the interconnection unless serious technical restraints render it unfeasible.

Concerning the better strategy for the evolution of the thermal components it must be observed that:

- once the gas turbine of Huambo does not operate at the most suitable conditions, due to the altitude at which it is installed, it seems justifiable to transfer it to Namibe, by change with the diesel units of Namibe and Lobito (11,5 + 20,0 = 31,5 MW), after the needful rehabilitation, to Huambo, where they will be needed around the year 2005.
- the two new turbines to be installed at the C.EG.S., eventually burning natural gas, must be located at the area of Benguela and Lobito.

(*) Taking as basis 440 USD per kW.

TABLE 1

INSTALLED AND AVAILABLE GENERATING CAPACITY IN JAN.90 (Part 1)

SYSTEM AND PROVINCE	NAME OF PLANT	TYPE (a)	NUMBER OF UNITS AND UNIT POWER (MW)	CAPACITY (MW) INSTALLED	CAPACITY (MW) AVAILABLE	DATE OF COMMISSION. MONTH/YEAR	DATE OF UNAVAILABI. INDISPON.
North							
Kuanza N.	Cambambe	H	2x45+2x45	180.0	135.0	1963,1973	
Bengo	Mabubas	H	2x3+2x5.9	17.8	---	1953,1959	2/1986
Luanda	Luanda TG1	GT	1x25.6	25.6	20.0	1980	
"	Luanda TG2	GT	1x31.2	31.2	30.0	8/1985	
Subtotal				254.6	185.0		
Central							
Benguela	Lomaum	H	2x10+1x15	35.0	---	1964,1972	3/1983
"	Biopio	H	4x3.6	14.4	10.8	1957	
"	Biopio	GT	1x22.8	22.8	---	2/1974	1988
"	Biopio	D	2x1.5	3.0	---	1982	
"	Lobito	D	4x5 (b)	20.0	5.0	1986	1989
Huambo	Huambo	GT	1x10 (c)	10.0	10.0	1981	
"	Huambo	D	4x0.8+2x0.85	4.9	0.8	1953-1986	
Subtotal				110.1	26.6		
South							
Huila	Matala	H	2x13.6	27.2	13.6	1959	1984
"	Lubango	D	3x0.4+12x0.2	3.6	---	n.d.	
"	Nabime	D	2x5.75	11.5	5.75	1980	
"	Tombwe	D	1x1.6	1.6	---	1970	
"	Jamba	D	3x1.9	5.7	---	1968	
"	Saco	D	2x1.45	2.9	---	n.d.	
Subtotal				52.5	19.35		

a) H = Hidroelectric; GT = Gas Turbine; D = Diesel

b) Railway carriage mounted.

c) ISO rating 13,5 MW. Derating of 26% due to altitude.

SOURCE: SADCC, SONEFE and ENE.

T A B L E 1

INSTALLED AND AVAILABLE GENERATING CAPACITY IN JAN.90 (Part 2)

SYSTEM AND PROVINCE	NAME OF PLANT	TYPE (a)	NUMBER OF UNITS AND UNIT POWER (MW)	CAPACITY (MW) INSTALLED	AVAILABLE	DATE OF COMMISSION. MONTH/YEAR	DATE OF UNAVAILABI. INDISPON.
Isolated Systems							
Cabinda	Malongo	GT	1x12.3	12.3	10.0	1980	
"	Movel	D	3x1.5	4.5	1.5	8/1971	
"	Cacongo	D	4x0.3	1.2	1.2	n.d.	
Uige	Luquixe	H	3x0.36	1.1	1.1	1957,1968,1971	
"	Uige	D	3x0.6	1.8	1.4	n.d.	
"	Movel	D	1x1,5	1.5	1.5	1982	
Lunda N	Luaximo	H	4x2.4	9.6	---	1957	
"	Luxilo	D	1x1.5	1.5	---	n.d.	
"	Lucapa	D	2x3.2	6.4	---	n.d.	
Bie	Andulo	H	2x0.05	0.1	---	n.d.	
"	Kunje	H	3x0.54	1.6	---	1/1971	
"	Coemba	H	2x.01	0.2	---	n.d.	
"	Kuito	D	1x0.8+1x0.5	1.3	---	n.d.	
Moxico	Luena	D	2x0.6	1.2	---	1974	
Huila	Kubango	H	2x0.15	0.3	---	8/1972	
Subtotal				44.6	16.7		
TOTAL ANGOLA				**461.8**	**247.6**		

TABLE 2

TOTAL GENERATION BY TYPE OF PLANT
(GWh)

	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
HYDRO																				
CAMBAMBE	255.7	303.2	370.7	502.6	555.2	421.4	338.6	394.7	419.4	465.0	489.9	506.7	545.0	574.4	555.6	544.2	590.4	624.6	646.0	661.8
MABUBAS	46.7	72.5	67.4	27.7	15.2	6.3	0.3	1.3	2.9	1.3	2.4	1.6	1.9	4.1	3.6	4.7	1.3	0.0	0.0	1.3
LOMAUM	81.9	97.9	109.9	120.8	125.8	92.4	63.4	72.4	90.4	85.3	112.4	99.4	112.5	2.4	0.0	0.0	0.0	0.0	0.0	0.0
BIOPIO	37.2	34.9	34.1	43.1	37.6	42.7	14.4	24.0	16.0	39.0	22.6	32.1	38.3	34.5	16.4	12.0	35.1	34.3	46.4	42.0
MATALA	91.5	61.8	67.5	77.8	65.2	73.0	34.4	26.2	30.7	35.3	37.5	37.6	42.1	48.1	51.1	49.7	56.2	53.7	61.3	43.2
Other	30.7	34.7	30.7	42.1	62.1	69.3	9.6	10.8	8.7	10.5	10.5	10.7	8.6	10.9	8.0	9.6	8.1	6.9	6.2	6.7
Total hydro	543.7	605.0	680.3	814.1	858.1	705.1	460.7	529.4	568.1	636.4	675.3	688.1	748.4	674.3	634.7	620.2	691.1	719.5	759.9	755.0
GAS TURBINES																				
LUANDA	---	---	---	---	---	---	---	---	---	---	0.1	0.0	0.3	0.1	0.5	6.2	14.2	1.6	9.4	32.1
BIOPIO	---	---	---	---	8.0	0.0	0.0	0.0	0.1	0.0	1.8	8.8	0.7	60.0	61.9	49.7	15.5	27.1	0.0	0.0
HUAMBO	---	---	---	---	---	---	---	---	---	---	1.8	1.7	0.1	11.0	7.1	2.9	0.0	0.0	0.0	0.0
CABINDA	---	---	---	---	---	---	---	---	---	---	6.0	9.9	18.8	14.2	13.6	18.1	5.7	0.0	0.0	0.0
Total G.T.	0.0	0.0	0.0	0.0	8.0	0.0	0.0	0.0	0.1	0.0	9.7	20.4	19.9	85.3	88.1	76.3	35.4	28.7	9.4	32.1
DIESEL GENERATION	100.0	137.0	158.5	170.2	162.7	133.2	71.4	28.8	15.0	13.0	5.3	8.0	10.3	4.2	3.6	8.3	27.0	66.7	73.3	57.1
Total Angola	643.7	742.0	838.8	984.3	1028.8	838.3	532.1	558.2	588.2	649.4	690.3	716.5	778.6	763.8	726.4	704.8	753.5	814.9	842.6	844.2
Average growth rate (%)		15.3	13.0	17.3	4.5	-18.5	-36.5	4.9	4.5	11.4	6.3	3.8	8.7	-1.9	-4.9	-3.0	6.9	8.1	3.4	0.2
Percentage of Total																				
Hydro	84.46	81.54	81.10	82.71	88.41	84.11	86.58	94.84	97.41	98.00	97.83	96.04	96.12	88.28	87.98	88.11	91.72	88.29	90.19	89.43
Gas turbines	0.00	0.00	0.00	0.00	0.78	0.00	0.00	0.00	0.02	0.00	1.41	2.85	2.56	11.17	11.44	10.83	4.70	4.18	1.61	5.05
Diesel	15.54	18.46	18.90	17.29	15.81	15.89	13.42	5.16	2.57	2.00	0.77	1.12	1.32	0.56	1.18	1.06	3.58	7.53	8.20	5.52

Source: SADCC, SONEFE and ENE.

TABLE 3

BREAKDOWN GENERATION BY SYSTEM AND POWER PLANT

(GWh)

SYSTEM/PLANT	Type a)	1982	1983	1984	1985	1986	1987	1988	1989
NORTH									
Cambambe	H	544,964	574,256	555,642	544,156	590,448	624,6	646,0	661,8
Mabubas	H	1,851	4,113	3,572	4,660	1,266	0,0	0,0	1,3
Luanda	GT	0,272	0,055	0,496	6,208	14,234	1,6	9,4	32,1
Sub-total		547,087	578,424	559,710	555,024	605,948	626,2	655,4	695,2
CENTRAL									
Lomaum	H	112,500	2,428	0,0	0,0	0,0	0,0	0,0	0,0
Biopio	H	38,300	34,516	16,408	12,801	35,114	34,3	46,4	42,0
Biopio	GT+0	0,700	60,042	61,896	49,746	15,531	27,1	0,0	6,1
Huambo	GT+D	0,070	11,000	7,106	2,275	2,021	5,3	4,2	4,4
Lobito	D	0,0	0,0	3,932	1,822	10,615	31,8	44,8	12,8
Blackstone sets	D	0,0	0,0	0,0	0,505	11,948	3,6	1,5	8,1
Others		-----	-----	-----	-----	-----	0,9	2,6	4,4
Sub-total		151,570	107,986	89,342	67,149	75,229	103,0	99,5	77,8
SOUTH									
Matala	H	42,127	48,104	51,113	49,698	56,212	53,7	61,3	43,2
Lubango	D	-----	-----	-----	-----	-----	---	---	2,5
Namibe	D	1,253	0,0	0,0	3,178	0,118	8,2	2,4	3,2
Sub-total		43,380	48,104	51,113	52,876	56,330	61,9	63,7	48,9
Total		742,037	734,514	700,165	675,049	737,507	791,1	818,6	821,9
Cabinda									
Malongo	GT+D	187,681	14,240	13,618	18,029	5,690	3,8	16,8	15,8
Movel	D						10,6	0,0	0,0
Cacongo	D						0,3	0,0	0,0
Sub-total							14,7	16,8	15,8
Uige									
Luquixe	H	5,000	5,323	3,360	4,533	2,891	1,7	0,6	0,0
Uige	D	0,787	0,927	3.092	0,502	0,919	1,9	2,0	1,3
Sub-total		5,787	6,250	6,452	5,035	3,810	3,6	2,6	1,3
Bié									
Kunge	H	5,310	5,338	3,555	4,533	4,751	4,3	3,4	4,0
Andulo	H	0,270	0,289	0,150	0,257	0,245	0,2	0,2	0,1
Coemba	H	0,235	0,228	0,152	0,228	0,182	0,2	0,1	0,3
Kuito	D	1,400	0,985	1,698	1,277	1,197	0,2	0,6	0,2
Chinguar	D	-----	-----	0,026	0.098	0,0	0,1	0,0	0,0
N'harea	D	-----	0,011	0,0	0,0	0,0	0,0	0,0	0,0
Sub-total		7,215	6,851	5,581	6,655	6,375	5,0	4,3	4,6
Moxico									
Luena	D	4,679	1,907	0,590	0,122	0,090	0,5	0,3	0,6
Total Isolated		36,449	29,248	26,241	29,841	15,965	23,8	24,0	22,3
Total Angola		778,486	763,762	726,406	704,890	753,472	814,9	842,6	844,2

a) H = Hidroelectric; D = Diesel; GT = Gas turbine
Source: ENE, SONEFE and MEP.

TABLE 1

CAPANDA -- MONTHLY INFLOWS (M m3)

Total Basin = 111,214 Km2

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
1953	1810.0	1800.0	2490.0	3670.0	2630.0	1270.0	858.0	636.0	465.0	426.0	619.0	959.0	17633.0
1954	1180.0	1220.0	2550.0	3690.0	2920.0	1440.0	919.0	697.0	563.0	512.0	820.0	1110.0	17621.0
1955	1400.0	1130.0	1310.0	2230.0	1790.0	924.0	621.0	505.0	409.0	434.0	905.0	1750.0	13408.0
1956	2170.0	2330.0	2070.0	2950.0	3030.0	1320.0	783.0	593.0	507.0	469.0	732.0	1070.0	18024.0
1957	2030.0	2270.0	3100.0	3260.0	1730.0	892.0	688.0	553.0	481.0	535.0	775.0	1450.0	17764.0
1958	1780.0	1130.0	1150.0	1290.0	854.0	481.0	443.0	393.0	333.0	339.0	546.0	961.0	9700.0
1959	1420.0	2110.0	3280.0	3880.0	2290.0	1180.0	753.0	572.0	486.0	456.0	615.0	1180.0	18222.0
1960	1770.0	2460.0	4160.0	4830.0	3140.0	1620.0	994.0	742.0	571.0	555.0	842.0	1530.0	23214.0
1961	2020.0	3090.0	5120.0	7000.0	4690.0	2330.0	1480.0	1050.0	827.0	923.0	1560.0	3300.0	33390.0
1962	5680.0	3960.0	4640.0	7110.0	3390.0	1850.0	1350.0	1070.0	841.0	827.0	1070.0	2050.0	33838.0
1963	2720.0	3500.0	4100.0	4810.0	3130.0	1740.0	1240.0	960.0	740.0	731.0	1190.0	1650.0	26511.0
1964	2080.0	2840.0	3890.0	3340.0	1720.0	939.0	762.0	635.0	531.0	488.0	732.0	1190.0	19147.0
1965	2400.0	2570.0	3100.0	3200.0	1930.0	1050.0	764.0	623.0	515.0	682.0	648.0	1300.0	18782.0
1966	2180.0	3590.0	5690.0	5250.0	2680.0	1480.0	1050.0	838.0	707.0	759.0	970.0	1070.0	26264.0
1967	1390.0	1820.0	2610.0	3150.0	3290.0	1550.0	974.0	792.0	649.0	686.0	1480.0	2630.0	21021.0
1968	4040.0	5150.0	6740.0	5240.0	3230.0	1750.0	1250.0	973.0	769.0	741.0	1210.0	1900.0	32993.0
1969	3830.0	3710.0	6390.0	6480.0	3010.0	1650.0	1190.0	984.0	739.0	950.0	1390.0	2830.0	33153.0
1970	3390.0	3650.0	6080.0	3860.0	2420.0	1370.0	1080.0	910.0	732.0	821.0	1190.0	1720.0	27223.0
1971	2600.0	1820.0	2260.0	3200.0	2090.0	1130.0	891.0	770.0	668.0	549.0	660.0	857.0	17495.0
1972	1328.0	992.0	1010.0	1760.0	1274.0	662.0	565.0	463.0	372.0	473.0	864.0	1432.0	11195.0
MEAN	2360.9	2557.1	3587.0	4010.0	2561.9	1331.4	932.7	737.9	595.2	617.8	940.9	1596.9	21829.9

Average flow : 692.2 m3/s

Source : B E P Study (Jul 86)

TABLE 2

CAMBAMBE -- MONTHLY INFLOWS (M m3)

Total Basin = 115,500 Km2

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
1953	1927.9	1916.0	2657.0	3903.0	2801.9	1353.0	913.1	677.9	495.1	452.9	657.8	1019.9	18775.5
1954	1255.9	1299.1	2715.9	3924.0	3102.1	1533.9	977.9	741.9	599.0	552.0	883.9	1197.0	18782.6
1955	1513.0	1214.0	1412.1	2403.3	1934.1	994.8	669.9	544.0	440.9	466.0	972.0	1882.9	14447.0
1956	2328.1	2411.9	2219.9	3165.1	3256.9	1418.1	841.0	636.9	544.1	493.1	770.1	1130.0	19215.2
1957	2137.1	2389.9	3262.0	3429.0	1816.0	938.0	722.9	580.9	504.9	564.9	819.1	1536.9	18701.6
1958	1878.1	1190.0	1218.9	1366.0	902.6	508.0	469.0	414.9	352.0	362.1	582.9	1026.1	10270.6
1959	1516.0	2257.1	3498.0	4138.9	2444.8	1262.0	804.1	610.9	517.9	489.9	661.0	1266.9	19467.5
1960	1907.0	2556.6	4478.0	5188.9	3375.1	1747.0	1068.9	797.9	614.0	594.9	902.0	1644.0	24874.3
1961	2163.9	3311.9	5491.0	7505.9	5030.0	2501.0	1588.0	1124.9	885.9	964.0	1633.0	3451.9	35651.4
1962	5938.0	4136.8	4853.0	7433.9	3540.8	1927.9	1413.9	1113.9	878.9	852.0	1099.0	2107.9	35296.0
1963	2796.0	3607.0	4224.1	4958.0	3225.1	1793.9	1278.1	988.1	762.0	752.9	1229.1	1702.9	27317.2
1964	2140.0	2825.1	4006.9	3440.1	1768.0	967.1	785.0	654.1	546.9	500.9	751.9	1218.9	19604.9
1965	2460.9	2636.9	3181.9	3284.1	1979.1	1078.0	785.0	639.9	529.0	715.1	679.1	1360.9	19329.9
1966	2282.0	3759.0	5962.1	5502.8	2809.9	1550.0	1104.0	878.0	741.1	804.1	1025.9	1127.9	27546.8
1967	1473.1	1930.0	2759.0	3333.1	3479.0	1643.1	1030.9	838.1	686.9	710.0	1533.9	2723.9	22141.0
1968	4181.0	5150.0	6979.9	5421.9	3342.9	1812.1	1299.0	1007.1	796.0	766.0	1249.1	1965.9	33970.9
1969	3958.7	3841.9	6613.0	6706.0	3115.0	1706.1	1228.8	1018.1	764.9	1010.0	1474.8	3007.8	34445.1
1970	3607.8	3879.9	6460.0	4098.0	2573.9	1459.0	1152.0	966.9	778.1	876.1	1267.0	1840.1	28958.8
1971	2768.9	1947.0	2410.0	3413.9	2227.9	1205.0	951.1	822.0	713.1	578.0	694.9	902.9	18634.7
1972	1398.1	1009.0	1063.1	1853.0	1341.9	697.0	594.9	486.9	390.9	497.9	910.1	1507.9	11750.7
MEAN	2481.6	2663.5	3773.3	4223.4	2703.3	1404.7	983.9	777.2	627.1	650.1	989.8	1681.1	22959.0

Average flow : 728.0 m3/s

Source : B E P Study (Jul 86)

CAMBAMBE -- MONTHLY INFLOWS (M m3)

Intermediate Basin = 4,286 Km2

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
1953	117.9	116.0	167.0	233.0	171.9	83.0	55.1	41.9	30.1	26.9	38.8	60.9	1142.5
1954	75.9	79.1	165.9	234.0	182.1	93.9	58.9	44.9	36.0	40.0	63.9	87.0	1161.6
1955	113.0	84.0	102.1	173.3	144.1	70.8	48.9	39.0	31.9	32.0	67.0	132.9	1039.0
1956	158.1	81.9	149.9	215.1	226.9	98.1	58.0	43.9	37.1	24.1	38.1	60.0	1191.2
1957	107.1	119.9	162.0	169.0	86.0	46.0	34.9	27.9	23.9	29.9	44.1	86.9	937.6
1958	98.1	60.0	68.9	76.0	48.6	27.0	26.0	21.9	19.0	23.1	36.9	65.1	570.6
1959	96.0	147.1	218.0	258.9	154.8	82.0	51.1	38.9	31.9	33.9	46.0	86.9	1245.5
1960	137.0	96.6	318.0	358.9	235.1	127.0	74.9	55.9	43.0	39.9	60.0	114.0	1660.3
1961	143.9	221.9	371.0	505.9	340.0	171.0	108.0	74.9	58.9	41.0	73.0	151.9	2261.4
1962	258.0	176.8	213.0	323.9	150.8	77.9	63.9	43.9	37.9	25.0	29.0	57.9	1458.0
1963	76.0	107.0	124.1	148.0	95.1	53.9	38.1	28.1	22.0	21.9	39.1	52.9	806.2
1964	60.0	-14.9	116.9	100.1	48.0	28.1	23.0	19.1	15.9	12.9	19.9	28.9	457.9
1965	60.9	66.9	81.9	84.1	49.1	28.0	21.0	16.9	14.0	33.1	31.1	60.9	547.9
1966	102.0	169.0	272.1	252.8	129.9	70.0	54.0	40.0	34.1	45.1	55.9	57.9	1282.8
1967	83.1	110.0	149.0	183.1	189.0	93.1	56.9	46.1	37.9	24.0	53.9	93.9	1120.0
1968	141.0	0.0	239.9	181.9	112.9	62.1	49.0	34.1	27.0	25.0	39.1	65.9	977.9
1969	128.7	131.9	223.0	226.0	105.0	56.1	38.8	34.1	25.9	60.0	84.8	177.8	1292.1
1970	217.8	229.9	380.0	238.0	153.9	89.0	72.0	56.9	46.1	55.1	77.0	120.1	1735.8
1971	168.9	127.0	150.0	213.9	137.9	75.0	60.1	52.0	45.1	29.0	34.9	45.9	1139.7
1972	70.1	17.0	53.1	93.0	67.9	35.0	29.9	23.9	18.9	24.9	46.1	75.9	555.7
MEAN	120.7	106.4	186.3	213.4	141.4	73.3	51.2	39.3	31.9	32.3	48.9	84.2	1129.1

