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Angola

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

PURPOSE

The Joint UNDP/World Bank Energy Sector Management Assistance Programme (ESMAP) is a special global technical assistance program run as part of the World Bank's Energy, Mining and Telecommunications Department. ESMAP provides advice to governments on sustainable energy development. Established with the support of UNDP and bilateral official donors in 1983, it focuses on the role of energy in the development process with the objective of contributing to poverty alleviation, improving living conditions and preserving the environment in developing countries and transition economies. ESMAP centers its interventions on three priority areas: sector reform and restructuring; access to modern energy for the poorest; and promotion of sustainable energy practices.

GOVERNANCE AND OPERATIONS

ESMAP is governed by a Consultative Group (ESMAP CG) composed of representatives of the UNDP and World Bank, other donors, and development experts from regions benefiting from ESMAP's assistance. The ESMAP CG is chaired by a World Bank Vice President, and advised by a Technical Advisory Group (TAG) of four independent energy experts that reviews the Programme's strategic agenda, its work plan, and its achievements. ESMAP relies on a cadre of engineers, energy planners, and economists from the World Bank to conduct its activities under the guidance of the Manager of ESMAP, responsible for administering the Programme.

FUNDING

ESMAP is a cooperative effort supported over the years by the World Bank, the UNDP and other United Nations agencies, the European Union, the Organization of American States (OAS), the Latin American Energy Organization (OLADE), and public and private donors from countries including Australia, Belgium, Canada, Denmark, Germany, Finland, France, Iceland, Ireland, Italy, Japan, the Netherlands, New Zealand, Norway, Portugal, Sweden, Switzerland, the United Kingdom, and the United States of America.

FURTHER INFORMATION

An up-to-date listing of completed ESMAP projects is appended to this report. For further information, a copy of the ESMAP Annual Report, or copies of project reports, contact:

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(ESMAP)

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Foreword

The Africa Gas Initiative (AGI) Study is aimed at identifying countries where gas flaring could be reduced, for better utilization in the industrial and commercial sectors of their economies. This study was conducted by Mourad Belguedj, Senior Energy Specialist and Team Leader at the Oil and Gas Division of the World Bank and Henri Beaussant, Gas Economist and consultant.

The focus of the study, aimed initially at select countries on the West Coast of Africa, is of direct relevance to ESMAP's mandate and might be useful to Policy makers, Industry and practitioners in the target countries. The Study is published as part of the ESMAP series of reports and may usefully contribute to Project Identification and to addressing key Policy Issues in these countries, as well as enriching the debate on Energy Sector Reform. The authors wish to express their gratitude to all the colleagues who contributed directly or indirectly, to the review and completion of this work.

Abbreviations and Acronyms

CABGOC	Cabinda Gulf Oil Corporation
CCGT	Combined-Cycle Gas Turbine
CIF	Cost, Insurance, Freight
EDEL	Empresa De Electricidade De Luanda
ENE	Empresa Nacional De Electricidade
FGD	Flue Gas Desulfurizer
FOB	Free On Board
GDP	Gross Domestic Product
GNP	Gross National Product
GoA	Government Of Angola
GT	Gas Turbine
HHV	Higher Heating Value
HV	High Voltage
IMF	International Monetary Fund
IOC	International Oil Company
ISO	International Standards Organization
LHV	Lower Heating Value
LNG	Liquefied Natural Gas
LPG	Liquefied Petroleum Gases
PSA	Production Sharing Agreement
SSA	Sub Saharan Africa
UNDP	United Nations Development Program
UNIDO	United Nations Industrial Development Organization
USD	US Dollar