Average flow : 35.8 m3/s

Source : B E P Study (Jul 86)

TABLE 3

CACOMBO -- MONTHLY INFLOWS (M m3)

Total Basin = 2,725 Km2

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
1953	104.5	181.7	205.4	217.5	100.8	66.6	53.9	41.8	30.5	40.5	54.0	37.0	1134.2
1954	89.4	72.7	179.9	107.9	49.7	35.7	31.3	24.4	18.4	25.6	30.6	55.7	721.3
1955	62.6	86.9	220.2	164.0	76.2	50.2	39.9	30.5	21.5	24.9	33.4	101.8	912.1
1956	160.5	64.2	126.3	74.9	39.2	28.7	24.5	19.0	14.2	19.4	25.9	84.7	681.5
1957	36.1	17.5	84.7	120.7	52.0	29.4	22.3	18.4	12.7	16.9	33.3	81.4	525.4
1958	22.5	8.0	35.0	43.5	18.4	9.3	7.9	6.0	4.5	6.0	13.8	8.0	182.9
1959	62.8	93.2	257.8	157.8	70.8	44.9	37.4	29.4	20.0	38.3	88.1	126.2	1026.7
1960	159.4	155.5	270.1	106.2	62.3	42.3	33.4	26.3	20.3	28.6	65.6	53.3	1023.3
1961	46.4	39.6	126.7	130.5	51.8	34.3	26.8	19.3	13.9	16.9	39.6	23.9	569.7
1962	145.4	90.7	135.8	131.1	72.0	43.0	34.1	26.6	19.4	22.4	92.7	85.3	898.5
1963	104.5	181.7	205.4	217.5	100.8	66.6	53.9	41.8	30.5	40.5	54.0	37.0	1134.2
1964	89.4	72.7	179.9	107.9	49.7	35.7	31.3	24.4	18.4	25.6	30.6	55.7	721.3
1965	62.6	86.9	220.2	164.0	76.2	50.2	39.9	30.5	21.5	24.9	33.4	101.8	912.1
1966	160.5	64.2	126.3	74.9	39.2	28.7	24.5	19.0	14.2	19.4	25.9	84.7	681.5
1967	36.1	17.5	84.7	120.7	52.0	29.4	22.3	18.4	12.7	16.9	33.3	81.4	525.4
1968	145.4	90.7	135.8	131.1	72.0	43.0	34.1	26.6	19.4	22.4	92.7	85.3	898.5
1969	62.8	93.2	257.8	157.8	70.8	44.9	37.4	29.4	20.0	38.3	88.1	126.2	1026.7
1970	159.4	155.5	270.1	106.2	62.3	42.3	33.4	26.3	20.3	28.6	65.6	53.3	1023.3
1971	46.4	39.6	126.7	130.5	51.8	34.3	26.8	19.3	13.9	16.9	39.6	23.9	569.7
1972	22.5	8.0	35.0	43.5	18.4	9.3	7.9	6.0	4.5	6.0	13.8	8.0	182.9
MEAN	89.0	81.0	164.2	125.4	59.3	38.4	31.1	24.2	17.5	23.9	47.7	65.7	767.6

Average flow : 24.3 m3/s

Source : E N E

TABLE 4

LOMAUM -- MONTHLY INFLOWS (M m3)

Total Basin = 8,296 Km2

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
1953	380.2	664.3	669.1	748.3	347.3	226.3	181.6	145.6	111.6	142.1	184.6	155.0	3956.0
1954	378.8	279.9	585.6	399.8	183.4	129.5	109.8	91.5	72.3	98.5	141.0	252.2	2722.3
1955	293.0	367.7	656.6	524.0	245.0	159.5	126.1	97.5	76.6	93.0	125.7	352.4	3117.1
1956	587.9	267.2	542.9	359.9	170.6	118.0	95.7	77.8	62.5	93.4	129.7	294.9	2800.5
1957	169.7	89.9	339.4	376.4	197.8	108.7	82.8	65.4	46.2	109.5	216.1	300.9	2102.8
1958	105.3	41.7	120.6	199.0	84.7	41.2	32.6	24.1	18.0	24.0	65.8	32.0	789.0
1959	200.2	287.6	805.8	533.3	246.1	154.9	121.7	96.2	71.7	129.9	385.9	428.5	3461.8
1960	550.4	465.9	724.5	339.9	211.9	140.8	111.1	91.8	72.6	114.9	265.5	210.6	3299.9
1961	190.7	143.2	320.3	375.4	160.1	151.1	81.7	61.6	48.9	83.2	154.4	115.7	1886.3
1962	472.3	314.0	430.1	467.7	276.7	157.1	121.8	93.8	71.7	102.6	318.5	260.7	3087.0
1963	380.2	664.3	669.1	748.3	347.3	226.3	181.6	145.6	111.6	142.1	184.6	155.0	3956.0
1964	378.8	279.9	585.6	399.8	183.4	129.5	109.8	91.5	72.3	98.5	141.0	252.2	2722.3
1965	293.0	367.7	656.6	524.0	245.0	159.5	126.1	97.5	76.6	93.0	125.7	352.4	3117.1
1966	587.9	267.2	542.9	359.9	170.6	118.0	95.7	77.8	62.5	93.4	129.7	294.9	2800.5
1967	169.7	89.9	339.4	376.4	197.8	108.7	82.8	65.4	46.2	109.5	216.1	300.9	2102.8
1968	472.3	314.0	430.1	467.7	276.7	157.1	121.8	93.8	71.7	102.6	318.5	260.7	3087.0
1969	200.2	287.6	805.8	533.3	246.1	154.9	121.7	96.2	71.7	129.9	385.9	428.5	3461.8
1970	550.4	465.9	724.5	339.9	211.9	140.8	111.1	91.8	72.6	114.9	265.5	210.6	3299.9
1971	190.7	143.2	320.3	375.4	160.1	151.1	81.7	61.6	48.9	83.2	154.4	115.7	1886.3
1972	105.3	41.7	120.6	199.0	84.7	41.2	32.6	24.1	18.0	24.0	65.8	32.0	789.0
MEAN	332.8	292.1	519.5	432.4	212.4	138.7	106.5	84.5	65.2	99.1	198.7	240.3	2722.3

Average flow : 86.3 m3/s

Source : E N E

LOMAUM -- MONTHLY INFLOWS (M m3)

Intermediate Basin = 5,571 Km2

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
1953	275.7	482.6	463.7	530.8	246.5	159.7	127.7	103.8	81.1	101.6	130.6	118.0	2821.8
1954	289.4	207.2	405.7	291.9	133.7	93.8	78.5	67.1	53.9	72.9	110.4	196.5	2001.0
1955	230.4	280.8	436.4	360.0	168.8	109.3	86.2	67.0	55.1	68.1	92.3	250.6	2205.0
1956	427.4	203.0	416.6	285.0	131.4	89.3	71.2	58.8	48.3	74.0	103.8	210.2	2119.0
1957	133.6	72.4	254.7	255.7	145.8	79.3	60.5	47.0	33.5	92.6	182.8	219.5	1577.4
1958	82.8	33.7	85.6	155.5	66.3	31.9	24.7	18.1	13.5	18.0	52.0	24.0	606.1
1959	137.4	194.4	548.0	375.5	175.3	110.0	84.3	66.8	51.7	91.6	297.8	302.3	2435.1
1960	391.0	310.4	454.4	233.7	149.6	98.5	77.7	65.5	52.3	86.3	199.9	157.3	2276.6
1961	144.3	103.6	193.6	244.9	108.3	116.8	54.9	42.3	35.0	66.3	114.8	91.8	1316.6
1962	326.9	223.3	294.3	336.6	204.7	114.1	87.7	67.2	52.3	80.2	225.8	175.4	2188.5
1963	275.7	482.6	463.7	530.8	246.5	159.7	127.7	103.8	81.1	101.6	130.6	118.0	2821.8
1964	289.4	207.2	405.7	291.9	133.7	93.8	78.5	67.1	53.9	72.9	110.4	196.5	2001.0
1965	230.4	280.8	436.4	360.0	168.8	109.3	86.2	67.0	55.1	68.1	92.3	250.6	2205.0
1966	427.4	203.0	416.6	285.0	131.4	89.3	71.2	58.8	48.3	74.0	103.8	210.2	2119.0
1967	133.6	72.4	254.7	255.7	145.8	79.3	60.5	47.0	33.5	92.6	182.8	219.5	1577.4
1968	326.9	223.3	294.3	336.6	204.7	114.1	87.7	67.2	52.3	80.2	225.8	175.4	2188.5
1969	137.4	194.4	548.0	375.5	175.3	110.0	84.3	66.8	51.7	91.6	297.8	302.3	2435.1
1970	391.0	310.4	454.4	233.7	149.6	98.5	77.7	65.5	52.3	86.3	199.9	157.3	2276.6
1971	144.3	103.6	193.6	244.9	108.3	116.8	54.9	42.3	35.0	66.3	114.8	91.8	1316.6
1972	82.8	33.7	85.6	155.5	66.3	31.9	24.7	18.1	13.5	18.0	52.0	24.0	606.1
MEAN	243.9	211.1	355.3	307.0	153.0	100.3	75.3	60.4	47.7	75.2	151.0	174.6	1954.7

Average flow : 62.0 m3/s

Source : E N E

TABLE 5

BIOPIO -- MONTHLY INFLOWS (M m3)

Total Basin = 15,550 Km2

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
1953	505.7	763.9	976.9	1167.3	448.0	289.7	230.6	180.5	132.8	198.9	302.7	164.3	5361.3
1954	503.8	321.9	855.0	623.7	236.6	165.8	139.4	113.5	86.0	137.9	231.2	267.3	3682.1
1955	389.7	422.9	958.6	817.4	316.1	204.2	160.1	120.9	91.2	130.2	206.1	373.5	4190.9
1956	781.9	307.3	792.6	561.4	220.1	151.0	121.5	96.5	74.4	130.8	212.7	312.6	3762.8
1957	225.7	103.4	495.5	587.2	255.2	139.1	105.2	81.1	55.0	153.3	354.4	319.0	2874.1
1958	140.0	48.0	176.1	310.4	109.3	52.7	41.4	29.9	21.4	33.6	107.9	33.9	1104.6
1959	266.3	330.7	1176.5	831.9	317.5	198.3	154.6	119.3	85.3	181.9	632.9	454.2	4749.4
1960	732.0	535.8	1057.8	530.2	273.4	180.2	141.1	113.8	86.4	160.9	435.4	223.2	4470.2
1961	253.6	164.7	467.6	585.6	206.5	193.4	103.8	76.4	58.2	116.5	253.2	122.6	2602.1
1962	628.2	361.1	627.9	729.6	356.9	201.1	154.7	116.3	85.3	143.6	522.3	276.3	4203.3
1963	505.7	763.9	976.9	1167.3	448.0	289.7	230.6	180.5	132.8	198.9	302.7	164.3	5361.3
1964	503.8	321.9	855.0	623.7	236.6	165.8	139.4	113.5	86.0	137.9	231.2	267.3	3682.1
1965	389.7	422.9	958.6	817.4	316.1	204.2	160.1	120.9	91.2	130.2	206.1	373.5	4190.9
1966	781.9	307.3	792.6	561.4	220.1	151.0	121.5	96.5	74.4	130.8	212.7	312.6	3762.8
1967	225.7	103.4	495.5	587.2	255.2	139.1	105.2	81.1	55.0	153.3	354.4	319.0	2874.1
1968	628.2	361.1	627.9	729.6	356.9	201.1	154.7	116.3	85.3	143.6	522.3	276.3	4203.3
1969	266.3	330.7	1176.5	831.9	317.5	198.3	154.6	119.3	85.3	181.9	632.9	454.2	4749.4
1970	732.0	535.8	1057.8	530.2	273.4	180.2	141.1	113.8	86.4	160.9	435.4	223.2	4470.2
1971	253.6	164.7	467.6	585.6	206.5	193.4	103.8	76.4	58.2	116.5	253.2	122.6	2602.1
1972	140.0	48.0	176.1	310.4	109.3	52.7	41.4	29.9	21.4	33.6	107.9	33.9	1104.6
MEAN	442.6	335.9	758.5	674.5	274.0	177.5	135.2	104.8	77.6	138.7	325.9	254.7	3700.1

Average flow : 117.3 m3/s

Source : E N E

BIOPIO -- MONTHLY INFLOWS (M m3)

Intermediate Basin = 7,254 Km2

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
1953	125.5	99.6	307.8	419.0	100.7	63.4	49.0	34.9	21.2	56.8	118.1	9.3	1405.3
1954	125.0	42.0	269.4	223.9	53.2	36.3	29.6	22.0	13.7	39.4	90.2	15.1	959.8
1955	96.7	55.2	302.0	293.4	71.1	44.7	34.0	23.4	14.6	37.2	80.4	21.1	1073.8
1956	194.0	40.1	249.7	201.5	49.5	33.0	25.8	18.7	11.9	37.4	83.0	17.7	962.3
1957	56.0	13.5	156.1	210.8	57.4	30.4	22.4	15.7	8.8	43.8	138.3	18.1	771.3
1958	34.7	6.3	55.5	111.4	24.6	11.5	8.8	5.8	3.4	9.6	42.1	1.9	315.6
1959	66.1	43.1	370.7	298.6	71.4	43.4	32.9	23.1	13.6	52.0	247.0	25.7	1287.6
1960	181.6	69.9	333.3	190.3	61.5	39.4	30.0	22.0	13.8	46.0	169.9	12.6	1170.3
1961	62.9	21.5	147.3	210.2	46.4	42.3	22.1	14.8	9.3	33.3	98.8	6.9	715.8
1962	155.9	47.1	197.8	261.9	80.2	44.0	32.9	22.5	13.6	41.0	203.8	15.6	1116.3
1963	125.5	99.6	307.8	419.0	100.7	63.4	49.0	34.9	21.2	56.8	118.1	9.3	1405.3
1964	125.0	42.0	269.4	223.9	53.2	36.3	29.6	22.0	13.7	39.4	90.2	15.1	959.8
1965	96.7	55.2	302.0	293.4	71.1	44.7	34.0	23.4	14.6	37.2	80.4	21.1	1073.8
1966	194.0	40.1	249.7	201.5	49.5	33.0	25.8	18.7	11.9	37.4	83.0	17.7	962.3
1967	56.0	13.5	156.1	210.8	57.4	30.4	22.4	15.7	8.8	43.8	138.3	18.1	771.3
1968	155.9	47.1	197.8	261.9	80.2	44.0	32.9	22.5	13.6	41.0	203.8	15.6	1116.3
1969	66.1	43.1	370.7	298.6	71.4	43.4	32.9	23.1	13.6	52.0	247.0	25.7	1287.6
1970	181.6	69.9	333.3	190.3	61.5	39.4	30.0	22.0	13.8	46.0	169.9	12.6	1170.3
1971	62.9	21.5	147.3	210.2	46.4	42.3	22.1	14.8	9.3	33.3	98.8	6.9	715.8
1972	34.7	6.3	55.5	111.4	24.6	11.5	8.8	5.8	3.4	9.6	42.1	1.9	315.6
MEAN	109.8	43.8	239.0	242.1	61.6	38.8	28.7	20.3	12.4	39.6	127.2	14.4	977.8

Average flow : 31.0 m3/s

Source : E N E

TABLE 6

GOVE -- MONTHLY INFLOWS (M m3)

Total Basin = 4,811 Km2

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
1953	124.0	170.8	320.3	340.1	240.8	122.9	76.3	54.6	38.1	35.1	28.3	108.5	1659.8
1954	289.3	396.7	547.7	489.9	320.3	117.9	127.0	88.9	58.1	69.1	45.1	61.9	2611.9
1955	71.2	67.3	81.7	80.1	62.9	38.9	31.1	24.6	17.9	24.9	38.9	144.6	684.1
1956	284.2	279.9	289.3	275.0	217.0	94.9	71.2	49.6	34.0	26.8	25.9	32.1	1679.9
1957	61.9	144.7	263.6	214.9	88.9	46.9	36.2	31.9	27.0	32.1	53.9	130.2	1132.2
1958	170.6	149.3	189.1	140.0	61.9	36.0	31.1	20.6	14.0	12.3	31.9	71.2	928.0
1959	152.9	186.8	217.0	183.0	118.9	68.9	48.5	32.9	20.0	12.3	37.1	80.6	1158.9
1960	152.9	224.0	258.5	194.9	131.2	84.0	60.0	40.2	23.8	31.1	65.1	196.3	1462.0
1961	258.5	256.7	408.2	489.9	299.7	165.9	118.9	87.9	58.1	57.9	88.1	465.0	2754.8
1962	392.7	238.0	330.8	355.1	222.3	136.1	90.8	74.5	42.0	39.4	102.1	206.8	2230.6
1963	309.9	326.6	480.5	399.9	255.5	148.0	110.6	78.5	49.0	32.4	60.9	83.3	2335.1
1964	111.4	147.3	243.5	186.1	92.7	51.3	46.6	31.6	20.0	18.2	37.3	86.2	1072.2
1965	258.2	277.5	575.1	370.9	215.1	134.8	99.1	62.7	38.6	33.7	40.4	199.0	2305.1
1966	356.5	258.6	463.1	225.5	145.2	99.3	76.3	52.8	31.6	19.3	26.7	68.3	1823.2
1967	63.7	39.4	109.5	270.6	178.6	94.6	66.7	41.5	21.8	26.0	111.7	330.8	1354.9
1968	707.9	338.0	359.7	300.7	189.4	110.4	84.6	58.1	37.6	30.3	78.8	147.3	2442.8
1969	264.6	303.4	694.0	396.6	214.5	125.5	95.1	67.5	41.5	119.5	211.0	361.3	2894.5
1970	428.0	472.0	745.7	368.1	311.8	187.9	148.1	106.3	67.7	40.7	73.6	115.7	3065.6
1971	179.7	137.7	200.6	191.3	128.0	71.8	52.0	35.1	19.4	14.5	35.5	42.1	1107.7
1972	72.3	48.9	69.1	168.0	99.1	51.6	40.2	26.8	15.0	11.2	23.1	68.3	693.6
MEAN	235.5	223.2	342.3	282.0	179.7	99.4	75.5	53.3	33.8	34.3	60.8	150.0	1769.8

Average flow : 56.1 m3/s

Source : T H E M A G

TABLE 7

MATALA -- MONTHLY INFLOWS (M m3)

Total Basin = 28,037 Km2

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
1953	291.4	428.9	947.1	1040.2	604.8	293.2	179.2	123.7	78.0	68.3	112.0	255.8	4422.6
1954	810.2	1382.6	2363.4	1990.9	947.1	276.6	302.9	205.7	135.0	160.4	99.0	143.6	8817.4
1955	164.2	155.6	189.9	186.1	145.7	82.9	54.9	40.4	30.3	42.1	82.9	330.0	1505.0
1956	810.2	799.1	825.2	775.8	563.0	224.2	162.8	128.8	66.1	43.7	42.2	58.9	4500.0
1957	143.6	405.2	712.5	572.1	209.2	106.0	72.3	56.8	46.4	55.7	126.0	309.6	2815.4
1958	422.7	358.3	474.9	334.9	143.6	72.1	54.1	34.6	25.1	23.6	59.1	168.7	2171.7
1959	364.0	483.6	563.0	452.6	278.8	159.7	110.6	62.9	33.4	23.0	74.9	189.9	2796.4
1960	371.5	598.0	705.8	497.7	315.0	194.1	140.6	84.6	40.7	53.3	153.2	286.3	3440.8
1961	705.8	718.3	1392.0	1970.2	869.7	414.5	273.7	205.7	136.1	134.5	205.0	1742.8	8768.3
1962	1289.4	637.5	1032.5	1101.6	576.9	323.2	211.9	171.1	92.0	81.7	132.7	420.8	6071.3
1963	916.0	1014.6	1832.0	1363.4	697.7	359.5	261.9	184.0	112.0	102.3	143.3	174.1	7160.8
1964	294.6	350.5	884.4	540.4	223.9	142.8	116.5	82.5	46.7	47.7	72.3	172.8	2975.1
1965	544.3	757.9	1957.1	1275.8	564.6	286.4	227.1	166.3	114.8	108.2	74.9	600.8	6678.2
1966	1344.3	598.8	1191.6	571.3	323.0	204.5	162.0	116.2	74.1	70.4	82.9	205.2	4944.3
1967	133.1	122.9	140.1	659.4	394.8	159.9	118.4	84.1	51.8	48.7	222.7	1009.0	3144.9
1968	2376.3	861.0	947.6	827.4	430.7	244.2	188.6	137.9	93.8	62.9	117.7	265.2	6553.3
1969	410.3	538.5	1727.8	904.9	411.1	227.1	172.0	125.1	79.6	194.2	476.4	737.9	6004.9
1970	792.8	1172.1	2074.7	688.2	524.4	274.2	211.1	145.2	88.6	102.9	166.9	215.3	6456.4
1971	321.4	252.8	443.3	382.3	242.1	150.6	122.9	86.8	53.1	45.3	88.1	68.0	2256.7
1972	123.2	63.6	115.7	313.4	165.0	82.2	65.6	49.3	33.2	61.9	92.0	207.8	1372.9
MEAN	631.4	585.0	1026.0	822.4	431.6	213.9	160.4	114.6	71.6	76.5	131.2	378.1	4642.8

Average Flow : 147.2m3/s

Source : T H E M A G

MATALA -- MONTHLY INFLOWS (M m3)

Intermediate Basin = 23,226 Km2

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
1953	167.4	258.1	626.8	700.1	364.0	170.3	102.9	69.1	39.9	33.2	83.7	147.3	2762.8
1954	520.9	985.9	1815.7	1501.0	626.8	158.7	175.9	116.8	76.9	91.3	53.9	81.7	6205.5
1955	93.0	88.3	108.2	106.0	82.8	44.0	23.8	15.8	12.4	17.2	44.0	185.4	820.9
1956	526.0	519.2	535.9	500.8	346.0	129.3	91.6	79.2	32.1	16.9	16.3	26.8	2820.1
1957	81.7	260.5	448.9	357.2	120.3	59.1	36.1	24.9	19.4	23.6	72.1	179.4	1683.2
1958	252.1	209.0	285.8	194.9	81.7	36.1	23.0	14.0	11.1	11.3	27.2	97.5	1243.7
1959	211.1	296.8	346.0	269.6	159.9	90.8	62.1	30.0	13.4	10.7	37.8	109.3	1637.5
1960	218.6	374.0	447.3	302.8	183.8	110.1	80.6	44.4	16.9	22.2	88.1	90.0	1978.8
1961	447.3	461.6	983.8	1480.3	570.0	248.6	154.8	117.8	78.0	76.6	116.9	1277.8	6013.5
1962	896.7	399.5	701.7	746.5	354.6	187.1	121.1	96.6	50.0	42.3	30.6	214.0	3840.7
1963	606.1	688.0	1351.5	963.5	442.2	211.5	151.3	105.5	63.0	69.9	82.4	90.8	4825.7
1964	183.2	203.2	640.9	354.3	131.2	91.5	69.9	50.9	26.7	29.5	35.0	86.6	1902.9
1965	286.1	480.4	1382.0	904.9	349.5	151.6	128.0	103.6	76.2	74.5	34.5	401.8	4373.1
1966	987.8	340.2	728.5	345.8	177.8	105.2	85.7	63.4	42.5	51.1	56.2	136.9	3121.1
1967	69.4	83.5	30.6	388.8	216.2	65.3	51.7	42.6	30.0	22.7	111.0	678.2	1790.0
1968	1668.4	523.0	587.9	526.7	241.3	133.8	104.0	79.8	56.2	32.6	38.9	117.9	4110.5
1969	145.7	235.1	1033.8	508.3	196.6	101.6	76.9	57.6	38.1	74.7	265.4	376.6	3110.4
1970	364.8	700.1	1329.0	320.1	212.6	86.3	63.0	38.9	20.9	62.2	93.3	99.6	3390.8
1971	141.7	115.1	242.7	191.0	114.1	78.8	70.9	51.7	33.7	30.8	52.6	25.9	1149.0
1972	50.9	14.7	46.6	145.4	65.9	30.6	25.4	22.5	18.2	50.7	68.9	139.5	679.3
MEAN	395.9	361.8	683.7	540.4	251.9	114.5	84.9	61.3	37.8	42.2	70.4	228.1	2873.0

Average Flow : 91.1 m3/s

Source : T H E M A G

TABLE 8 --- RESERVOIRS' CHARACTERISTICS

HYDRO PROJECT	RIVER	TYPE	T V (Hm3)	D V (Hm3)	M. L. (m)	m. L. (m)	D. L. (m)	Level - Volume Function $L = Lo + \gamma x (V - Vo)^{\beta}$			
								Lo (m)	γ	Vo (Hm3)	β
LOW CAMBAMBE	KWANZA	RUN-OF-RIVER	20.10	19.10	102.00	101.00	16.00	101.00	1.00000	19.10	1.00000
HIGH CAMBAMBE	KWANZA	STORAGE	91.00	71.00	130.00	125.00	16.00	115.00	0.48293	38.90	0.87074
LOW CAPANDA	KWANZA	STORAGE	1409.00	1230.00	920.00	917.00	851.50	870.00	4.60000	279.00	0.33940
HIGH CAPANDA	KWANZA	STORAGE	4618.00	1230.00	950.00	917.00	851.50	870.00	4.60000	279.00	0.33940
CACOMBO	CATUMBELA	STORAGE	800.90	102.70	1390.00	1350.00	1315.00	1350.00	0.44018	102.70	0.69039
LOMAUN	CATUMBELA	RUN-OF-RIVER	20.50	20.00	1061.00	1060.00	873.00	1060.00	2.00000	20.00	1.00000
BIOPIO	CATUMBELA	RUN-OF-RIVER	20.50	20.00	135.00	134.00	106.00	134.00	2.00000	20.00	1.00000
GOVE	CUNENE	STORAGE	2574.10	210.00	1590.00	1564.30	1545.00	1563.00	0.38345	174.40	0.56208
MATALA	CUNENE	RUN-OF-RIVER	90.00	68.34	1305.65	1300.00	1283.00	1290.00	0.26083	30.00	1.00000

TABLE 9 --- EVAPORATION HEIGHTS (mm)

HYDRO PROJECT	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
CAPANDA	154.00	154.00	165.00	145.00	154.00	149.00	149.00	151.00	141.00	147.00	142.00	139.00
CAMBAMBE	174.00	173.00	169.00	139.00	132.00	108.00	104.00	116.00	145.00	155.00	158.00	158.00
CACOMBO	95.00	98.00	80.00	95.00	123.00	136.00	163.00	195.00	190.00	160.00	106.00	104.00
LOMAUM	148.00	149.00	118.00	111.00	139.00	134.00	146.00	166.00	175.00	162.00	139.00	144.00
BIOPIO	200.00	200.00	155.00	127.00	155.00	133.00	129.00	138.00	160.00	163.00	172.00	183.00
GOVE	147.00	147.00	128.00	161.00	224.00	252.00	290.00	352.00	348.00	222.00	166.00	150.00
MATALA	182.00	165.00	129.00	147.00	182.00	195.00	227.00	253.00	331.00	282.00	206.00	194.00

TABLE 10 ----- POWER STATIONS' CHARACTERISTICS

HYDRO PROJECT	RIVER	TYPE	N. of units	Hn,nom (m)	F (i) (m3/s)	F (a) (m3/s)	C (i) (MW)	C (a) (MW)
LOW CAMBAMBE	KWANZA	RUN OF RIVER	4	84.0	4 x 65.0=260.0	3 x 65.0=195.0	4 x 45.0=180.0	3 x 45.0=135.0
HIGH CAMBAMBE	KWANZA	STORAGE	4	110.0	4 x 75.0=300.0	3 x 75.0=225.0	4 x 65.0=260.0	3 x 65.0=195.0
HIGH CAMBAMBE - G 5	KWANZA	STORAGE	5	110.0	300+1 x 135.0=435.0	225+1 x 135.0=360.0	260+1 x 130.0=390.0	195+1 x 130.0=325.0
HIGH CAMBAMBE - G 6	KWANZA	STORAGE	6	110.0	300+2 x 135.0=570.0	300+2 x 135.0=570.0	260+2 x 130.0=520.0	195+2 x 130.0=455.0
LOW CAPANDA	KWANZA	STORAGE	4	66.8	4 x 171.4=685.6 a)		4 x 100.0=400.0 a)	
HIGH CAPANDA	KWANZA	STORAGE	4	80.0	4 x 187.5=750.0 a)		4 x 130.0=520.0 a)	
CACOMBO 2 nd phase	CATUMBELA	STORAGE	3	52.8	3 x 30.0=90.0	2 x 30.0=60.0	3 x 12.0=36.0	2 x 12.0=24.0
LOMAUN 1 st phase	CATUMBELA	RUN-OF-RIVER	3	182.2	3 x 10.5=31.5	2 x 10.5=21.0	3 x 15.0=45.0	2 x 15.0=30.0
LOMAUN 2 nd phase	CATUMBELA	RUN-OF-RIVER	5	182.2	3 x 10.5+2 x 7.0=45.5	3 x 10.5+1 x 7.0=38.5	3 x 15.0+2 x 10.0=65.0	3 x 15.0+1 x 10.0=55.0
BIOPIO	CATUMBELA	RUN-OF-RIVER	4	27.0	4 x 14.0=56.0	3 x 14.0=42.0	4 x 3.6=14.4	3 x 3.6=10.8
GOVE 2 nd phase	CUNENE	STORAGE	3	44.0	3 x 39.5=118.5	2 x 39.5=79.0	3 x 15.0=45.0	2 x 15.0=30.0
MATALA	CUNENE	RUN-OF-RIVER	3	19.8	3 x 79.0=237.0	2 x 79.0=158.0	3 x 13.6=40.8	2 x 13.6=27.2

a)It was assumed that CAPANDA's plant has the following maintenance outage rate : Jan.,Feb.,Dec.=0.050;other months =0.250
Hn,nom - Nominal net head
F - turbined water flow -(i) installed , (a) available
C - capacity -(i) installed , (a) available

T A B L E 11

DEMAND FORECAST a)

	HIGH SCENARIO			LOW SCENARIO		
YEAR	GENERATION (GWh)	GROWTH RATE (%)	CAPACITY (MW)	GENERATION (GWh)	GROWTH RATE (%)	CAPACITY (MW)
1989	695,2*			695,2*		
1990	730,0	5,0	132,3	727	4,61	131,8
1991	766,5	5,0	138,8	765	5,21	138,6
1992	820,2	7,0	148,6	807	5,51	146,3
1993	885,8	8,0	160,5	854	5,80	154,8
1994	974,4	10,0	176,5	904	5,31	163,8
1995	1091,3	12,0	197,7	959	6,12	173,8
1996	1222,2	12,0	221,4	1016	5,92	184,1
1997	1368,9	12,0	248,0	1073	6,26	194,5
1998	1519,4	11,0	275,3	1147	6,29	207,9
1999	1656,2	9,0	300,1	1220	6,32	221,1
2000	1788,8	8,0	324,1	1302	6,70	236,0
2001	1914,0	7,0	346,8	1367	6,55	247,7
2002	2048,0	7,0	371,1	1479	6,61	268,0
2003	2191,3	7,0	397,1	1577	6,67	285,0
2004	2344,8	7,0	424,9	1683	6,73	305,0
2005	2508,9	7,0	454,6	1791	6,40	324,6
2006	2659,4	6,0	481,9	1888	5,43	342,2
2007	2819,0	6,0	510,8	1985	5,10	359,7
2008	2988,1	6,0	541,4	2087	5,15	378,2
2009	3167,4	6,0	573,9	2186	4,77	396,2
2010	3357,5	6,0	608,4	2292	4,81	415,0
2011	3525,3	5,0	638,8	2403	4,84	435,5
2012	3701,6	5,0	670,7	2520	4,88	456,7
2013	3886,7	5,0	704,3	2644	4,92	479,2
2014	4081,0	5,0	739,5	2775	4,96	502,9
2015	4285,0	5,0	776,4	2914	5,00	528,1

a) At generation level
* Value actually verified
Load factor at generation: 0.63

T A B L E 12

CAPANDA INVESTMENT PROGRAM - ALT.I

(in thousands of USD)

CAPANDA	SUB-TOTAL	1985/88	1989	1990	1991	1992	1993	G1	G2	G3	G4
PLANNING/DESIGN	28,200	10,000	---	3.100	3,200	3,200	8,700				
SUBSTRUCTURE LUANDA	61.734	61,734									
SUBSTRUCTURE CAPANDA	100,407	53,706	16,572	8,645	7,529			13.955			
URBANIZATION	15,002							5,000	10,002		
REACTIVATION OF THE SITE								10.330	7,020	6,820	6,020
CIVIL CONSTRUCTION											
RIVER DIVERSION	14,459	7,185	7,197			77					
DAM	81,053	131	15,001	40,925	23.981	1,015					
WATERWAYS	29,468	39	2,532	21,873	3,376	1,048					
POWER STATION	23,086	1,837	2,873	8,327	8,461			794	794	794	794
SUBSTATION	15,793							7,793		8,000	
EQUIPMENTS											
TURBINES (2)	24,050		100					11,925	12,025	12,025	12,025
GENERATORS (2)	22,300							11.150	11.150	11,150	11,150
TRANSFORMERS (7)	5,400							3,085	2,315	2,315	2,315
SUBSTATION	17,800							8,900	8,900	8,900	8,900
GATES AND MECHAN. EQUIPMENT	68,100		100	7,400	56,000	4,600					
INSTALLATION AND TRANSPORTS	36,600		410	1,160	7,200	12.998		7,416	7,416	7,416	7,416
SERVICES TPE	16,800		9,300	2,300	1,900	800		1,600	1,600	1,600	1,600
SERV. FURNAS,INSURANCES,ETC	104,063	43,326	10,178	15,385	11,119	7,459		8,298	8,298	8,298	8,298
INDIRECT COSTS	484,156	305,862	54,889	51,009	33.526	7,792		23,387	7,691	7,691	7,691
T O T A L	1140,471*	483,820	119,152	160,124	156,192	38,989	8,700	113,633	77,211	75,009	66,209

* without REACTIVATION OF THE SITE

Source: GAMEK

T A B L E 13

CAPANDA INVESTMENT PROGRAM - ALT.II

(in thousands of USD)

CAPANDA	SUB-TOTAL	1985/88	1989	1990	1991	1992	1993	1994	G1	G2
PLANNING.DESIGN	23.200	10.000	---	3.100	3.200	3.200	3.700			
SUBSTRUCTURE LUANDA	61.734	61.734	---	---	---	---				
SUBSTRUCTURE CAPANDA	100.407	53.706	16.572	8,645	13.206	8,278				
URBANIZATION	15,002	---	---	---	4.358	10,644				
REACTIVATION OF THE SITE									6,020	6.020
CIVIL CONSTRUCTION										
RIVER DIVERSION	14,459	7,185	7.197	---	---	77				
DAM	81,053	131	16.001	40.925	23.981	1,015				
WATERWAYS	29,468	39	2.532	21,573	3.378	1,046				
POWER STATION	23,086	1,837	2.873	8,327	8,462	1.587			734	734
SUBSTATION	15.793	---	---	---	8.766	7,027				
EQUIPMENTS										
TURBINES (2)	24,350	---	100	50	300	22,100	1,000		12.025	12.025
GENERATORS (2)	22.300	---	---	---	20.600	1,700			11.150	11.150
TRANSFORMERS (7)	5,400	---	---	---	---	5.400			2.375	2,375
SUBSTATION	17,800	---	---	---	12.800	5.000			8.900	8.900
GATES	35.300	---	---	1,400	33.900	---				
MECHANICAL EQUIPMENT	13.800	---	---	3.800	10.000	---				
OTHER EQUIPMENT	19,000	---	100	2,200	12.100	4,500				
INSTALLATION	28,350	---	---	750	6.600	21.000			7.415	7.416
TRANSPORTS	8,250	---	410	410	2.310	5.120				
SERVICES TPE	16,800	---	9,300	2,300	1,900	1,700	1,600		1.600	1,600
SERV. FURNAS,INSURANCES,ETC	104,063	43,326	10,178	15.385	12.799	11,793	8,310	2.272	8.298	8,298
INDIRECT COSTS	484.156	305,862	54,989	51.009	42.625	24,542	5,228		7.591	7.591
T O T A L	1148,471	483.820	113.152	160,174	222.384	135,831	24,838	2.272	66.203	66,203

Source: GAMEK

TABLE 14

CAPANDA INVESTMENT PROGRAM - ALT.III

(in thousands of USD)

CAPANDA	SUB-TOTAL	1985/88	1989	1990	1991	1992	1993	G1	G2	HEIGTHNING OF THE DAM	G3	G4
PLANNING/DESIGN	28,200	10,000	---	3,100	3,200	3,200	8,700					
SUBSTRUCTURE LUANDA	61,734	61,734										
SUBSTRUCTURE CAPANDA	100,407	53,706	16,572	8,645	7,529			13,955				
URBANIZATION	15,002							5,000	10,002			
REACTIVATION OF THE SITE								10,330	7,020	5,520	6,820	6,020
CIVIL CONSTRUCTION												
RIVER DIVERSION	14,459	7,185	7,197			77						
DAM	81,053	131	15,001	40,925	8,496					16,500		
WATERWAYS	29,468	39	2,532	21,873	3,976	1,048						
POWER STATION	23,086	1,837	2,873	8,327	8,461			794	794		794	794
SUBSTATION	15,793							7,793			8,000	
EQUIPMENTS												
TURBINES (2)	24,050		100					11,925	12,025		12,025	12,025
GENERATORS (2)	22,300							11,150	11,150		11,150	11,150
TRANSFORMERS (7)	5,400							3,085	2,315		2,315	2,315
SUBSTATION	17,800							8,900	8,900		8,900	8,900
GATES AND MECHAN. EQUIPMENT	68,100		100	7,400	44,430	4,600				11,570		
INSTALLATION AND TRANSPORTS	36,600		410	1,160	7,200	9,296		7,416	7,416	3,702	7,416	7,416
SERVICES TPE	16,800		9,300	2,300	1,200	800		1,600	1,600		1,600	1,600
SERV. FURNAS,INSURANCES,ETC	104,063	43,326	10,178	15,385	8,200	5,459		8,298	8,298	4,319	8,298	8,298
INDIRECT COSTS	484,156	305,862	54,889	51,009	20,813	2,000		23,387	7,691	18,505	7,691	7,691
TOTAL	1140,471	483,820	119,152	160,124	113,505	26,480	8,700	113,633	77,211	60,716	75,009	66,209

* without REACTIVATION OF THE SITE

Source: GAMEK

TABLE 15 HIGH CAPANDA / HIGH SCENARIO -- ALT I . A

Year	GWh					MW					GENERATION (GWh)					
	Demand	FIRM ENERGY				Peak	FIRM CAPACITY				WITHOUT INTERCONNECTION			WITH INTERCONNECTION		
											CAMBAMBE			CAMBAMBE		
		CAM	CAP	GT	TOTAL		CAM	CAP	GT	TOTAL	TOTAL	D	CAPANDA	TOTAL	D	CAPANDA
1990	730	790			790	132.3	135			135						
1991	766	790			790	138.8	135		3.8	138.8						
1992	820	790		30	820	148.6	135		13.6	148.6						
1993	886	1080			1080	160.5	135		25.5	160.5	886					
1994	974	1080			1080	176.5	135		41.5	176.5	974					
1995	1091	1080		11	1091	197.7	135		50.0	185	1080					
1996	1222	1080	U1 1195		2275	221.4	135	125		260	553		669	696		714
1997	1369	1080	1195		2275	248.0	135	125		260	588		781	707		830
1998	1519	1080	1195		2275	275.3	135	125		260	626		893	718		965
1999	1656	1080	U2 2170		3250	300.1	135	250		385	568		1088	729		1112
2000	1789	1080	2170		3250	324.1	135	250		385	573		1216	740		1276
2001	1914	1080	2170		3250	346.8	135	250		385	578		1336	752		1415
2002	2048	1080	2170		3250	371.1	135	250		385	583		1465	764		1560
2003	2191	1080	2170		3250	397.1	135	250		385	588		1603	776		1720
2004	2345	1080	2170		3250	424.9	135	250		385	593		1752	788		1870
2005	2509	1080	U3 2350		3430	454.6	135	365		500	598		1911	800		2046
2006	2659	1080	2350		3430	481.9	135	365		500	683		1976	868		2133
2007	2819	1080	2350		3430	510.8	135	365		500	768		2050	941		2223
2008	2988	1080	2350		3430	541.4	135	365		500	853		2135	1021		2318
2009	3167	1080	U4 2450		3530	573.9	135	445		580	938		2229	1080		2416
2010	3358	1080	2450		3530	608.4	135	445		580	1025		2333	1080		2518
2011	3525	↑ 1385	2492		3877	638.8	195	445		640	1105	25	2420	1303	223	2625
2012	3702	1385	2492		3877	670.7	195	445		640	1191	111	2511	1385	305	2737
2013	3887	U5 1955	2935		4890	704.3	325	445		770	1284	204	2603	1532	452	2853
2014	4081	1955	2935		4890	739.5	325	445		770	1384	304	2697	1661	581	2974
2015	4285	1955	2935		4890	776.4	325	445		770	1492	412	2793	1800	720	3100
2016	4493	1955	2935		4890	814.7	325	445		770	1624	544	2869	1920	840	3253
2017	4714	U6 2440	2790		5230	855.4	455	445		900	1768	688	2946	2045	965	3400
2018	4946	2440	2790		5230	897.5	455	445		900	1924	844	3022	2180	1100	3400
2019	5190	2440	2790		5230	941.6	455	445		900	2094	1014	3096	2400	1320	3400
2020	5445	2440	2790		5230	987.8					2280	1200	3165	2642	1562	3400
2021	5713	2440	2790		5230	1036.4					2480	1400	3232	2908	1828	3400
2022	5994	2440	2790		5230	1087.4					2700	1620	3294	3200	2120	3400
2023	6289	2440	2790		5230	1140.9					2939	1859	3350	3200	2120	3400
2024	6600	2440	2790		5230	1197.0					3200	2120	3400	3200	2120	3400
2025	6925	2440	2790		5230	1255.9					3200	2120	3400	3200	2120	3400