Units of Measure

bcf	billion cubic feet
bcm	billion cubic meters
bcmy	billion cubic meters per year
bl, bbl	barrel, barrels
bpd	barrel per day
cf	cubic foot (feet)
cfd	cubic feet per day
GJ	gigajoule
cm	cubic meter
GWh	gigawatthour
kcal	kilocalorie
km2	square kilometer
kW	kilowatt
kWh	kilowatthour
Mcal	megacalorie
mcf	thousand cubic feet
mcfd	thousand cubic feet per day
mcm	thousand cubic
mcmd	thousand cubic
mcmy	thousand cubic
mmbtu	million BTU (British Thermal Units)
mmcfd	million cubic feet per day
mmcm	million cubic meters
mmcmd	million cubic meters per day
mmcmy	million cubic meters per year
mmt	million ton
mt	thousand ton
mty	thousand ton per year
MW	megawatt
MWh	megawatthour
t	ton
tcf	trillion cubic feet
tcm	trillion cubic meters
toe	ton oil equivalent
tpy	ton per year
TWh	terawatthour

Conversion Factors

Volume

1 barrel	=	159 liters
1 cm	=	6.29 barrels
1 cm	=	35.315 cf
1,000 cf	=	28.3 cm

Energy

1 mmbtu	=	252 Mcal = 293 kWh
1 mmbtu	~	1 mcf
1 GJ	=	0.95 mmbtu
1 kWh	=	0.86 Mcal = 3,412 btu

Oil products

crude oil	7.30 bbl/ton
diesel/gas oil	7.46 bbl/ton
fuel oil	6.66 bbl/ton
jet fuel	7.93 bbl/ton
kerosene	7.74 bbl/ton
naphtha	8.80 bbl/ton

Rule of Thumb

1 bpd	~	50 tpy
1 mmbtu	~	1 mcf ~ 1 GJ
1 mmcfd	~	10 mmcmy
1 USD/mmbtu	~	40 USD/mcm
1 tcf	~	30 bcm

1

Oil and Gas Resources

Overview of the Gas and Oil Sector

1.1 The petroleum industry in Angola began in 1955 when oil was discovered in the onshore Kwanza valley by Petrofina, which together with the local government (then under Portuguese rule) established the jointly-owned company, Fina Petroleos de Angola (Petrangol) and constructed a refinery at Luanda to process the oil. Over the years Angola, which became independent in 1975, has emerged as one of the major oil producing countries of Africa and today the petroleum industry is the economic mainstay of the Government of Angola (GoA). With oil, associated gas is also produced and more often than not, flared in huge volumes. This is an attempt to investigate ways to reduce flaring and putting natural gas to productive use.

1.2 Two decades of civil war, which erupted soon after independence, have taken their toll on Angola's economy and virtually destroyed its infrastructure, leaving GNP per capita at only USD 312, and a 1998 inflation rate estimated at 91 percent. Due to failure by UNITA to comply with the Lusaka Protocol signed by the two parties, the UN imposed sanctions on UNITA in June 1998. Civil war actually resumed while UN peacekeepers left the country in February 1999, putting more strain on the people and the economy. Real GDP growth rate is estimated at –2 percent in 1999 (following 1 percent the previous year), while inflation rate is expected to have reached 250 percent in that year.

1.3 In 1960, oil accounted for less than 8 percent of gross domestic product, while agriculture contributed about 50 percent. By 1995, agriculture's share had fallen to 17 percent and that of oil had jumped to 40 percent. Today, crude oil accounts for 90 percent of total exports, more than 80 percent of government revenues and 42 percent of the country's GDP. Oil output reached 735,000 bpd in 1998 and is expected to reach one million barrels per day around the year 2000, making Angola the second most significant oil producer in Sub-Saharan Africa after Nigeria and the larger non-OPEC oil exporter outside the Western Hemisphere.

1.4 The national oil company, Sociedade Nacional de Combustiveis de Angola (Sonangol), was established in 1976, and the hydrocarbon law passed in 1978 made Sonangol sole concessionaire for exploration and production. Associations with foreign companies are in the form of either joint ventures (JV), where investment costs and production are divided according to the party's share in the venture, or production sharing agreements (PSA), in which the foreign partners act as contractors to Sonangol. The contractors finance all investment costs, and recover their investments when production begins. The PSAs commit partners to carry out exploration and development within a pre-determined time (usually three years for each phase).

1.5 Crude production, which comes almost entirely from offshore fields because of war risks, has more than doubled in the past ten years from 359,000 bpd in 1987 to close to 800,000 bpd in 1999. Two thirds of the oil reserves are found off the coastal enclave of Cabinda and off Angola's northern coast near Soyo, while the few onshore fields are located near Luanda in the Kwanza River Basin and further south in the Namibe Basin. During the past decade, new discoveries have added new reserves at a greater rate than existing reserves were depleted. Angola's total proven oil reserves are estimated at 5.4 billion barrels at the end of 1998, giving the country a reserves-to-production (RTP) ratio of 20 years. Following recent further discoveries, its upstream potential is likely to remain extremely positive due to its promising geology, a good record of exploration success, low operating costs and relatively attractive fiscal terms. These factors have already made Angola a key player in Africa's oil industry, both as a major producer and exporter.

1.6 Meanwhile, oil exploration has resulted in the discovery of significant natural gas reserves, which remained undeveloped and often relinquished by the IOCs to the Angolan State via Sonangol. Over seventy percent of the gas produced in association with oil is flared, while the remainder is used for gas lift and injection to boost oil production from declining fields in Cabinda, or is used by the industry. Under most of the PSAs, the associated gas, which is not required for gas lift operations or for re-injection for reservoir pressure maintenance, belongs to the State or to Sonangol. Since oil production is essential for government revenues, the flaring has been authorized. It is estimated that in 1998 nearly 140 bcf of associated gas was flared. The lack of gas-based infrastructure is hindering Angola's development and usage of natural gas in its energy sector.

1.7 Oil sales, which account for 90 percent of the country's exports and roughly half of its GDP, has fallen to USD 3.6 bn in 1998, compared with USD 4.9 bn in 1997, due to depressed prices. Figures for 1999 should significantly improve with the barrel reaching USD 25 in the fall. Privatization and the planned establishment of a series of development corridors and energy intensive free-trade zones would help diversify the economy. The IMF has agreed to begin an economic monitoring program[1], which was a precondition to extend soft credits. However, the resumption of the civil war with UNITA has stalled the implementation of the ESAF. Whether the current trend in oil prices continues or falls again in the near future, for the country to finance its rebuilding efforts, it is important that Angola starts giving priority to commercial development of its natural gas reserves.

[1] Enhanced Structural Adjustment Facility (ESAF).

Oil and Gas Potential

Exploration and Production

1.8 ***Production sites.*** The main expansion of Angola's upstream oil industry came in the late 1960s when the Cabinda Gulf Oil Co (CABGOC), a Chevron (then Gulf) subsidiary, discovered oil offshore of the Angolan coastal enclave of Cabinda, located north of the mouth of River Congo. The national oil company (Sonangol) was also established to manage oil production and fuels distribution. In the late 1970s, the government initiated a program to attract foreign oil companies. The Angolan coastline, excluding Cabinda, was divided into 13 exploration blocks, which were leased to foreign companies under production sharing agreements. In 1978, the Angolan government authorized Sonangol to acquire a 51 percent interest in all oil companies operating in Angola, although the management of operations remained under the control of IOCs.

1.9 Three major sedimentary basins prone to accumulation of hydrocarbons span Angola's entire coastline. The lower Congo basin, which extends from the Republic of Congo south through Cabinda and into the northern part of Angola, is the only basin from which oil and gas are currently being produced. The Kwanza basin extends from Luanda south to the coastal town of Benguela, and the Namibe basin extends from the Benguela area south into Namibia.

1.10 Crude production, which has doubled in the past ten years, is located mainly in Block Zero, offshore Cabinda, which includes Area A, Area B, and Area C. It accounts for nearly 65 percent of crude production. CABGOC is the operator of the fields and it has a 39.2 percent share in the JV. Other partners include Sonangol (41 percent), Elf (10 percent) and Agip (9.8 percent). The largest producing fields are Takula and Numbi (Area A), and Kokongo (Area B). CABGOC and its partners hope to expand production in the three areas from 510,000 to 600,000 bpd in 2001. Investment plans include USD 4 bn over the five coming years. The start-up of production from the Lomba (Area B) field was announced in May 1998. Production is currently 15,000 bpd, and was expected to increase to 27,000 bpd by the end of 1998.