↑ -- Heightening of dam

D -- Generation of 2ª Plant = Total-1080

TABLE 16 HIGH CAPANDA / HIGH SCENARIO -- ALT II . A

Year	Demand	GWh FIRM ENERGY CAM	CAP	GT	TOTAL	MW Peak	FIRM CAPACITY CAM	CAP	GT	TOTAL	GENERATION (GWh) WITHOUT INTERCONNECTION CAMBAMBE TOTAL	D	CAPANDA	WITH INTERCONNECTION CAMBAMBE TOTAL	D	CAPANDA
1990	730	790			790	132.3	135			135						
1991	766	790			790	138.8	135		3.8	138.8						
1992	820	790		30	820	148.6	135		13.6	148.6						
1993	886	1080	U1U2 -		1080	160.5	135		25.5	160.5	886		-			
1994	974	1080	-		1080	176.5	135		41.5	176.5	974		-			
1995	1091	1080	-	11	1091	197.7	135		50.0	185	1080		-			
1996	1222	1080	1195		2275	221.4	135	125		260	553		669			
1997	1369	1080	1195		2275	248.0	135	125		260	588		781			
1998	1519	1080	1195		2275	275.3	135	125		260	626		893			
1999	1656	1080	2170		3250	300.1	135	250		385	568		1088			
2000	1789	1080	2170		3250	324.1	135	250		385	573		1216			
2001	1914	1080	2170		3250	346.8	135	250		385	578		1336			
2002	2048	1080	2170		3250	371.1	135	250		385	583		1465			
2003	2191	1080	2170		3250	397.1	135	250		385	588		1603			
2004	2345	1080	2170		3250	424.9	135	250		385	593		1751			
2005	2509	1080	U3 2350		3430	454.6	135	365		500	598		1911			
2006	2659	1080	2350		3430	481.9	135	365		500	683		1976			
2007	2819	1080	2350		3430	510.8	135	365		500	768		2050			
2008	2988	1080	2350		3430	541.4	135	365		500	853		2135			
2009	3167	1080	U4 2450		3530	573.9	135	445		580	938		2229			
2010	3358	1080	2450		3530	609.4	135	445		580	1025		2333			
2011	3525	↑ 1385	2492		3877	638.8	195	445		640	1105	25	2420			
2012	3702	1385	2492		3877	670.7	195	445		640	1191	111	2511			
2013	3887	U5 1955	2935		4890	704.3	325	445		770	1284	204	2603			
2014	4081	1955	2935		4890	739.5	325	445		770	1384	304	2697			
2015	4285	1955	2935		4890	776.4	325	445		770	1492	412	2793			
2016	4493	1955	2935		4890	814.7	325	445		770	1624	544	2869			
2017	4714	U6 2440	2790		5230	855.4	455	445		900	1768	688	2946			
2018	4946	2440	2790		5230	897.5	455	445		900	1924	844	3022			
2019	5190	2440	2790		5230	941.6	455	445		900	2094	1014	3096			
2020	5445	2440	2790		5230	987.8					2280	1200	3165			
2021	5713	2440	2790		5230	1036.4					2480	1400	3232			
2022	5994	2440	2790		5230	1087.4					2700	1620	3294			
2023	6289	2440	2790		5230	1140.9					2939	1859	3350			
2024	6600	2440	2790		5230	1197.0					3200	2120	3400			
2025	6925	2440	2790		5230	1255.9					3200	2120	3400			

↑ -- Heightening of dam

D -- Generation of 2ª Plant = Total-1080

TABLE 17 LOW CAPANDA / HIGH SCENARIO -- ALT III . A

Year	GWh					MW					GENERATION (GWh)					
	Demand	FIRM ENERGY				Peak	FIRM CAPACITY				WITHOUT INTERCONNECTION			WITH INTERCONNECTION		
											CAMBAMBE			CAMBAMBE		
		CAM	CAP	GT	TOTAL		CAM	CAP	GT	TOTAL	TOTAL	D	CAPANDA	TOTAL	D	CAPANDA
1990	730	790			790	132.3	135			135						
1991	766	790			790	138.8	135		3.8	138.8						
1992	820	790		30	820	148.6	135		13.6	148.6						
1993	886	1080			1080	160.5	135		25.5	160.5	886					
1994	974	1080			1080	176.5	135		41.5	176.5	974					
1995	1091	1080		11	1091	197.7	135		50.0	185	1080					
1996	1222	1080	U1 795		1875	221.4	135	95		230	757		465			
1997	1369	1080	795		1875	248.0	135	95		230	848		521			
1998	1519	1080	U2 1450		2530	275.3	135	180		315	687		832			
1999	1656	1080	1450		2530	300.1	135	180		315	749		907			
2000	1789	1080	1450		2530	324.1	135	180		315	809		980			
2001	1914	1080	1450		2530	346.8	135	180		315	866		1048			
2002	2048	1080	∩ 2170		3250	371.1	135	250		385	583		1465			
2003	2191	1080	2170		3250	397.1	135	250		385	588		1603			
2004	2345	1080	2170		3250	424.9	135	250		385	593		1752			
2005	2509	1080	U3 2350		3430	454.6	135	365		500	598		1911			
2006	2659	1080	2350		3430	481.9	135	365		500	683		1976			
2007	2819	1080	2350		3430	510.8	135	365		500	768		2050			
2008	2988	1080	2350		3430	541.4	135	365		500	853		2135			
2009	3167	1080	U4 2450		3530	573.9	135	445		580	938		2229			
2010	3358	1080	2450		3530	608.4	135	445		580	1025		2333			
2011	3525	↑ 1385	2492		3877	638.8	195	445		640	1105	25	2420			
2012	3702	1385	2492		3877	670.7	195	445		640	1191	111	2511			
2013	3887	U5 1955	2935		4890	704.3	325	445		770	1284	204	2603			
2014	4081	1955	2935		4890	739.5	325	445		770	1384	304	2697			
2015	4285	1955	2935		4890	776.4	325	445		770	1492	412	2793			
2016	4493	1955	2935		4890	814.7	325	445		770	1624	544	2869			
2017	4714	U6 2440	2790		5230	855.4	455	445		900	1768	688	2946			
2018	4946	2440	2790		5230	897.5	455	445		900	1924	844	3022			
2019	5190	2440	2790		5230	941.6	455	445		900	2094	1014	3096			
2020	5445	2440	2790		5230	987.8					2280	1200	3165			
2021	5713	2440	2790		5230	1036.4					2480	1400	3232			
2022	5994	2440	2790		5230	1087.4					2700	1620	3294			
2023	6289	2440	2790		5230	1140.9					2939	1859	3350			
2024	6600	2440	2790		5230	1197.0					3200	2120	3400			
2025	6925	2440	2790		5230	1255.9					3200	2120	3400			

↑ e ∩ -- Heightening of dam

D - Generation of 2ª Plant = Total-1080

TABLE 18 HIGH CAPANDA / LOW SCENARIO -- ALT I. B

Year	GWh					MW					GENERATION (GWh)					
	Demand	FIRM ENERGY				Peak	FIRM CAPACITY				WITHOUT INTERCONNECTION			WITH INTERCONNECTION		
											CAMBAMBE			CAMBAMBE		
		CAM	CAP	GT	TOTAL		CAM	CAP	GT	TOTAL	TOTAL	D	CAPANDA	TOTAL	D	CAPANDA
1990	727	790			790	131.8	135			135						
1991	765	790			790	138.6	135		3.6	138.6						
1992	807	790		17	807	146.3	135		11.3	146.3						
1993	854	1080			1080	154.8	135		19.8	154.8	854					
1994	904	1080			1080	163.8	135		28.8	163.8	904					
1995	959	1080			1080	173.8	135		38.8	173.8	959					
1996	1016	1080			1080	184.1	135		49.1	184.1	1016					
1997	1073	1080			1080	194.5	135		50.0	185	1073					
1998	1147	1080	U1 1195		2275	207.9	135	125		260	520		627			
1999	1220	1080	1195		2275	221.1	135	125		260	537		683			
2000	1302	1080	1195		2275	236.0	135	125		260	573		729			
2001	1367	1080	1195		2275	247.7	135	125		260	588		779			
2002	1479	1080	1195		2275	268.0	135	125		260	621		858			
2003	1577	1080	1195		2275	285.0	135	125		260	663		914			
2004	1683	1080	U2 2170		3250	305.0	135	250		385	570		1113			
2005	1791	1080	2170		3250	324.6	135	250		385	574		1217			
2006	1888	1080	2170		3250	342.2	135	250		385	577		1311			
2007	1985	1080	2170		3250	359.7	135	250		385	581		1404			
2008	2087	1080	2170		3250	378.2	135	250		385	585		1502			
2009	2186	1080	2170		3250	396.2	135	250		385	589		1597			
2010	2292	1080	2170		3250	415.0	135	250		385	592		1700			
2011	2403	1080	U3 2350		3430	435.5	135	365		500	596		1807			
2012	2520	1080	2350		3430	456.7	135	365		500	600		1920			
2013	2644	1080	2350		3430	479.2	135	365		500	655		1989			
2014	2775	1080	2350		3430	502.9	135	365		500	715		2060			
2015	2914	1080	2350		3430	528.1	135	365		500	781		2133			
2016	3060	1080	2350		3430	554.6	135	365		500	853		2207			
2017	3216	1080	U4 2450		3530	582.8	135	445		580	931		2285			
2018	3380	1080	2450		3530	612.6	135	445		580	1017		2363			
2019	3554	↑ 1385	2492		3877	644.1	195	445		640	1110	30	2444			
2020	3738	1385	2492		3877	677.4	195	445		640	1212	132	2526			
2021	3934	U5 1955	2935		4890	713.0	325	445		770	1323	243	2611			
2022	4141	1955	2935		4890	750.5	325	445		770	1445	365	2696			
2023	4360	1955	2935		4890	790.2	325	445		770	1578	498	2782			
2024	4593	1955	2935		4890	832.4	325	445		770	1723	643	2870			
2025	4839	U6 2440	2790		5230	877.0	455	445		900	1882	802	2957			

↑ -- Heightening of dam

D -- Generation of 2ª Plant = Total-1080

TABLE 19 HIGH CAPANDA / LOW SCENARIO -- ALT II . B

Year	GWh					MW					GENERATION (GWh)					
	Demand	FIRM ENERGY				Peak	FIRM CAPACITY				WITHOUT INTERCONNECTION			WITH INTERCONNECTION		
											CAMBAMBE			CAMBAMBE		
		CAM	CAP	GT	TOTAL		CAM	CAP	GT	TOTAL	TOTAL	D	CAPANDA	TOTAL	D	CAPANDA
1990	727	790			790	131.8	135			135						
1991	765	790			790	138.6	135		3.6	138.6						
1992	807	790		17	807	146.3	135		11.3	146.3						
1993	854	1080	U1U2 -		1080	154.8	135		19.8	154.8	854		-			
1994	904	1080	-		1080	163.8	135		28.8	163.8	904		-			
1995	959	1080	-		1080	173.8	135		38.8	173.8	959		-			
1996	1016	1080	-		1080	184.1	135		49.1	184.1	1016		-			
1997	1073	1080	-		1080	194.5	135		50.0	185	1073		-			
1998	1147	1080	1195		2275	207.9	135	125		260	520		627			
1999	1220	1080	1195		2275	221.1	135	125		260	537		683			
2000	1302	1080	1195		2275	236.0	135	125		260	573		729			
2001	1367	1080	1195		2275	247.7	135	125		260	588		779			
2002	1479	1080	1195		2275	268.0	135	125		260	621		858			
2003	1577	1080	1195		2275	285.0	135	125		260	663		914			
2004	1683	1080	2170		3250	305.0	135	250		385	570		1113			
2005	1791	1080	2170		3250	324.6	135	250		385	574		1217			
2006	1888	1080	2170		3250	342.2	135	250		385	577		1311			
2007	1985	1080	2170		3250	359.7	135	250		385	581		1404			
2008	2087	1080	2170		3250	378.2	135	250		385	585		1502			
2009	2186	1080	2170		3250	396.2	135	250		385	589		1597			
2010	2292	1080	2170		3250	415.0	135	250		385	592		1700			
2011	2403	1080	U3 2350		3430	435.5	135	365		500	596		1807			
2012	2520	1080	2350		3430	456.7	135	365		500	600		1920			
2013	2644	1080	2350		3430	479.2	135	365		500	655		1989			
2014	2775	1080	2350		3430	502.9	135	365		500	715		2060			
2015	2914	1080	2350		3430	528.1	135	365		500	781		2133			
2016	3060	1080	2350		3430	554.6	135	365		500	853		2207			
2017	3216	1080	U4 2450		3530	582.8	135	445		580	931		2285			
2018	3380	1080	2450		3530	612.6	135	445		580	1017		2363			
2019	3554	↑ 1385	2492		3877	644.1	195	445		640	1110	30	2444			
2020	3738	1385	2492		3877	677.4	195	445		640	1212	132	2526			
2021	3934	U5 1955	2935		4890	713.0	325	445		770	1323	243	2611			
2022	4141	1955	2935		4890	750.5	325	445		770	1445	365	2696			
2023	4360	1955	2935		4890	790.2	325	445		770	1578	498	2782			
2024	4593	1955	2935		4890	832.4	325	445		770	1723	643	2870			
2025	4839	U6 2440	2790		5230	877.0	455	445		900	1882	802	2957			

↑ -- Heightening of dam

D -- Generation of 2ª Plant = Total-1080

TABLE 20 LOW CAPANDA / LOW SCENARIO -- ALT III . B

Year	Demand	GWh FIRM ENERGY				Peak (MW)	MW FIRM CAPACITY				GENERATION (GWh) WITHOUT INTERCONNECTION			GENERATION (GWh) WITH INTERCONNECTION		
		CAM	CAP	GT	TOTAL		CAM	CAP	GT	TOTAL	CAMBAMBE TOTAL	CAMBAMBE D	CAPANDA	CAMBAMBE TOTAL	CAMBAMBE D	CAPANDA
1990	727	790			790	131.8	135			135						
1991	765	790			790	138.6	135		3.6	138.6						
1992	807	790		17	807	146.3	135		11.3	146.3						
1993	854	1080			1080	154.8	135		19.8	154.8	854					
1994	904	1080			1080	163.8	135		28.8	163.8	904					
1995	959	1080			1080	173.8	135		38.8	173.8	959					
1996	1016	1080			1080	184.1	135		49.1	184.1	1016					
1997	1073	1080			1080	194.5	135		50.0	185	1073					
1998	1147	1080	U1 795		1875	207.9	135	95		230	711		436			
1999	1220	1080	795		1875	221.1	135	95		230	756		464			
2000	1302	1080	795		1875	236.0	135	95		230	807		495			
2001	1367	1080	795		1875	247.7	135	95		230	847		520			
2002	1479	1080	U2 1450		2530	268.0	135	180		315	669		810			
2003	1577	1080	1450		2530	285.0	135	180		315	713		864			
2004	1683	1080	1450		2530	305.0	135	180		315	761		922			
2005	1791	1080	1450		2530	324.6	135	180		315	810		981			
2006	1888	1080	1450		2530	342.2	135	180		315	854		1034			
2007	1985	1080	⋂ 2170		3250	359.7	135	250		385	581		1404			
2008	2087	1080	2170		3250	378.2	135	250		385	585		1502			
2009	2186	1080	2170		3250	396.2	135	250		385	589		1597			
2010	2292	1080	2170		3250	415.0	135	250		385	592		1700			
2011	2403	1080	U3 2350		3430	435.5	135	365		500	596		1807			
2012	2520	1080	2350		3430	456.7	135	365		500	600		1920			
2013	2644	1080	2350		3430	479.2	135	365		500	655		1989			
2014	2775	1080	2350		3430	502.9	135	365		500	715		2060			
2015	2914	1080	2350		3430	528.1	135	365		500	781		2133			
2016	3060	1080	2350		3430	554.6	135	365		500	853		2207			
2017	3216	1080	U4 2450		3530	582.8	135	445		580	931		2285			
2018	3380	1080	2450		3530	612.6	135	445		580	1017		2363			
2019	3554	↑ 1385	2492		3877	644.1	195	445		640	1110	30	2444			
2020	3738	1385	2492		3877	677.4	195	445		640	1212	132	2526			
2021	3934	U5 1955	2935		4890	713.0	325	445		770	1323	243	2611			
2022	4141	1955	2935		4890	750.5	325	445		770	1445	365	2696			
2023	4360	1955	2935		4890	790.2	325	445		770	1578	498	2782			
2024	4593	1955	2935		4890	832.4	325	445		770	1723	643	2870			
2025	4839	U6 2440	2790		5230	877.0	455	445		900	1882	802	2957			

↑ e ⋂ -- Heightening of dam

D - Generation of 2ª Plant = Total-1080

TABLE 21 -- SUMMARY OF THE EXPANTION OF THE N. E G. S.

Year	HIGH SCENARIO							LOW SCENARIO						
	GWh	ALT. I.A CAP	ALT. I.A CAM	ALT. II.A CAP	ALT. II.A CAM	ALT. III.A CAP	ALT. III.A CAM	GWh	ALT. I.B CAP	ALT. I.B CAM	ALT. II.B CAP	ALT. II.B CAM	ALT. III.B CAP	ALT. III.B CAM
1990	730							727						
1991	766							765						
1992	820							807						
1993	886			U1,U2				854			U1,U2			
1994	974							904						
1995	1091							959						
1996	1222	U1				U1		1016						
1997	1369							1073						
1998	1519					U2		1147	U1				U1	
1999	1656	U2						1220						
2000	1789							1302						
2001	1914							1367						
2002	2048					∩		1479					U2	
2003	2191							1577						
2004	2345							1683	U2					
2005	2509	U3		U3		U3		1791						
2006	2659							1888						
2007	2819							1985					∩	
2008	2988							2087						
2009	3167	U4		U4		U4		2186						
2010	3358							2292						
2011	3525		↑		↑		↑	2403	U3		U3		U3	
2012	3702							2520						
2013	3887		U5		U5		U5	2644						
2014	4081							2775						
2015	4285							2914						
2016	4493							3060						
2017	4714		U6		U6		U6	3216	U4		U4		U4	
2018	4946							3380						
2019	5190							3554		↑		↑		↑
2020	5445							3738						
2021	5713							3934		U5		U5		U5
2022	5994							4141						
2023	6289							4360						
2024	6600							4593						
2025	6925							4839		U6		U6		U6

M.USD -- c/kWh	ALT. I.A	ALT. II.A	ALT. III.A	ALT. I.B	ALT. II.B	ALT. III.B	Discount Rate
	1,347.9 -- 11,84	1,385.4 -- 12,17	1,326.9 -- 12,21	1,257.2 -- 16,99	1,321.6 -- 17,86	1,229.2 -- 17,91	10%
	1,324.9 -- 16,96	1,368.1 -- 17,51	1,301.5 -- 17,66	1,247.4 -- 25,68	1,318.1 -- 27,13	1,217.1 -- 27,50	12%
	1,319.8 -- 27,62	1,369.5 -- 28,66	1,294.0 -- 29,24	1,258.3 -- 44,85	1,335.2 -- 47,59	1,225.9 -- 49,29	15%

CAMBAMBE - COST ESTIMATES AND INVESTMENT PLANS

(Price system reference: end of 1989)

A - HEIGHTENING OF THE DAM

At prices of 1984 this work was estimated at 111.9 millions of USD (Study BEP, JUL/86).

Assuming an annual average growth of the civil construction costs of about 10%, at prices of the end of 1989 that cost will reach an ammount of 180.0 millions of USD (M.USD).

For a time of construction of 5 years the corresponding investment plan is:

YEAR	1	2	3	4	5
M.USD	27.0	45.0	45.0	45.0	18.0

B - NEW POWER STATION (1ST PHASE:Units U5 and U6 of 130 MW each one)

At prices of 1984 this work, then foreseen for the installation of two units of 110 MW each one, was estimated as follows (Study B.E.P., JUL/86):

Civil construction ... 79.45 M.USD

Equipments .... 142.91 M.USD

However the cost of the generating units seems to be very overenhanced (47% above the corresponding to the Capanda units); so, after the necessary adjusting that cost was fixed at 107.05 M.USD.