1.11 The second largest area of production in Angola is Block 3, which is located offshore, off Luanda along the northern coast. The largest fields on Block 3 are Pacassa, Cobo/Pambi, and Palanca. Storage and export facilities are provided by a terminal located on the Palanca field. Elf (now part of the French TotalFina group) is operator with a 50 percent interest. Other partners include Sonangol, Agip, Svenska Petroleum, Nis Naftgas (Serbia), Ina Naftaplin (Croatia), and Ajoco. The Oombo field, a satellite of the Cobo/Pambi field, came on stream in January 1998 producing 9,500 bpd.

1.12 Block 2, located offshore, off the northern Angolan city of Soyo, is also currently in production, with Texaco and TotalFina both operators. Major fields include Lombo, Sulele, and Tubarao. Historically, Petrofina of Belgium (now TotalFina) is the operator of Angola's onshore production, centered on two areas, Kwanza near Luanda and the Congo basin near Soyo. Production facilities near Soyo were damaged during the civil war, and a USD 250 million post-war rehabilitation program is underway.

1.13 ***Exploration***. CABGOC made a significant oil discovery in deeper waters offshore Cabinda in April 1997. The field, designated Kuito, has estimated recoverable reserves of 1 - 2 billion barrels. Kuito lies in waters 1,300 feet (400 meters) deep in Block 14, which is adjacent to Areas B and C. CABGOC is the operator of the PSA working on Block 14 and it has 31 percent interest in the venture. Other partners in the PSA are Sonangol (20 percent), TotalFina (20 percent), Agip (20 percent), and Petrogal (9 percent).

1.14 Chevron also announced a significant oil discovery in deepwater Block 14. The new field has been named Belize and follows its three predecessors - Kuito, Landana, and Benguela. Initial production from Kuito during Phase One is expected to be 75,000 bpd and will reach peak production of 100,000 bpd by 2002. As per Chevron, Kuito will be Angola's first deepwater, zero-gas flared field. Kuito gas, produced in association with the oil, will be reinjected into the reservoir. Chevron's Nemba and Lomba fields, located in shallower water nearby Block Zero, are also zero-flare.

1.15 Angola's oil industry is an attractive investment opportunity, offering foreign companies favorable geology, low operating costs, and a constructive business approach from the Angolan government. TotalFina's foreign investment in oil exploration and production has been USD 2.7 billion from 1980-86, USD 2 billion from 1987-90 and was reportedly USD 4 billion from 1993-97. Out of the total estimated oil production in 1998, of the major operators Chevron produces 450,000 bpd in Cabinda, Elf will expand its production to reach 200,000 bpd in its concessions in Blocks 3/80, 3/85 and 3/91, and Texaco will reach 75,000 bpd.

1.16 The recent offshore discoveries in Angola have sparked interest in Angola's unclaimed blocks. Block 19, located in deepwater offshore Luanda, was awarded to a group composed of Fina (30 percent and operator), Ranger (25 percent), Sonangol (20 percent), U.S. United Meridian Corporation (now Ocean Energy) (20 percent), and Israeli firm Naphta (5 percent). Texaco was named operator of Block 22, and Australian firm BHP was named operator of Block 21 in June 1997. Bids for Blocks 23, 24 and 25 were accepted in 1997, while license awards for Blocks 31-34 have been granted by the end of 1998. There are plans to establish as many as fifteen new deepwater blocks along Angola's southern coast.Refining and Downstream Oil Activities

1.17 The Fina Petroleos De Angola refinery in Luanda has current nominal capacity of 1.9 mty (38,000 bpd) although current throughput is around 1.6 mty. The refinery is a joint-venture between Sonangol (36 percent), Fina (61 percent, operator), and private investors (3 percent). Angola refines about 20,000 bpd for its domestic market and exports naphtha, bunkering oils and heavy fuel oil. Plans for a second refinery were announced in January 1998. The 200,000 bpd facility, would be located in the central coastal city of Lobito. However, this project depends on raising the USD 2 bn to finance its construction as well as improved export prospects and lasting political stability. The proposed refinery could supply the southern part of the country with LPG and petroleum products. It could also run on natural gas, if available at a competitive cost, thus producing large volumes of liquid fuels for export. Estimated natural gas demand would be about 200 mmcm per year.