Assuming an annual average growth of the equipment costs of about 7% and taking in account the increase of the unitary capacity from 110 MW to 130 MW, at prices of the end of 1989 the cost of this new power station will reach the following values:

Civil construction .... 151.0 M.USD

Equipment .... 177.0 M.USD

Total .... 328.0 M.USD

For a time of construction of 5 years and the initial installation of only one unit, it results the following investment plan (in M.USD):

YEAR	1	2	3	4	5	6
Civil const.	22.0	38.0	38.0	38.0	15.0	
Equipment				42.5	42.5	G5

REMARK: As the inlet works of the new power station must be built during the heightening of the dam, the coresponding equipments, whose cost is estimated at 7.0 M.USD, will have to be installed until the end of that heightening.

So, a possible total investment plan is of the following type (in M.USD).

YEAR		1	2	3	4	5	6	7	8	?	?	?
Heightening	C.C.	27.0	45.0	45.0	45.0	18.0						
	EQ.				3.5	3.5						
New Power Station	C.C.			22.0	38.0	38.0	38.0	15.0				
	EQ.						42.5	42.5	G5	42.5	42.5	G6

TABLE 22

ALT. I. A

YEARS	INVESTMENT (millions USD)		O & M (millions USD)		GENERATION (GWh) Without interconnection		GENERATION (GWh) With interconnection	
	CAPANDA	CAMBAMBE	CAPANDA	CAMBAMBE	CAPANDA	CAMBAMBE	CAPANDA	CAMBAMBE
1985	91.0							
1986	111.0							
1987	181.0							
1988	100.8							
1989	119.2							
1990	160.2							
1991	156.2							
1992	39.0							
1993	8.7		2.0					
1994	59.4		2.0					
1995	54.2		2.0					
1996	U1		3.7		669		714	
1997	40.4		3.7		781		830	
1998	36.8		3.7		893		965	
1999	U2		5.5		1088		1112	
2000			5.5		1216		1276	
2001			5.5		1336		1415	
2002			5.5		1465		1560	
2003	39.2		5.5		1603		1720	
2004	35.8		5.5		1752		1870	
2005	U3		7.2		1911		2046	
2006		27.0	7.2		1976		2133	
2007	34.6	45.0	7.2		2050		2223	
2008	31.6	67.0	7.2		2135		2318	
2009	U4	86.5	8.9		2229		2416	
2010		59.5	8.9		2333		2518	
2011		↑ 80.5	8.9	2.0	2420	25	2625	223
2012		57.5	8.9	2.0	2511	111	2737	305
2013		U5	8.9	3.7	2603	204	2853	452
2014			8.9	3.7	2697	304	2974	581
2015		42.5	8.9	3.7	2793	412	3100	720
2016		42.5	8.9	3.7	2869	544	3253	840
2017		U6	8.9	5.5	2946	688	3400	965
2018			8.9	5.5	3022	844	3400	1100
2019			8.9	5.5	3096	1014	3400	1320
2020			8.9	5.5	3165	1200	3400	1562
2021			8.9	5.5	3232	1400	3400	1828
2022			8.9	5.5	3294	1620	3400	2120
2023			8.9	5.5	3350	1859	3400	2120
2024			8.9	5.5	3400	2120	3400	2120
2025			8.9	5.5	3400	2120	3400	2120
...			...	...	...	...	...	...
TOTAL	1299.1	508.0						

TABLE 23

ALT. II. A

YEARS	INVESTMENT (millions USD)		O & M (millions USD)		GENERATION (GWh)	
	CAPANDA	CAMBAMBE	CAPANDA	CAMBAMBE	CAPANDA	CAMBAMBE
1985	91.0					
1986	111.0					
1987	181.0					
1988	100.8					
1989	119.2					
1990	160.2					
1991	222.4					
1992	135.8					
1993	U1,U2 24.8		2.0			
1994	2.3		2.0			
1995			2.0			
1996			3.7		669	
1997			3.7		781	
1998			3.7		893	
1999			5.5		1088	
2000			5.5		1216	
2001			5.5		1336	
2002			5.5		1465	
2003	34.6		5.5		1603	
2004	31.6		5.5		1752	
2005	U3		7.2		1911	
2006		27.0	7.2		1976	
2007	34.6	45.0	7.2		2050	
2008	31.6	67.0	7.2		2135	
2009	U4	86.5	8.9		2229	
2010		59.5	8.9		2333	
2011		↑ 80.5	8.9	2.0	2420	25
2012		57.5	8.9	2.0	2511	111
2013		U5	8.9	3.7	2603	204
2014			8.9	3.7	2697	304
2015		42.5	8.9	3.7	2793	412
2016		42.5	8.9	3.7	2869	544
2017		U6	8.9	5.5	2946	688
2018			8.9	5.5	3022	844
2019			8.9	5.5	3096	1014
2020			8.9	5.5	3165	1200
2021			8.9	5.5	3232	1400
2022			8.9	5.5	3294	1620
2023			8.9	5.5	3350	1859
2024			8.9	5.5	3400	2120
2025			8.9	5.5	3400	2120
...			...	...	...	...
TOTAL	1280.9	508.0				

TABLE 24

ALT. III. A

YEARS	INVESTMENT (millions USD)		O & M (millions USD)		GENERATION (GWh)	
	CAPANDA	CAMBAMBE	CAPANDA	CAMBAMBE	CAPANDA	CAMBAMBE
1985	91.0					
1986	111.0					
1987	181.0					
1988	100.8					
1989	119.2					
1990	160.1					
1991	113.5					
1992	26.5					
1993	8.7		2.0			
1994	62.0		2.0			
1995	53.4		2.0			
1996	U1 36.8		3.7		465	
1997	38.6		3.7		521	
1998	U2		5.5		832	
1999			5.5		907	
2000	31.7		5.5		980	
2001	29.0		5.5		1048	
2002	∩		5.5		1465	
2003	39.2		5.5		1603	
2004	35.8		5.5		1752	
2005	U3		7.2		1911	
2006		27.0	7.2		1976	
2007	34.6	45.0	7.2		2050	
2008	31.6	67.0	7.2		2135	
2009	U4	86.5	8.9		2229	
2010		59.5	8.9		2333	
2011		↑ 80.5	8.9	2.0	2420	25
2012		57.5	8.9	2.0	2511	111
2013		U5	8.9	3.7	2603	204
2014			8.9	3.7	2697	304
2015		42.5	8.9	3.7	2793	412
2016		42.5	8.9	3.7	2869	544
2017		U6	8.9	5.5	2946	688
2018			8.9	5.5	3022	844
2019			8.9	5.5	3096	1014
2020			8.9	5.5	3165	1200
2021			8.9	5.5	3232	1400
2022			8.9	5.5	3294	1620
2023			8.9	5.5	3350	1859
2024			8.9	5.5	3400	2120
2025			8.9	5.5	3400	2120
...			...	...	...	...
TOTAL	1304.5	508.0				

TABLE 25

ALT. I. B

YEARS	INVESTMENT (millions USD)		O & M (millions USD)		GENERATION (GWh)	
	CAPANDA	CAMBAMBE	CAPANDA	CAMBAMBE	CAPANDA	CAMBAMBE
1985	91.0					
1986	111.0					
1987	181.0					
1988	100.8					
1989	119.2					
1990	160.2					
1991	156.2					
1992	39.0					
1993	8.7		2.0			
1994			2.0			
1995			2.0			
1996	59.4		2.0			
1997	54.2		2.0			
1998	U1		3.7		627	
1999			3.7		683	
2000			3.7		729	
2001			3.7		779	
2002	40.4		3.7		858	
2003	36.9		3.7		914	
2004	U2		5.5		1113	
2005			5.5		1217	
2006			5.5		1311	
2007			5.5		1404	
2008			5.5		1502	
2009	39.2		5.5		1597	
2010	35.8		5.5		1700	
2011	U3		7.2		1807	
2012			7.2		1920	
2013			7.2		1989	
2014		27.0	7.2		2060	
2015	34.6	45.0	7.2		2133	
2016	31.6	67.0	7.2		2207	
2017	U4	86.5	8.9		2285	
2018		59.5	8.9		2363	
2019		↑ 80.5	8.9	2.0	2444	30
2020		57.5	8.9	2.0	2526	132
2021		U5	8.9	3.7	2611	243
2022			8.9	3.7	2696	365
2023		42.5	8.9	3.7	2782	498
2024		42.5	8.9	3.7	2870	643
2025		U6	8.9	5.5	2957	802
2026			8.9	5.5	3027	976
2027			8.9	5.5	3098	1166
2028			8.9	5.5	3171	1374
2029			8.9	5.5	3245	1601
2030			8.9	5.5	3322	1849
2031			8.9	5.5	3400	2120
...			...	...	...	...
TOTAL	1299.2	508.0				

TABLE 26

ALT. II. B

YEARS	INVESTMENT (millions USD)		O & M (millions USD)		GENERATION (GWh)	
	CAPANDA	CAMBAMBE	CAPANDA	CAMBAMBE	CAPANDA	CAMBAMBE
1985	91.0					
1986	111.0					
1987	181.0					
1988	100.8					
1989	119.2					
1990	160.2					
1991	222.4					
1992	135.8					
1993	U1,U2 24.8		2.0			
1994	2.3		2.0			
1995			2.0			
1996			2.0			
1997			2.0			
1998			3.7		627	
1999			3.7		683	
2000			3.7		729	
2001			3.7		779	
2002			3.7		858	
2003			3.7		914	
2004			5.5		1113	
2005			5.5		1217	
2006			5.5		1311	
2007			5.5		1404	
2008			5.5		1502	
2009	34.6		5.5		1597	
2010	31.6		5.5		1700	
2011	U3		7.2		1807	
2012			7.2		1920	
2013			7.2		1989	
2014		27.0	7.2		2060	
2015	34.6	45.0	7.2		2133	
2016	31.6	67.0	7.2		2207	
2017	U4	86.5	8.9		2285	
2018		59.5	8.9		2363	
2019		↑ 80.5	8.9	2.0	2444	30
2020		57.5	8.9	2.0	2526	132
2021		U5	8.9	3.7	2611	243
2022			8.9	3.7	2696	365
2023		42.5	8.9	3.7	2782	498
2024		42.5	8.9	3.7	2870	643
2025		U6	8.9	5.5	2957	802
2026			8.9	5.5	3027	976
2027			8.9	5.5	3098	1166
2028			8.9	5.5	3171	1374
2029			8.9	5.5	3245	1601
2030			8.9	5.5	3322	1849
2031			8.9	5.5	3400	2120
...			...	...	...	...
TOTAL	1280.9	508.0				

TABLE 27

ALT. III. B

YEARS	INVESTMENT (millions USD)		O & M (millions USD)		GENERATION (GWh)	
	CAPANDA	CAMBAMBE	CAPANDA	CAMBAMBE	CAPANDA	CAMBAMBE
1985	91.0					
1986	111.0					
1987	181.0					
1988	100.8					
1989	119.2					
1990	160.1					
1991	113.5					
1992	26.5					
1993	8.7		2.0			
1994			2.0			
1995			2.0			
1996	59.4		2.0			
1997	54.2		2.0			
1998	U1		3.7		436	
1999			3.7		464	
2000	40.4		3.7		495	
2001	36.8		3.7		520	
2002	U2		5.5		810	
2003			5.5		864	
2004			5.5		922	
2005	31.7		5.5		981	
2006	29.0		5.5		1034	
2007	↑		5.5		1404	
2008			5.5		1502	
2009	39.2		5.5		1597	
2010	35.8		5.5		1700	
2011	U3		7.2		1807	
2012			7.2		1920	
2013			7.2		1989	
2014		27.0	7.2		2060	
2015	34.6	45.0	7.2		2133	
2016	31.6	67.0	7.2		2207	
2017	U4	86.5	8.9		2285	
2018		59.5	8.9		2363	
2019		↑ 80.5	8.9	2.0	2444	30
2020		57.5	8.9	2.0	2526	132
2021		U5	8.9	3.7	2611	243
2022			8.9	3.7	2696	365
2023		42.5	8.9	3.7	2782	498
2024		42.5	8.9	3.7	2870	643
2025		U6	8.9	5.5	2957	802
2026			8.9	5.5	3027	976
2027			8.9	5.5	3098	1166
2028			8.9	5.5	3171	1374
2029			8.9	5.5	3245	1601
2030			8.9	5.5	3322	1849
2031			8.9	5.5	3400	2120
...			...	...	...	...
TOTAL	1304.5	508.0				

TABLE 28

ALT. I. A
HIGH SCENARIO - Long Range Marginal Costs

OBS: -Values discounted to January . 1990
-Unit 1 of CAPANDA in January . 1996
-Heightening of CAMBAMBE dam in January . 2011
-Reference prices: end of 1989

		DISCOUNT RATE		
		10.0%	12.0%	15.0%
CAPANDA	Discounted costs (millions USD)			
	Investment	1229.9	1241.5	1268.3
	O & M	40.4	30.2	20.6
	Total	1270.3	1271.7	1288.9
	Total discounted generation (GWh)			
	Without interconnection	10088.3	7119.9	4495.3
	With Interconnection	10768.9	7609.7	4806.3
	Levelized generating cost (USD/kWh)			
	Without interconnection	0.1259	0.1786	0.2867
	With Interconnection	0.1180	0.1671	0.2682
CAMBAMBE	Discounted costs (millions USD)			
	Investment	71.8	49.9	29.4
	O & M	5.8	3.3	1.5
	Total	77.6	53.2	30.9
	Total discounted generation (GWh)			
	Without interconnection	1297.1	692.5	282.9
	With interconnection	1579.3	866.5	369.2
	Levelized generating cost (USD/kWh)			
	Without Interconnection	0.0598	0.0768	0.1092
	With Interconnection	0.0491	0.0614	0.0837
CAPANDA + CAMBAMBE	Discounted costs (millions USD)			
	Investment	1301.7	1291.4	1297.7
	O & M	46.2	33.5	22.1
	Total	1347.9	1324.9	1319.8
	Total discounted generation (GWh)			
	Without Interconnection	11385.4	7812.4	4778.2
	With Interconnection	12348.2	8476.2	5175.5
	Levelized generating cost (USD/kWh)			
	Without Interconnection	0.1184	0.1696	0.2762
	With Interconnection	0.1092	0.1563	0.2550

TABLE 29

ALT. II. A
HIGH SCENARIO - Long Range Marginal Costs

OBS: -Values discounted to January . 1990
-Units 1 and 2 of CAPANDA in Jan. 93 and Jul. 93
-Heightening of CAMBAMBE dam in January . 2011
-Reference prices: end of 1989

		DISCOUNT RATE 10.0%	DISCOUNT RATE 12.0%	DISCOUNT RATE 15.0%
CAPANDA	Discounted costs (millions USD)			
	Investment	1267.4	1284.7	1318.0
	O & M	40.4	30.2	20.6
	Total	1307.8	1314.9	1338.6
	Total discounted generation (GWh)	10088.3	7119.9	4495.3
	Levelized generating cost (USD/kWh)	0.1296	0.1847	0.2978
CAMBAMBE	Discounted costs (millions USD)			
	Investment	71.8	49.9	29.4
	O & M	5.8	3.3	1.5
	Total	77.6	53.2	30.9
	Total discounted generation (GWh)	1297.1	692.5	282.9
	Levelized generating cost (USD/kWh)	0.0598	0.0768	0.1092
CAPANDA + CAMBAMBE	Discounted costs (millions USD)			
	Investment	1339.2	1334.6	1347.4
	O & M	46.2	33.5	22.1
	Total	1385.4	1368.1	1369.5
	Total discounted generation (GWh)	11385.4	7812.4	4778.2
	Levelized generating cost (USD/kWh)	0.1217	0.1751	0.2866

TABLE 30

ALT. III. A
HIGH SCENARIO - Long Range Marginal Costs

OBS: -Values discounted to January . 1990
-Unit 1 of CAPANDA in January . 1996
-Heightening of CAPANDA dam in January . 2002
-Heightening of CAMBAMBE dam in January . 2011
-Reference prices: end of 1989

		DISCOUNT RATE		
		10.0%	12.0%	15.0%
CAPANDA	Discounted costs (millions USD)			
	Investment	1208.1	1217.4	1241.9
	O & M	41.2	30.9	21.2
	Total	1249.3	1248.3	1263.1
	Total discounted generation (GWh)	9567.8	6676.0	4143
	Levelized generating cost (USD/kWh)	0.1306	0.1870	0.3049
CAMBAMBE	Discounted costs (millions USD)			
	Investment	71.8	49.9	29.4
	O & M	5.8	3.3	1.5
	Total	77.6	53.2	30.9
	Total discounted generation (GWh)	1297.1	692.5	282.9
	Levelized generating cost (USD/kWh)	0.0598	0.0768	0.1092
CAPANDA + CAMBAMBE	Discounted costs (millions USD)			
	Investment	1279.9	1267.3	1271.3
	O & M	47.0	34.2	22.7
	Total	1326.9	1301.5	1294.0
	Total discounted generation (GWh)	10864.9	7368.5	4425.9
	Levelized generating cost (USD/kWh)	0.1221	0.1766	0.2924

TABLE 31

ALT. I. B
LOW SCENARIO - Long Range Marginal Costs

OBS: -Values discounted to January . 1990
-Unit 1 of CAPANDA in January . 1998
-Heightening of CAMBAMBE dam in January . 2019
-Reference prices: end of 1989

		DISCOUNT RATE		
		10.0%	12.0%	15.0%
CAPANDA	Discounted costs (millions USD)			
	Investment	1189.0	1202.1	1232.1
	O & M	32.2	23.8	16.1
	Total	1221.2	1225.9	1248.2
	Total discounted generation (GWh)	6748.4	4555.6	2704.2
	Levelized generating cost (USD/kWh)	0.1810	0.2691	0.4616
CAMBAMBE	Discounted costs (millions USD)			
	Investment	33.5	20.2	9.6
	O & M	2.5	1.3	0.5
	Total	36.0	21.5	10.1
	Total discounted generation (GWh)	649.6	302.6	101.2
	Levelized generating cost (USD/kWh)	0.0554	0.0711	0.0998
CAPANDA + CAMBAMBE	Discounted costs (millions USD)			
	Investment	1222.5	1222.3	1241.7
	O & M	34.7	25.1	16.6
	Total	1257.2	1247.4	1258.3
	Total discounted generation (GWh)	7398.0	4858.2	2805.4
	Levelized generating cost (USD/kWh)	0.1699	0.2568	0.4485

TABLE 32

ALT. II. B
LOW SCENARIO - Long Range Marginal Costs

OBS: -Values discounted to January . 1990
-Units 1 and 2 of CAPANDA in Jan. 93 and Jul. 93
-Heightening of CAMBAMBE dam in January . 2019
-Reference prices: end of 1989

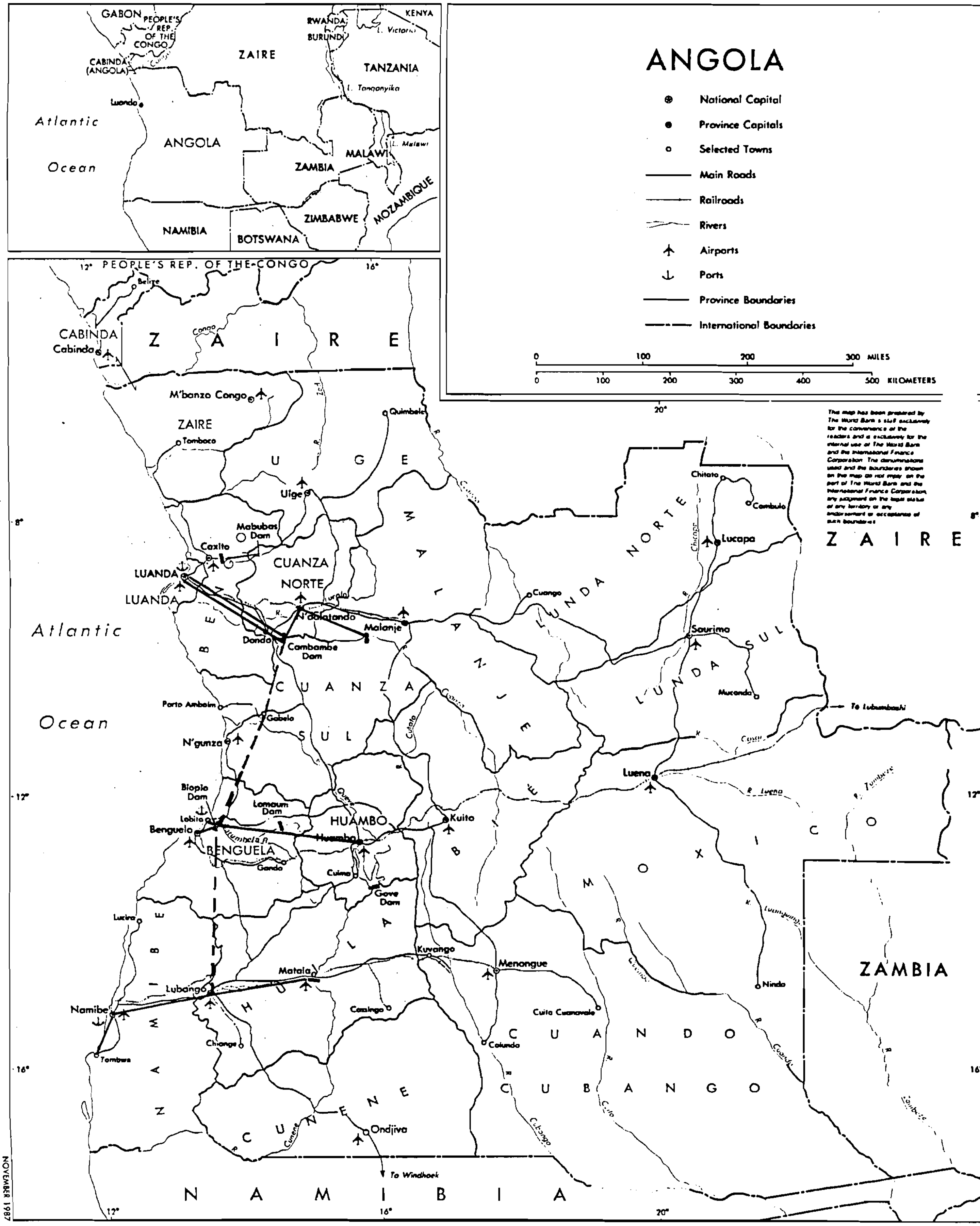
		DISCOUNT RATE		
		10.0%	12.0%	15.0%
CAPANDA	Discounted costs (millions USD)			
	Investment	1253.4	1272.8	1309.0
	O & M	32.2	23.8	16.1
	Total	1285.6	1296.6	1325.1
	Total discounted generation (GWh)	6748.4	4555.6	2704.2
	Levelized generating cost (USD/kWh)	0.1905	0.2846	0.4900
CAMBAMBE	Discounted costs (millions USD)			
	Investment	33.5	20.2	9.6
	O & M	2.5	1.3	0.5
	Total	36.0	21.5	10.1
	Total discounted generation (GWh)	649.6	302.6	101.2
	Levelized generating cost (USD/kWh)	0.0554	0.0711	0.0998
CAPANDA + CAMBAMBE	Discounted costs (millions USD)			
	Investment	1286.9	1293.0	1318.6
	O & M	34.7	25.1	16.6
	Total	1321.6	1318.1	1335.2
	Total discounted generation (GWh)	7398.0	4858.2	2805.4
	Levelized generating cost (USD/kWh)	0.1786	0.2713	0.4759

TABLE 33

ALT. III. B
LOW SCENARIO - Long Range Marginal Costs

OBS: -Values discounted to January . 1990
-Unit 1 of CAPANDA in January . 1998
-Heightening of CAPANDA dam in January . 2007
-Heightening of CAMBAMBE dam in January . 2019
-Reference prices: end 1989

		DISCOUNT RATE		
		10.0%	12.0%	15.0%
CAPANDA	Discounted costs (millions USD)			
	Investment	1159.9	1171.0	1199.1
	O & M	33.3	24.6	16.7
	Total	1193.2	1195.6	1215.8
	Total discounted generation (GWh)	6214.4	4123.6	2386.1
	Levelized generating cost (USD/kWh)	0.1920	0.2899	0.5095
CAMBAMBE	Discounted costs (millions USD)			
	Investment	33.5	20.2	9.6
	O & M	2.5	1.3	0.5
	Total	36.0	21.5	10.1
	Total discounted generation (GWh)	649.6	302.6	101.2
	Levelized generating cost (USD/kWh)	0.0554	0.0711	0.0998
CAPANDA + CAMBAMBE	Discounted costs (millions USD)			
	Investment	1193.4	1191.2	1208.7
	O & M	35.8	25.9	17.2
	Total	1229.2	1217.1	1225.9
	Total discounted generation (GWh)	6864.0	4426.2	2487.3
	Levelized generating cost (USD/kWh)	0.1791	0.2750	0.4929



220kV Transmission line for the interconnection of the Northern System to the Central and Southern Systems

TABLE 34

ANGOLA
C. E G. S. AND S. E G. S.
(expansions with interconnection)

C. E G. S.			1995	1998	2005	2010	2015
COMPONENT	DEMAND		255 Gwh	266 Gwh	638 Gwh	895 Gwh	1198 Gwh
HYDRO :							
CACOMBO						0 MW (R)	24 MW
LOMAUM			45 MW		65 MW		
BIOPIO			14.4 MW				
THERMAL :							
WITHOUT		A)		21.0Gwh (1.89 M USD)	117.9Gwh (11.12 M USD)		414.2Gwh (41.43 M USD)
INTERCONNECTION		B)		0.0 Mw	51.9Mw (3.27 M USD)		140.8Mw (8.87 M USD)
WITH		A)		0.0Gwh	13.9Gwh (1.27 M USD)		80.0Gwh (8.01 M USD)
INTERCONNECTION		B)		0.0 Mw	0.0Mw		56.1Mw (3.53 M USD)
S. E G. S.			**1995**	**1998**	**2005**	**2010**	**2015**
COMPONENT	DEMAND		115 Gwh	124 Gwh	237 Gwh	317 Gwh	405 Gwh
HYDRO :							
GOVE			0 MW (R)				45 MW
MATALA			40.8 MW				
THERMAL :							
WITHOUT		A)		0.0Gwh	94.0Gwh (10.03 M USD)		125.2Gwh (13.44 M USD)
INTERCONNECTION		B)		0.0 Mw	27.0Mw (1.70 M USD)		47.9Mw (3.02 M USD)
WITH		A)		0.0Gwh	0.0Gwh		17.6Gwh (1.89 M USD)
INTERCONNECTION		B)		0.0 Mw	0.0Mw		32.7Mw (2.06 M USD)
INTERCONNECTION VALUE (M USD)	C. E G. S.	A)		1.89-0.0=1.89	11.12-1.27=9.85		41.43-8.01=33.42
		B)		+ 0.0	+ 3.27-0.0=3.27		+ 8.87-3.53=5.34
				1.89	13.12		38.76
	S. E G. S.	A)		0.0	10.03-0.0=10.03		13.44-1.89= 11.55
		B)		+ 0.0	+ 1.70-0.0=1.70		+ 3.02-2.06=0.96
				0.0	11.73		12.51
	TOTAL			1.89+0.0=1.89	13.12+11.73 - 0.99* =23.86		38.76+12.51 - 3.61*=47.66

* Increase of NORTHERN SYSTEM's fuel costs due to the interconnection

[n n MW] Integration of the scheme in the system, with the indicated power output

(R) Only for regulating purposes

A) Generation at the average of the hydrological regimes and respective fuel costs

B) Emergency capacity necessary in new gas turbines during critical period (dec.1958) and corresponding annual charge (discount rate: 10%)

TABLE 35

ANGOLA
C.E.G.S. AND S.E.G.S.
(expansions with interconnection)

C.E.G.S.		1995	1996	2005	2010	2015
COMPONENT	DEMAND	255 Gwh	288 Gwh	838 Gwh	895 Gwh	1198 Gwh
HYDRO:						
CACOMBO					0 MW (R)	24 MW
LOMAUM		45 MW		65 MW		
BIOPIO		14.4 MW				
THERMAL:						
WITHOUT		A)	21.0Gwh (1.89 M USD)	117.9Gwh (11.12 M USD)		414.2Gwh (41.43 M USD)
INTERCONNECTION		B)	0.0 Mw	51.9Mw (3.79 M USD)		140.8Mw (10.28 M USD)
WITH		A)	0.0Gwh	13.9Gwh (1.27 M USD)		80.0Gwh (8.01 M USD)
INTERCONNECTION		B)	0.0 Mw	0.0Mw		56.1Mw (4.10 M USD)
S.E.G.S.		**1995**	**1996**	**2005**	**2010**	**2015**
COMPONENT	DEMAND	115 Gwh	124 Gwh	237 Gwh	317 Gwh	405 Gwh
HYDRO:						
GOVE		0 MW (R)				45 MW
MATALA		40.8 MW				
THERMAL:						
WITHOUT		A)	0.0Gwh	94.0Gwh (10.03 M USD)		125.2Gwh (13.44 M USD)
INTERCONNECTION		B)	0.0 Mw	27.0Mw (1.97 M USD)		47.9Mw (3.50 M USD)
WITH		A)	0.0Gwh	0.0Gwh		17.6Gwh (1.89 M USD)
INTERCONNECTION		B)	0.0 Mw	0.0Mw		32.7Mw (2.39 M USD)

			1996	2005	2015
INTERCONNECTION VALUE (M USD)	C.E.G.S.	A)	1.89-0.0=1.89	11.12-1.27=9.85	41.43-8.01=33.42
		B)	+ 0.0	+ 3.79-0.0=3.79	+10.28-4.10=6.18
			1.89	13.64	39.60
	S.E.G.S.	A)	0.0	10.03-0.0=10.03	13.44-1.89= 11.55
		B)	+ 0.0	+ 1.97-0.0=1.97	+ 3.50-2.39=1.11
			0.0	12.00	12.66
	TOTAL		1.89+0.0=1.89	13.64+12.00 - 0.99* =24.65	39.60+12.66 - 3.61*=48.65

* Increase of NORTHERN SYSTEM's fuel variable costs due to the interconnection

[n n MW] Integration of the scheme in the system, with the indicated power output

(R) Only for regulating purposes

A) Generation at the average of the hydrological regimes and respective fuel costs

B) Emergency capacity necessary in new gas turbines during critical period (dec. 58) and corresponding annual charge (discount rate: 12%)

TABLE 36

ANGOLA
C.E.G.S. AND S.E.G.S.
(expansions with interconnection)

C.E.G.S.			1995	1998	2005	2010	2015
COMPONENT	DEMAND		255 Gwh	286 Gwh	638 Gwh	895 Gwh	1198 Gwh
HYDRO :							
CACOMBO						0 MW (R)	24 MW
LOMAUM			45 MW		65 MW		
BIOPIO			14.4 MW				
THERMAL :							
WITHOUT		A)		21.0Gwh (1.89 M USD)	117.9Gwh (11.12 M USD)		414.2Gwh (41.43 M USD)
INTERCONNECTION		B)		0.0 Mw	51.9Mw (4.62 M USD)		140.8Mw (12.53 M USD)
WITH		A)		0.0Gwh	13.9Gwh (1.27 M USD)		80.0Gwh (8.01 M USD)
INTERCONNECTION		B)		0.0 Mw	0.0Mw		56.1Mw (4.99 M USD)
S.E.G.S.			**1995**	**1998**	**2005**	**2010**	**2015**
COMPONENT	DEMAND		115 Gwh	124 Gwh	237 Gwh	317 Gwh	405 Gwh
HYDRO :							
GOVE			0 MW (R)				45 MW
MATALA			40.8 MW				
THERMAL :							
WITHOUT		A)		0.0Gwh	94.0Gwh (10.03 M USD)		125.2Gwh (13.44 M USD)
INTERCONNECTION		B)		0.0 Mw	27.0Mw (2.40 M USD)		47.8Mw (4.28 M USD)
WITH		A)		0.0Gwh	0.0Gwh		17.6Gwh (1.89 M USD)
INTERCONNECTION		B)		0.0 Mw	0.0Mw		32.7Mw (2.91 M USD)
INTERCONNECTION VALUE (M USD)	C.E.G.S.	A)		1.89-0.0=1.89	11.12-1.27=9.85		41.43-8.01=33.42
		B)		+ 0.0	+ 4.62-0.0=4.62		+12.53-4.99=7.54
				1.89	14.47		40.96
	S.E.G.S.	A)		0.0	10.03-0.0=10.03		13.44-1.89= 11.55
		B)		+ 0.0	+ 2.40-0.0=2.40		+ 4.26-2.91=1.35
				0.0	12.43		12.90
	TOTAL			1.89+0.0=1.89	14.47+12.43 - 0.99* =25.91		40.96+12.90 - 3.61*=50.25

* Increase of NORTHERN SYSTEM's fuel costs due to the interconnection

[n n MW] Integration of the scheme in the system, with the indicated power output

(R) Only for regulating purposes

A) Generation at the average of the hydrological regimes and respective fuel costs

B) Emergency capacity necessary in new gas turbines during critical period (dec. 1958) and corresponding annual charge (discount rate: 15%)

The VALORAGUA model

The basic planning problem for an electric utility is to design a system so that it can be built and operated in the most economical manner and provide a satisfactory quality of service.

The optimal expansion of the electric power system is a multidimensional sequential decision problem and it requires the application of several models integrated in a global methodology.

The two great groups of models are classified, according to their main purposes, as following:

- "dynamic" models, aiming at the optimal expansion of the power system over time, thus joining investment and management decisions;
- "static" models whose purpose is the optimal management of the system operation once the investment decisions, and therefore the system composition, are known.

The VALORAGUA model, developed by Electricidade de Portugal, EDP, is included in the second group above referred to. It studies the optimal management of a predetermined power system configuration.

In an electric power system with significant hydroelectric regulation capabilities, the hydroelectric storage can be use to attenuate the seasonal flutuations of power demand or of water inflows by transferring water from periods with high inflows to periods of lower inflows, taking into account the expected power demand over those periods. So a decision of water release or water retention at a given period will have almost surely an instantaneous consequence in the reduction or increase of the operation costs, but also it will influence the operation in the future by the side of a modification of water available in the reservoirs in the future.

The VALORAGUA model allows an integrated management of a fixed hydrothermal power configuration whose objective is to find the most economical operation policy, taking into account the physical constraints and the random conditions of the system operation.

The model considers the possibility of transfer water from periods of high inflows to periods of lower inflows, introducing the idea of value of water (VALOR da ÁGUA) resulting from the arbitration between immediate gain (associated to an economy on fuel) and expectation of a future gain.

To achieve this goal the optimal management of the system requires the solution of two problems:

. **medium-term management of the water reservoirs**

It determines the so called cost-to-go functions, related to the value of stored water, using a stochastic dynamic programming algorithm; the hydroelectric subsystem is fully aggregated into an equivalent one.

. **Short-term management of hydro thermal system**

For each period it determines the final storage of each reservoir and the system generation schedule in order to minimize the sum of operation costs in that period with the expected value of future operation costs.
This is a non linear optimization problem, solved by an appropriated non linear programming algorithm.
The hydrothermal electric system is completely disaggregated.

The model analyses a period of one year for which the composition of the generation system is well defined.The year is divided in twelve periods being the month the unit of time considered for management purposes. The model simulates the optimized operation of the system using a hydrological time series of inflows at each hydro power station. The VALORAGUA model allows an integrated management of a hydro-thermal electric power system, making the link between the water management and the thermal operation, taking into account not only physical and technical characteristics of the system but also economic parameters and variables, mainly a careful calculation of economic dual variables: marginal generation cost and marginal value of water.

This detailed information on the economic behaviour of the system enables two important applications of the model: economic evaluation of hydroelectric schemes and optimization of some if its technical characteristics.

Other type of application is the studies on a simplified generation-transmission network enabling the delimitation of interesting areas for future power plants locations and the eventual need of extension of the transmission network.

The country is divided into several interconnected areas, each of them with its own generation plants and load demands. Those areas are symbolized by nodes linked by transmission lines, which are defined by means of loss coefficients depending on their physical characteristics and by power flow bounds.

The model determines the optimal generation dispatches and both electrical power and monetary flows between nodes.

Power flows from nodes with lower generation costs to nodes with higher ones. So when marginal costs of those nodes are closer, less power flows between electrical nodes occurs.

TABLE 1

DEMAND FORECAST a)

HIGH SCENARIO

	SYSTEMS								
	NORTHERN Load Factor : 0.63			CENTRAL Load Factor : 0.624			SOUTHERN Load Factor : 0.57		
YEAR	Energy (GWh)	Growth rate (%)	Capacity (MW)	Energy (GWh)	Growth rate (%)	Capacity (MW)	Energy (GWh)	Growth rate (%)	Capacity (MW)
1987				↖ 108.5		20	↖ 62		12
1988	↖			112	3.0	20	63	1.0	13
1989	695		126	120	7.0	22	64	3.0	13
1990	730	5.0	132	133	11.0	24	68	5.0	14
1991	766	5.0	139	149	12.0	27	73	8.0	15
1992	820	7.0	149	169	13.0	31	80	10.0	16
1993	886	8.0	160	193	15.0	35	90	12.0	18
1994	974	10.0	177	222	15.0	41	104	15.0	21
1995	1091	12.0	198	255	15.0	47	115	11.0	23
1996	1222	12.0	221	286	12.0	52	124	8.0	25
1997	1369	12.0	248	320	12.0	59	134	8.0	27
1998	1519	11.0	275	359	12.0	66	145	8.0	29
1999	1656	9.0	300	398	11.0	73	156	8.0	31
2000	1789	8.0	324	434	9.0	79	169	8.0	34
2001	1914	7.0	347	469	8.0	86	181	7.0	36
2002	2048	7.0	371	507	8.0	93	194	7.0	39
2003	2191	7.0	397	547	8.0	100	207	7.0	41
2004	2345	7.0	425	591	8.0	108	222	7.0	44
2005	2509	7.0	455	638	8.0	117	237	7.0	47
2006	2659	6.0	482	683	7.0	125	251	6.0	50
2007	2819	6.0	511	731	7.0	134	266	6.0	53
2008	2988	6.0	541	782	7.0	143	282	6.0	56
2009	3167	6.0	574	836	7.0	153	299	6.0	60
2010	3357	6.0	608	895	7.0	164	317	6.0	63
2011	3525	5.0	639	949	6.0	174	333	5.0	67
2012	3701	5.0	671	1006	6.0	184	350	5.0	70
2013	3886	5.0	704	1066	6.0	195	367	5.0	73
2014	4081	5.0	739	1130	6.0	207	386	5.0	77
2015	4285	5.0	776	1198	6.0	219	405	5.0	81

a) At generation level

↖ Value actually verified

TABLE 2

C.E.G.S. of ANGOLA

EXPANSION WITHOUT INTERCONNECTION

		1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
	DEMAND (GWh)		255	286	320	359	398	434	469	507	547	591	638
Average	CACOMBO		—	—	—	—	—	R	R	R	90	83	95
	LOMAUM		181	200	260	292	323	348	372	377	362	376	392
	BIOPIO		62	65	50	56	62	70	72	75	70	74	78
	Thermal Units		12	21	10	11	13	16	25	55	25	48	73
Dry Year (1958)	CACOMBO		—	—	—	—	—	0	0	0	60	52	42
	LOMAUM		153	164	190	190	190	348	370	299	378	384	352
	BIOPIO		44	44	40	40	40	70	73	64	69	69	70
	Thermal Units		58	78	90	129	168	16	26	144	42	106	174
	DEMAND (MW)		47	52	59	68	73	79	86	93	100	108	117
Dec. 58	CACOMBO		—	—	—	—	—	0	0	0	7.6	4.8	2.0
	LOMAUM		19.2	22.9	30.0	30.0	30.0	55.0	53.3	32.5	55.0	40.8	26.5
	BIOPIO		5.0	6.3	6.0	6.0	6.0	10.8	9.9	6.5	10.8	7.9	5.0
	Thermal Units		22.8	22.8	23.0	30.0	37.0	13.2	22.8	54.0	26.6	54.5	83.5

COMPONENTS

	1994	1995–1996	1996	1997	2001–2002
THERMAL	Biopio(GT) 22.8MW Huambo(GT) 10.0MW Lobito(D) 20.0MW		GT +25MW	GT +30MW	
HYDRO	Lomaum 45 MW(I) 30 MW(a) Biopio 14.4 MW(I) 10.8 MW(a)	Lomaum 65 MW(I) 55 MW(a) Biopio 14.4 MW(I) 10.8 MW(a)			Cacombo 24 MW(I) 12 MW(a) Lomaum 65 MW(I) 55 MW(a) Biopio 14.4 MW(I) 10.8 MW(a)

R - Only for regulating purposes
(I) - Installed
(a) - available

TABLE 3

S.E.G.S. of ANGOLA

EXPANSION WITHOUT INTERCONNECTION

		1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
	DEMAND (GWh)	115	124	134	145	156	169	181	194	207	222	237
Average	GOVE	R	R	R	R	53	57	63	69	90	97	105
Average	MATALA	115	124	134	143	103	112	117	122	117	125	128
Average	Thermal Units	0	0	0	2	0	0	1	2.5	0	0	4
Dry Year (1958)	GOVE	R	R	R	R	58	63	74	79	85	93	95
Dry Year (1958)	MATALA	115	124	134	134	98	106	105	105	122	129	130
Dry Year (1958)	Thermal Units	0	0	0	11	0	0	2	10	0	0	12
	DEMAND (MW)	23.0	25.0	27.0	29.0	31.0	34.0	36.0	39.0	41.0	44.0	47.0
Dec. 58	GOVE	0	0	0	0	10.6	11.6	11.0	11.0	19.5	20.0	18.6
Dec. 58	MATALA	23.0	25.0	27.0	19.8	20.4	22.4	21.0	21.0	21.5	24.0	24.1
Dec. 58	Thermal Units	0	0	0	9.2	0	0	4.0	7.0	0	0	4.3

COMPONENTS	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
THERMAL	Namibe(D) 11.5MW											
HYDRO	Matala - 40.8 MW(I) - 27.2 MW(a)				Gove - 30 MW(I) - 15 MW(a)				Gove - 45 MW(I) - 30 MW(a)			

R - Only for regulating purposes
(I) - Installed
(a) - available

TABLE 4

INVESTMENTS
(M. USD)

	C. E G. S.			S. E G. S.	
	WITH INTERCONNECTION	WITHOUT INTERCONNECTION		WITH INTERCONNECTION	WITHOUT INTERCONNECTION
1992					
1993		CACOMBO	GAS TURBINES		
1994		15.0			
1995		22.5	5.5		
1996		30.0	12.1		GOVE
1997		30.0	6.6 25 MW		20.0
1998		30.0	30 MW		20.0
1999		22.5			Plant 30 MW
2000		Dam 16.0			
2001		16.0			
2002		16.0			20.0
2003	CACOMBO	Plant 24 MW			Plant 45 MW
2004	15.0				
2005	22.5				
2006	30.0	Study horizon			Study horizon
2007	30.0				
2008	30.0				
2009	22.5				
2010	Dam				
2011				GOVE	
2012	16.0			20.0	
2013	16.0			20.0	
2014	16.0			20.0	
2015	Plant 24 MW			Plant 45 MW	
	Study horizon			Study horizon	

INVESTIMENT COSTS DISCOUNTED TO THE BEGINNING OF 1995

Discount rate	C.E.G.S. With interconnection	C.E.G.S. Without interconnection	S.E.G.S. With interconnection	S.E.G.S. Without interconnection
10%	55.7	169.9	10.3	39.9
12%	44.2	162.3	7.4	37.1
15%	31.6	152.1	4.6	33.4

TABLE 23

ALT. II. A

YEARS	INVESTMENT (millions USD)		O & M (millions USD)		GENERATION (GWh)	
	CAPANDA	CAMBAMBE	CAPANDA	CAMBAMBE	CAPANDA	CAMBAMBE
1985	91.0					
1986	111.0					
1987	181.0					
1988	100.8					
1989	119.2					
1990	160.2					
1991	222.4					
1992	135.8					
1993	U1,U2 24.8		2.0			
1994	2.3		2.0			
1995			2.0			
1996			3.7		669	
1997			3.7		781	
1998			3.7		893	
1999			5.5		1088	
2000			5.5		1216	
2001			5.5		1336	
2002			5.5		1465	
2003	34.6		5.5		1603	
2004	31.6		5.5		1752	
2005	U3		7.2		1911	
2006		27.0	7.2		1976	
2007	34.6	45.0	7.2		2050	
2008	31.6	67.0	7.2		2135	
2009	U4	86.5	8.9		2229	
2010		59.5	8.9		2333	
2011		↑ 80.5	8.9	2.0	2420	25
2012		57.5	8.9	2.0	2511	111
2013		U5	8.9	3.7	2603	204
2014			8.9	3.7	2697	304
2015		42.5	8.9	3.7	2793	412
2016		42.5	8.9	3.7	2869	544
2017		U6	8.9	5.5	2946	688
2018			8.9	5.5	3022	844
2019			8.9	5.5	3096	1014
2020			8.9	5.5	3165	1200
2021			8.9	5.5	3232	1400
2022			8.9	5.5	3294	1620
2023			8.9	5.5	3350	1859
2024			8.9	5.5	3400	2120
2025			8.9	5.5	3400	2120
...			...	...	...	...
TOTAL	1280.9	508.0				

TABLE 24

ALT. III. A

YEARS	INVESTMENT (millions USD)		O & M (millions USD)		GENERATION (GWh)	
	CAPANDA	CAMBAMBE	CAPANDA	CAMBAMBE	CAPANDA	CAMBAMBE
1985	91.0					
1986	111.0					
1987	181.0					
1988	100.8					
1989	119.2					
1990	160.1					
1991	113.5					
1992	26.5					
1993	8.7		2.0			
1994	62.0		2.0			
1995	53.4		2.0			
1996	U1 36.8		3.7		465	
1997	38.6		3.7		521	
1998	U2		5.5		832	
1999			5.5		907	
2000	31.7		5.5		980	
2001	29.0		5.5		1048	
2002	∩		5.5		1465	
2003	39.2		5.5		1603	
2004	35.8		5.5		1752	
2005	U3		7.2		1911	
2006		27.0	7.2		1976	
2007	34.6	45.0	7.2		2050	
2008	31.6	67.0	7.2		2135	
2009	U4	86.5	8.9		2229	
2010		59.5	8.9		2333	
2011		↑ 80.5	8.9	2.0	2420	25
2012		57.5	8.9	2.0	2511	111
2013		U5	8.9	3.7	2603	204
2014			8.9	3.7	2697	304
2015		42.5	8.9	3.7	2793	412
2016		42.5	8.9	3.7	2869	544
2017		U6	8.9	5.5	2946	688
2018			8.9	5.5	3022	844
2019			8.9	5.5	3096	1014
2020			8.9	5.5	3165	1200
2021			8.9	5.5	3232	1400
2022			8.9	5.5	3294	1620
2023			8.9	5.5	3350	1859
2024			8.9	5.5	3400	2120
2025			8.9	5.5	3400	2120
...			...	...	...	...
TOTAL	1304.5	508.0				

TABLE 25

ALT. I. B

YEARS	INVESTMENT (millions USD)		O & M (millions USD)		GENERATION (GWh)	
	CAPANDA	CAMBAMBE	CAPANDA	CAMBAMBE	CAPANDA	CAMBAMBE
1985	91.0					
1986	111.0					
1987	181.0					
1988	100.8					
1989	119.2					
1990	160.2					
1991	156.2					
1992	39.0					
1993	8.7		2.0			
1994			2.0			
1995			2.0			
1996	59.4		2.0			
1997	54.2		2.0			
1998	U1		3.7		627	
1999			3.7		683	
2000			3.7		729	
2001			3.7		779	
2002	40.4		3.7		858	
2003	36.9		3.7		914	
2004	U2		5.5		1113	
2005			5.5		1217	
2006			5.5		1311	
2007			5.5		1404	
2008			5.5		1502	
2009	39.2		5.5		1597	
2010	35.8		5.5		1700	
2011	U3		7.2		1807	
2012			7.2		1920	
2013			7.2		1989	
2014		27.0	7.2		2060	
2015	34.6	45.0	7.2		2133	
2016	31.6	67.0	7.2		2207	
2017	U4	86.5	8.9		2285	
2018		59.5	8.9		2363	
2019		↑ 80.5	8.9	2.0	2444	30
2020		57.5	8.9	2.0	2526	132
2021		U5	8.9	3.7	2611	243
2022			8.9	3.7	2696	365
2023		42.5	8.9	3.7	2782	498
2024		42.5	8.9	3.7	2870	643
2025		U6	8.9	5.5	2957	802
2026			8.9	5.5	3027	976
2027			8.9	5.5	3098	1166
2028			8.9	5.5	3171	1374
2029			8.9	5.5	3245	1601
2030			8.9	5.5	3322	1849
2031			8.9	5.5	3400	2120
...			...	...	...	...
TOTAL	1299.2	508.0				

TABLE 26

ALT. II. B

YEARS	INVESTMENT (millions USD)		O & M (millions USD)		GENERATION (GWh)	
	CAPANDA	CAMBAMBE	CAPANDA	CAMBAMBE	CAPANDA	CAMBAMBE
1985	91.0					
1986	111.0					
1987	181.0					
1988	100.8					
1989	119.2					
1990	160.2					
1991	222.4					
1992	135.8					
1993	U1,U2 24.8		2.0			
1994	2.3		2.0			
1995			2.0			
1996			2.0			
1997			2.0			
1998			3.7		627	
1999			3.7		683	
2000			3.7		729	
2001			3.7		779	
2002			3.7		858	
2003			3.7		914	
2004			5.5		1113	
2005			5.5		1217	
2006			5.5		1311	
2007			5.5		1404	
2008			5.5		1502	
2009	34.6		5.5		1597	
2010	31.6		5.5		1700	
2011	U3		7.2		1807	
2012			7.2		1920	
2013			7.2		1989	
2014		27.0	7.2		2060	
2015	34.6	45.0	7.2		2133	
2016	31.6	67.0	7.2		2207	
2017	U4	86.5	8.9		2285	
2018		59.5	8.9		2363	
2019		↑ 80.5	8.9	2.0	2444	30
2020		57.5	8.9	2.0	2526	132
2021		U5	8.9	3.7	2611	243
2022			8.9	3.7	2696	365
2023		42.5	8.9	3.7	2782	498
2024		42.5	8.9	3.7	2870	643
2025		U6	8.9	5.5	2957	802
2026			8.9	5.5	3027	976
2027			8.9	5.5	3098	1166
2028			8.9	5.5	3171	1374
2029			8.9	5.5	3245	1601
2030			8.9	5.5	3322	1849
2031			8.9	5.5	3400	2120
...			...	...	...	...
TOTAL	1280.9	508.0				

TABLE 27

ALT. III. B

YEARS	INVESTMENT (millions USD)		O & M (millions USD)		GENERATION (GWh)	
	CAPANDA	CAMBAMBE	CAPANDA	CAMBAMBE	CAPANDA	CAMBAMBE
1985	91.0					
1986	111.0					
1987	181.0					
1988	100.8					
1989	119.2					
1990	160.1					
1991	113.5					
1992	26.5					
1993	8.7		2.0			
1994			2.0			
1995			2.0			
1996	59.4		2.0			
1997	54.2		2.0			
1998	U1		3.7		436	
1999			3.7		464	
2000	40.4		3.7		495	
2001	36.8		3.7		520	
2002	U2		5.5		810	
2003			5.5		864	
2004			5.5		922	
2005	31.7		5.5		981	
2006	29.0		5.5		1034	
2007	∩		5.5		1404	
2008			5.5		1502	
2009	39.2		5.5		1597	
2010	35.8		5.5		1700	
2011	U3		7.2		1807	
2012			7.2		1920	
2013			7.2		1989	
2014		27.0	7.2		2060	
2015	34.6	45.0	7.2		2133	
2016	31.6	67.0	7.2		2207	
2017	U4	86.5	8.9		2285	
2018		59.5	8.9		2363	
2019		↑ 80.5	8.9	2.0	2444	30
2020		57.5	8.9	2.0	2526	132
2021		U5	8.9	3.7	2611	243
2022			8.9	3.7	2696	365
2023		42.5	8.9	3.7	2782	498
2024		42.5	8.9	3.7	2870	643
2025		U6	8.9	5.5	2957	802
2026			8.9	5.5	3027	976
2027			8.9	5.5	3098	1166
2028			8.9	5.5	3171	1374
2029			8.9	5.5	3245	1601
2030			8.9	5.5	3322	1849
2031			8.9	5.5	3400	2120
...			...	...	...	...
TOTAL	1304.5	508.0				

TABLE 28

ALT. I. A
HIGH SCENARIO - Long Range Marginal Costs

OBS: -Values discounted to January . 1990
-Unit 1 of CAPANDA in January . 1996
-Heightening of CAMBAMBE dam in January . 2011
-Reference prices: end of 1989

		DISCOUNT RATE		
		10.0%	12.0%	15.0%
CAPANDA	Discounted costs (millions USD)			
	Investment	1229.9	1241.5	1268.3
	O & M	40.4	30.2	20.6
	Total	1270.3	1271.7	1288.9
	Total discounted generation (GWh)			
	Without interconnection	10088.3	7119.9	4495.3
	With Interconnection	10768.9	7609.7	4806.3
	Levelized generating cost (USD/kWh)			
	Without interconnection	0.1259	0.1786	0.2867
	With Interconnection	0.1180	0.1671	0.2682
CAMBAMBE	Discounted costs (millions USD)			
	Investment	71.8	49.9	29.4
	O & M	5.8	3.3	1.5
	Total	77.6	53.2	30.9
	Total discounted generation (GWh)			
	Without interconnection	1297.1	692.5	282.9
	With interconnection	1579.3	866.5	369.2
	Levelized generating cost (USD/kWh)			
	Without Interconnection	0.0598	0.0768	0.1092
	With Interconnection	0.0491	0.0614	0.0837
CAPANDA + CAMBAMBE	Discounted costs (millions USD)			
	Investment	1301.7	1291.4	1297.7
	O & M	46.2	33.5	22.1
	Total	1347.9	1324.9	1319.8
	Total discounted generation (GWh)			
	Without Interconnection	11385.4	7812.4	4778.2
	With Interconnection	12348.2	8476.2	5175.5
	Levelized generating cost (USD/kWh)			
	Without Interconnection	0.1184	0.1696	0.2762
	With Interconnection	0.1092	0.1563	0.2550

TABLE 29

ALT. II. A
HIGH SCENARIO - Long Range Marginal Costs

OBS: -Values discounted to January . 1990
-Units 1 and 2 of CAPANDA in Jan. 93 and Jul. 93
-Heightening of CAMBAMBE dam in January . 2011
-Reference prices: end of 1989

		DISCOUNT RATE		
		10.0%	12.0%	15.0%
CAPANDA	Discounted costs (millions USD)			
	Investment	1267.4	1284.7	1318.0
	O & M	40.4	30.2	20.6
	Total	1307.8	1314.9	1338.6
	Total discounted generation (GWh)	10088.3	7119.9	4495.3
	Levelized generating cost (USD/kWh)	0.1296	0.1847	0.2978
CAMBAMBE	Discounted costs (millions USD)			
	Investment	71.8	49.9	29.4
	O & M	5.8	3.3	1.5
	Total	77.6	53.2	30.9
	Total discounted generation (GWh)	1297.1	692.5	282.9
	Levelized generating cost (USD/kWh)	0.0598	0.0768	0.1092
CAPANDA + CAMBAMBE	Discounted costs (millions USD)			
	Investment	1339.2	1334.6	1347.4
	O & M	46.2	33.5	22.1
	Total	1385.4	1368.1	1369.5
	Total discounted generation (GWh)	11385.4	7812.4	4778.2
	Levelized generating cost (USD/kWh)	0.1217	0.1751	0.2866

TABLE 30

ALT. III. A
HIGH SCENARIO - Long Range Marginal Costs

OBS: -Values discounted to January . 1990
-Unit 1 of CAPANDA in January . 1996
-Heightening of CAPANDA dam in January . 2002
-Heightening of CAMBAMBE dam in January . 2011
-Reference prices: end of 1989

		DISCOUNT RATE		
		10.0%	12.0%	15.0%
CAPANDA	Discounted costs (millions USD)			
	Investment	1208.1	1217.4	1241.9
	O & M	41.2	30.9	21.2
	Total	1249.3	1248.3	1263.1
	Total discounted generation (GWh)	9567.8	6676.0	4143
	Levelized generating cost (USD/kWh)	0.1306	0.1870	0.3049
CAMBAMBE	Discounted costs (millions USD)			
	Investment	71.8	49.9	29.4
	O & M	5.8	3.3	1.5
	Total	77.6	53.2	30.9
	Total discounted generation (GWh)	1297.1	692.5	282.9
	Levelized generating cost (USD/kWh)	0.0598	0.0768	0.1092
CAPANDA + CAMBAMBE	Discounted costs (millions USD)			
	Investment	1279.9	1267.3	1271.3
	O & M	47.0	34.2	22.7
	Total	1326.9	1301.5	1294.0
	Total discounted generation (GWh)	10864.9	7368.5	4425.9
	Levelized generating cost (USD/kWh)	0.1221	0.1766	0.2924

TABLE 31

ALT. I. B
LOW SCENARIO - Long Range Marginal Costs

OBS: -Values discounted to January . 1990
-Unit 1 of CAPANDA in January . 1998
-Heightening of CAMBAMBE dam in January . 2019
-Reference prices: end of 1989

		DISCOUNT RATE		
		10.0%	12.0%	15.0%
CAPANDA	Discounted costs (millions USD)			
	Investment	1189.0	1202.1	1232.1
	O & M	32.2	23.8	16.1
	Total	1221.2	1225.9	1248.2
	Total discounted generation (GWh)	6748.4	4555.6	2704.2
	Levelized generating cost (USD/kWh)	0.1810	0.2691	0.4616
CAMBAMBE	Discounted costs (millions USD)			
	Investment	33.5	20.2	9.6
	O & M	2.5	1.3	0.5
	Total	36.0	21.5	10.1
	Total discounted generation (GWh)	649.6	302.6	101.2
	Levelized generating cost (USD/kWh)	0.0554	0.0711	0.0998
CAPANDA + CAMBAMBE	Discounted costs (millions USD)			
	Investment	1222.5	1222.3	1241.7
	O & M	34.7	25.1	16.6
	Total	1257.2	1247.4	1258.3
	Total discounted generation (GWh)	7398.0	4858.2	2805.4
	Levelized generating cost (USD/kWh)	0.1699	0.2568	0.4485

TABLE 32

ALT. II. B
LOW SCENARIO - Long Range Marginal Costs

OBS: -Values discounted to January . 1990
-Units 1 and 2 of CAPANDA in Jan. 93 and Jul. 93
-Heightening of CAMBAMBE dam in January . 2019
-Reference prices: end of 1989

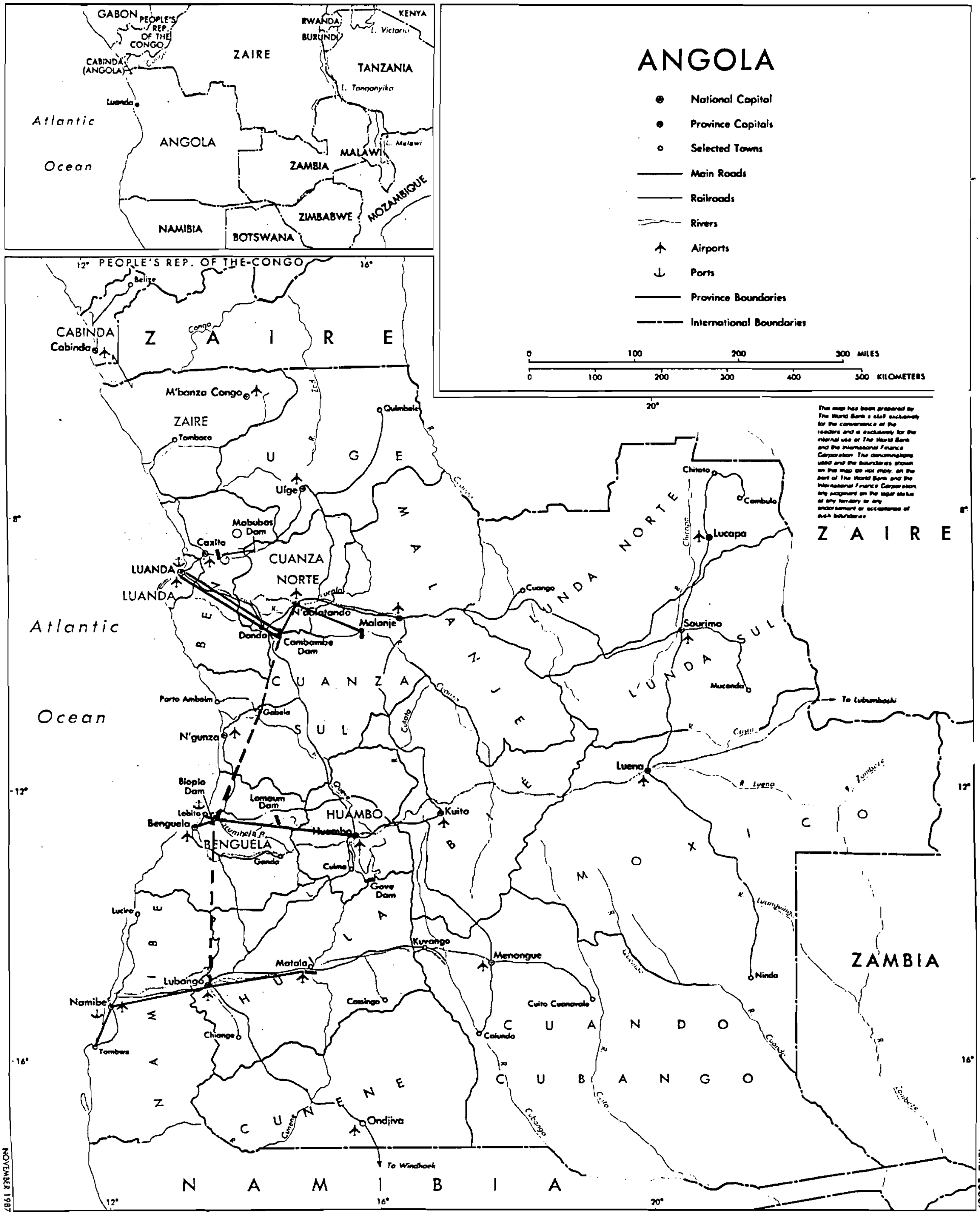
		DISCOUNT RATE		
		10.0%	12.0%	15.0%
CAPANDA	Discounted costs (millions USD)			
	Investment	1253.4	1272.8	1309.0
	O & M	32.2	23.8	16.1
	Total	1285.6	1296.6	1325.1
	Total discounted generation (GWh)	6748.4	4555.6	2704.2
	Levelized generating cost (USD/kWh)	0.1905	0.2846	0.4900
CAMBAMBE	Discounted costs (millions USD)			
	Investment	33.5	20.2	9.6
	O & M	2.5	1.3	0.5
	Total	36.0	21.5	10.1
	Total discounted generation (GWh)	649.6	302.6	101.2
	Levelized generating cost (USD/kWh)	0.0554	0.0711	0.0998
CAPANDA + CAMBAMBE	Discounted costs (millions USD)			
	Investment	1286.9	1293.0	1318.6
	O & M	34.7	25.1	16.6
	Total	1321.6	1318.1	1335.2
	Total discounted generation (GWh)	7398.0	4858.2	2805.4
	Levelized generating cost (USD/kWh)	0.1786	0.2713	0.4759

TABLE 33

ALT. III. B
LOW SCENARIO - Long Range Marginal Costs

OBS: -Values discounted to January . 1990
-Unit 1 of CAPANDA in January . 1998
-Heightening of CAPANDA dam in January . 2007
-Heightening of CAMBAMBE dam in January . 2019
-Reference prices: end 1989

		DISCOUNT RATE		
		10.0%	12.0%	15.0%
CAPANDA	Discounted costs (millions USD)			
	Investment	1159.9	1171.0	1199.1
	O & M	33.3	24.6	16.7
	Total	1193.2	1195.6	1215.8
	Total discounted generation (GWh)	6214.4	4123.6	2386.1
	Levelized generating cost (USD/kWh)	0.1920	0.2899	0.5095
CAMBAMBE	Discounted costs (millions USD)			
	Investment	33.5	20.2	9.6
	O & M	2.5	1.3	0.5
	Total	36.0	21.5	10.1
	Total discounted generation (GWh)	649.6	302.6	101.2
	Levelized generating cost (USD/kWh)	0.0554	0.0711	0.0998
CAPANDA + CAMBAMBE	Discounted costs (millions USD)			
	Investment	1193.4	1191.2	1208.7
	O & M	35.8	25.9	17.2
	Total	1229.2	1217.1	1225.9
	Total discounted generation (GWh)	6864.0	4426.2	2487.3
	Levelized generating cost (USD/kWh)	0.1791	0.2750	0.4929



220kV Transmission line for the interconnection of the Northern System to the Central and Southern Systems

TABLE 34

ANGOLA
C. E G. S. AND S. E G. S.
(expansions with interconnection)

C. E G. S.		1995	1996	2005	2010	2015
COMPONENT	DEMAND	255 Gwh	266 Gwh	638 Gwh	895 Gwh	1198 Gwh
HYDRO :						
CACOMBO					0 MW (R)	24 MW
LOMAUM		45 MW		65 MW		
BIOPIO		14.4 MW				
THERMAL :						
WITHOUT		A)	21.0Gwh (1.89 M USD)	117.9Gwh (11.12 M USD)		414.2Gwh (41.43 M USD)
INTERCONNECTION		B)	0.0 Mw	51.9Mw (3.27 M USD)		140.8Mw (8.87 M USD)
WITH		A)	0.0Gwh	13.9Gwh (1.27 M USD)		80.0Gwh (8.01 M USD)
INTERCONNECTION		B)	0.0 Mw	0.0Mw		56.1Mw (3.53 M USD)
S. E G. S.		**1995**	**1996**	**2005**	**2010**	**2015**
COMPONENT	DEMAND	115 Gwh	124 Gwh	237 Gwh	317 Gwh	405 Gwh
HYDRO :						
GOVE		0 MW (R)				45 MW
MATALA		40.8 MW				
THERMAL :						
WITHOUT		A)	0.0Gwh	94.0Gwh (10.03 M USD)		125.2Gwh (13.44 M USD)
INTERCONNECTION		B)	0.0 Mw	27.0Mw (1.70 M USD)		47.9Mw (3.02 M USD)
WITH		A)	0.0Gwh	0.0Gwh		17.6Gwh (1.89 M USD)
INTERCONNECTION		B)	0.0 Mw	0.0Mw		32.7Mw (2.06 M USD)
INTERCONNECTION VALUE (M USD)	C. E G. S.	A)	1.89-0.0=1.89	11.12-1.27=9.85		41.43-8.01=33.42
		B)	+ 0.0	+ 3.27-0.0=3.27		+ 8.87-3.53=5.34
			1.89	13.12		38.76
	S. E G. S.	A)	0.0	10.03-0.0=10.03		13.44-1.89= 11.55
		B)	+ 0.0	+ 1.70-0.0=1.70		+ 3.02-2.06=0.96
			0.0	11.73		12.51
	TOTAL		1.89+0.0=1.89	13.12+11.73 - 0.99* =23.86		38.76+12.51 - 3.61* =47.66

* Increase of NORTHERN SYSTEM's fuel costs due to the interconnection

[n n MW] Integration of the scheme in the system, with the indicated power output (R) Only for regulating purposes

A) Generation at the average of the hydrological regimes and respective fuel costs

B) Emergency capacity necessary in new gas turbines during critical period (dec.1958) and corresponding annual charge (discount rate: 10%)

TABLE 35

ANGOLA
C. E G. S. AND S. E G. S.
(expansions with interconnection)

C. E G. S.		1995	1996	2005	2010	2015
COMPONENT	DEMAND	255 Gwh	286 Gwh	638 Gwh	895 Gwh	1198 Gwh
HYDRO :						
CACOMBO					0 MW (R)	24 MW
LOMAUM		45 MW		65 MW		
BIOPIO		14.4 MW				
THERMAL :						
WITHOUT		A)	21.0Gwh (1.89 M USD)	117.9Gwh (11.12 M USD)		414.2Gwh (41.43 M USD)
INTERCONNECTION		B)	0.0 Mw	51.9Mw (3.79 M USD)		140.8Mw (10.28 M USD)
WITH		A)	0.0Gwh	13.9Gwh (1.27 M USD)		80.0Gwh (8.01 M USD)
INTERCONNECTION		B)	0.0 Mw	0.0Mw		56.1Mw (4.10 M USD)
S. E G. S.		**1995**	**1996**	**2005**	**2010**	**2015**
COMPONENT	DEMAND	115 Gwh	124 Gwh	237 Gwh	317 Gwh	405 Gwh
HYDRO :						
GOVE		0 MW (R)				45 MW
MATALA		40.8 MW				
THERMAL :						
WITHOUT		A)	0.0Gwh	94.0Gwh (10.03 M USD)		125.2Gwh (13.44 M USD)
INTERCONNECTION		B)	0.0 Mw	27.0Mw (1.97 M USD)		47.9Mw (3.50 M USD)
WITH		A)	0.0Gwh	0.0Gwh		17.6Gwh (1.89 M USD)
INTERCONNECTION		B)	0.0 Mw	0.0Mw		32.7Mw (2.39 M USD)
INTERCONNECTION VALUE (M USD)	C. E G. S.	A)	1.89-0.0=1.89	11.12-1.27=9.85		41.43-8.01=33.42
		B)	+ 0.0	+ 3.79-0.0=3.79		+10.28-4.10=6.18
			1.89	13.64		39.60
	S. E G. S.	A)	0.0	10.03-0.0=10.03		13.44-1.89= 11.55
		B)	+ 0.0	+ 1.97-0.0=1.97		+ 3.50-2.39=1.11
			0.0	12.00		12.66
	TOTAL		1.89+0.0=1.89	13.64+12.00 - 0.99* =24.65		39.60+12.66 - 3.61*=48.65

* Increase of NORTHERN SYSTEM's fuel variable costs due to the interconnection

[n n MW] Integration of the scheme in the system ,with the indicated power output

(R) Only for regulating purposes

A) Generation at the average of the hydrological regimes and respective fuel costs

B) Emergency capacity necessary in new gas turbines during critical period (dec. 58) and corresponding annual charge (discount rate: 12%)

TABLE 36

ANGOLA
C.E.G.S. AND S.E.G.S.
(expansions with interconnection)

C.E.G.S.		1995	1996	2005	2010	2015
COMPONENT	DEMAND	255 Gwh	286 Gwh	638 Gwh	895 Gwh	1198 Gwh
HYDRO :						
CACOMBO					0 MW (R)	24 MW
LOMAUM		45 MW		65 MW		
BIOPIO		14.4 MW				
THERMAL :						
WITHOUT		A)	21.0Gwh (1.89 M USD)	117.9Gwh (11.12 M USD)		414.2Gwh (41.43 M USD)
INTERCONNECTION		B)	0.0 Mw	51.9Mw (4.62 M USD)		140.8Mw (12.53 M USD)
WITH		A)	0.0Gwh	13.9Gwh (1.27 M USD)		80.0Gwh (8.01 M USD)
INTERCONNECTION		B)	0.0 Mw	0.0Mw		56.1Mw (4.99 M USD)
S.E.G.S.		**1995**	**1996**	**2005**	**2010**	**2015**
COMPONENT	DEMAND	115 Gwh	124 Gwh	237 Gwh	317 Gwh	405 Gwh
HYDRO :						
GOVE		0 MW (R)				45 MW
MATALA		40.8 MW				
THERMAL :						
WITHOUT		A)	0.0Gwh	94.0Gwh (10.03 M USD)		125.2Gwh (13.44 M USD)
INTERCONNECTION		B)	0.0 Mw	27.0Mw (2.40 M USD)		47.9Mw (4.26 M USD)
WITH		A)	0.0Gwh	0.0Gwh		17.6Gwh (1.89 M USD)
INTERCONNECTION		B)	0.0 Mw	0.0Mw		32.7Mw (2.91 M USD)
INTERCONNECTION VALUE (M USD)	C.E.G.S.	A)	1.89-0.0=1.89	11.12-1.27=9.85		41.43-8.01=33.42
		B)	+ 0.0	+ 4.62-0.0=4.62		+12.53-4.99=7.54
			1.89	14.47		40.96
	S.E.G.S.	A)	0.0	10.03-0.0=10.03		13.44-1.89= 11.55
		B)	+ 0.0	+ 2.40-0.0=2.40		+ 4.26-2.91=1.35
			0.0	12.43		12.90
	TOTAL		1.89+0.0=1.89	14.47+12.43 - 0.99* =25.91		40.96+12.90 - 3.61* =50.25

* Increase of NORTHERN SYSTEM's fuel costs due to the interconnection

[n n MW] Integration of the scheme in the system,with the indicated power output

(R) Only for regulating purposes

A) Generation at the average of the hydrological regimes and respective fuel costs

B) Emergency capacity necessary in new gas turbines during critical period (dec. 1956) and corresponding annual charge (discount rate: 15%)

The VALORAGUA model

The basic planning problem for an electric utility is to design a system so that it can be built and operated in the most economical manner and provide a satisfactory quality of service.

The optimal expansion of the electric power system is a multidimensional sequential decision problem and it requires the application of several models integrated in a global methodology.

The two great groups of models are classified, according to their main purposes, as following:

- "dynamic" models, aiming at the optimal expansion of the power system over time, thus joining investment and management decisions;
- "static" models whose purpose is the optimal management of the system operation once the investment decisions, and therefore the system composition, are known.

The VALORAGUA model, developed by Electricidade de Portugal, EDP, is included in the second group above referred to. It studies the optimal management of a predetermined power system configuration.

In an electric power system with significant hydroelectric regulation capabilities, the hydroelectric storage can be use to attenuate the seasonal flutuations of power demand or of water inflows by transferring water from periods with high inflows to periods of lower inflows, taking into account the expected power demand over those periods. So a decision of water release or water retention at a given period will have almost surely an instantaneous consequence in the reduction or increase of the operation costs, but also it will influence the operation in the future by the side of a modification of water available in the reservoirs in the future.

The VALORAGUA model allows an integrated management of a fixed hydrothermal power configuration whose objective is to find the most economical operation policy, taking into account the physical constraints and the random conditions of the system operation.

The model considers the possibility of transfer water from periods of high inflows to periods of lower inflows, introducing the idea of value of water (VALOR da AGUA) resulting from the arbitration between immediate gain (associated to an economy on fuel) and expectation of a future gain.

To achieve this goal the optimal management of the system requires the solution of two problems:

. **medium-term management of the water reservoirs**

It determines the so called cost-to-go functions, related to the value of stored water, using a stochastic dynamic programming algorithm; the hydroelectric subsystem is fully aggregated into an equivalent one.

. **Short-term management of hydro thermal system**

For each period it determines the final storage of each reservoir and the system generation schedule in order to minimize the sum of operation costs in that period with the expected value of future operation costs.
This is a non linear optimization problem, solved by an appropriated non linear programming algorithm.
The hydrothermal electric system is completely disaggregated.

The model analyses a period of one year for which the composition of the generation system is well defined.The year is divided in twelve periods being the month the unit of time considered for management purposes. The model simulates the optimized operation of the system using a hydrological time series of inflows at each hydro power station. The VALORAGUA model allows an integrated management of a hydro-thermal electric power system, making the link between the water management and the thermal operation, taking into account not only physical and technical characteristics of the system but also economic parameters and variables, mainly a careful calculation of economic dual variables: marginal generation cost and marginal value of water.

This detailed information on the economic behaviour of the system enables two important applications of the model: economic evaluation of hydroelectric schemes and optimization of some if its technical characteristics.

Other type of application is the studies on a simplified generation-transmission network enabling the delimitation of interesting areas for future power plants locations and the eventual need of extension of the transmission network.

The country is divided into several interconnected areas, each of them with its own generation plants and load demands. Those areas are symbolized by nodes linked by transmission lines, which are defined by means of loss coefficients depending on their physical characteristics and by power flow bounds.

The model determines the optimal generation dispatches and both electrical power and monetary flows between nodes.

Power flows from nodes with lower generation costs to nodes with higher ones. So when marginal costs of those nodes are closer, less power flows between electrical nodes occurs.

TABLE 1

DEMAND FORECAST a)

HIGH SCENARIO

	SYSTEMS								
	NORTHERN Load Factor : 0.63			CENTRAL Load Factor : 0.624			SOUTHERN Load Factor : 0.57		
YEAR	Energy (GWh)	Growth rate (%)	Capacity (MW)	Energy (GWh)	Growth rate (%)	Capacity (MW)	Energy (GWh)	Growth rate (%)	Capacity (MW)
1987				↖ 108.5		20	↖ 62		12
1988	↖			112	3.0	20	63	1.0	13
1989	695		126	120	7.0	22	64	3.0	13
1990	730	5.0	132	133	11.0	24	68	5.0	14
1991	766	5.0	139	149	12.0	27	73	8.0	15
1992	820	7.0	149	169	13.0	31	80	10.0	16
1993	886	8.0	160	193	15.0	35	90	12.0	18
1994	974	10.0	177	222	15.0	41	104	15.0	21
1995	1091	12.0	198	255	15.0	47	115	11.0	23
1996	1222	12.0	221	286	12.0	52	124	8.0	25
1997	1369	12.0	248	320	12.0	59	134	8.0	27
1998	1519	11.0	275	359	12.0	66	145	8.0	29
1999	1656	9.0	300	398	11.0	73	156	8.0	31
2000	1789	8.0	324	434	9.0	79	169	8.0	34
2001	1914	7.0	347	469	8.0	86	181	7.0	36
2002	2048	7.0	371	507	8.0	93	194	7.0	39
2003	2191	7.0	397	547	8.0	100	207	7.0	41
2004	2345	7.0	425	591	8.0	108	222	7.0	44
2005	2509	7.0	455	638	8.0	117	237	7.0	47
2006	2659	6.0	482	683	7.0	125	251	6.0	50
2007	2819	6.0	511	731	7.0	134	266	6.0	53
2008	2988	6.0	541	782	7.0	143	282	6.0	56
2009	3167	6.0	574	836	7.0	153	299	6.0	60
2010	3357	6.0	608	895	7.0	164	317	6.0	63
2011	3525	5.0	639	949	6.0	174	333	5.0	67
2012	3701	5.0	671	1006	6.0	184	350	5.0	70
2013	3886	5.0	704	1066	6.0	195	367	5.0	73
2014	4081	5.0	739	1130	6.0	207	386	5.0	77
2015	4285	5.0	776	1198	6.0	219	405	5.0	81

a) At generation level

↖ Value actually verified

ANNEX 3
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TABLE 2

C.E.G.S. of ANGOLA

EXPANSION WITHOUT INTERCONNECTION

	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
	DEMAND (GWh)	255	286	320	359	398	434	469	507	547	591	638
Average	CACOMBO	—	—	—	—	—	R	R	R	90	93	95
	LOMAUM	181	200	260	292	323	348	372	377	362	376	392
	BIOPIO	62	65	50	56	62	70	72	75	70	74	78
	Thermal Units	12	21	10	11	13	16	25	55	25	48	73
Dry Year (1958)	CACOMBO	—	—	—	—	—	0	0	0	60	62	42
	LOMAUM	153	164	190	190	190	348	370	299	378	364	352
	BIOPIO	44	44	40	40	40	70	73	64	69	69	70
	Thermal Units	58	78	90	129	168	16	26	144	42	106	174
	DEMAND (MW)	47	52	59	68	73	79	88	93	100	108	117
Dec. 58	CACOMBO	—	—	—	—	—	0	0	0	7.6	4.8	2.0
	LOMAUM	19.2	22.9	30.0	30.0	30.0	55.0	53.3	32.5	55.0	40.8	26.5
	BIOPIO	5.0	6.3	6.0	6.0	6.0	10.8	9.9	6.5	10.8	7.9	5.0
	Thermal Units	22.8	22.8	23.0	30.0	37.0	13.2	22.8	54.0	26.6	54.5	83.5

COMPONENTS	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
THERMAL	Biopio(GT) 22.8MW Huambo(GT)10.0MW Lobito(D) 20.0MW		GT +25MW	GT +30MW								
HYDRO	Lomaum 45 MW(I) 30 MW(a) Biopio 14.4 MW(I) 10.8 MW(a)	Lomaum 65 MW(I) 55 MW(a) Biopio 14.4 MW(I) 10.8 MW(a)							Cacombo 24 MW(I) 12 MW(a) Lomaum 65 MW(I) 55 MW(a) Biopio 14.4 MW(I) 10.8 MW(a)			

R - Only for regulating purposes
(I) - Installed
(a) - available

TABLE 3

S.E.G.S. of ANGOLA

EXPANSION WITHOUT INTERCONNECTION

		1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
	DEMAND (GWh)	115	124	134	145	158	169	181	194	207	222	237
Average	GOVE	R	R	R	R	53	57	63	69	90	97	105
	MATALA	115	124	134	143	103	112	117	122	117	125	128
	Thermal Units	0	0	0	2	0	0	1	2.5	0	0	4
Dry Year (1958)	GOVE	R	R	R	R	58	63	74	79	85	93	95
	MATALA	115	124	134	134	98	106	105	105	122	129	130
	Thermal Units	0	0	0	11	0	0	2	10	0	0	12
	DEMAND (MW)	23.0	25.0	27.0	29.0	31.0	34.0	36.0	39.0	41.0	44.0	47.0
Dec. 58	GOVE	0	0	0	0	10.6	11.6	11.0	11.0	19.5	20.0	18.6
	MATALA	23.0	25.0	27.0	19.8	20.4	22.4	21.0	21.0	21.5	24.0	24.1
	Thermal Units	0	0	0	9.2	0	0	4.0	7.0	0	0	4.3

COMPONENTS	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
THERMAL	Namibe(D) 11.5MW											
HYDRO	Matala - 40.8 MW(I) - 27.2 MW(a)			Gove - 30 MW(I) - 15 MW(a)				Gove - 45 MW(I) - 30 MW(a)				

R - Only for regulating purposes
(I) - Installed
(a) - available

TABLE 4

INVESTMENTS
(M. USD)

	C.E.G.S.			S.E.G.S.	
	WITH INTERCONNECTION	WITHOUT INTERCONNECTION		WITH INTERCONNECTION	WITHOUT INTERCONNECTION
1992					
1993		CACOMBO	GAS TURBINES		
1994		15.0			
1995		22.5	5.5		
1996		30.0	12.1		GOVE
1997		30.0	6.6 25 MW		20.0
1998		30.0	30 MW		20.0
1999		22.5			Plant 30 MW
2000		Dam 16.0			
2001		16.0			
2002		16.0			20.0
2003	CACOMBO	Plant 24 MW			Plant 45 MW
2004	15.0				
2005	22.5				
2006	30.0	Study horizon			Study horizon
2007	30.0				
2008	30.0				
2009	22.5				
2010	Dam				
2011				GOVE	
2012	16.0			20.0	
2013	16.0			20.0	
2014	16.0			20.0	
2015	Plant 24 MW			Plant 45 MW	
	Study horizon			Study horizon	

INVESTIMENT COSTS DISCOUNTED TO THE BEGINNING OF 1995

Discount rate	C.E.G.S. With interconnection	C.E.G.S. Without interconnection	S.E.G.S. With interconnection	S.E.G.S. Without interconnection
10%	55.7	169.9	10.3	39.9
12%	44.2	162.3	7.4	37.1
15%	31.6	152.1	4.6	33.4