1.18 Three firms, Sonangol, Fina, and Sonangalp, a joint venture between Sonangol (51 percent) and Petrogal (49 percent), provide products distribution and marketing in Angola. Plans by Sonangol to attract additional foreign companies to the country's downstream market are being hindered by the markets small size and lack of infrastructure.

Gas Reserves and Production

Natural Gas Resource Base

1.19 According to the US DoE, Angola had estimated reserves of 1.6 tcf of natural gas, as of early 1999, but recent discoveries may have boosted this figure to a much higher level. Angola's two offshore oil-producing areas have also proved to be bearing substantial gas reserves. The offshore Cabinda area has contributed about 70 percent of the country's total production and contains about two thirds of the total oil and gas reserves. It consists of blocks A, B, and C spread over a total area of about 5,000 square km. The second offshore area, which consists of blocks 2 and 3, is spread over an area of about 10,000 square km and contains about one third of the total oil and gas reserves.

Current Production And Usage - Gas Flaring

1.20 Gas production in 1998 was estimated to be about 280 bcf (8 bcm), of which over 70 percent are flared or vented, and about 20 percent re-injected to aid in crude production. However, non-existent gas pipeline infrastructure, undeveloped domestic and regional markets, and lack of financial resources to promote gas-based export schemes have hindered Angola's development and usage of natural gas in its energy sector.

1.21 Angola is currently responsible for about 15 percent of the total gas being flared in Africa and is next only to Nigeria. The total estimated energy-related carbon emissions as a result of flaring nearly 140 bcf of gas in 1997 were 3.2 million metric tons carbon. At the estimated rates of gas production from existing producing fields, Angola's gas flaring should reach about 230 bcf by the year 2000. This in addition to being a serious waste of a potentially valuable non-renewable resource has been a significant source of environmental pollution.

Table 1.1 – Gas Production and Usage (1997)

	(bcm)	*(bcf)*
Gas Reserves	48.6	1,620
Gas Production	6.2	208
RTP (years)	7.8	7.8
Gas Reinjected	1.3	42
Gas Flared/Vented	4.1	138
Other Gas Losses	0.2	8
Domestic use	0.6	20

Source: US DoE

2

Prospects for Natural Gas

2.1 Natural Gas development in Angola has been and continues to be hindered by three major factors:

- The rate of return on oil investments compared to gas is 3:1, and the contractual agreements with the operating IOCs have no explicit provisions for development of natural gas;
- Limited domestic and regional markets for gas due to minimal economic development; and
- Increased political risks as a result of over twenty years of civil war. These are more significant for gas projects, which have to be located onshore, while majority of the oil production as well as exportation is done from offshore facilities.

Power Generation

Overview of the sub-sector

2.2 The AGI has commissioned a pre-feasibility study of the use of gas for power generation, bearing in mind that a driving force – a sizable gas-consuming project -- is usually required to launch grass-root gas operation. Although Angola (in particular the northern areas where Luanda is located) is fairly well endowed with regard to hydro potential, using natural gas for power generation appears a very attractive option in comparison with high-cost, to-be-built hydro schemes. While the detailed approach and conclusions of the gas to power study are shown in Chapter 3, this section presents the summary of the current situation and the main conclusions of the study.

2.3 Angola is well endowed with potential sources for the production of electricity, both hydroelectric and thermal (using locally produced oil and gas). As of 1997, the electric generation capacity was 617 megawatts while electricity generation was 1.11 TWh and the electricity consumed was 745 GWh, giving a high 33 percent level of own consumption, transmission and distribution losses.

2.4 Electricity supply in Angola consists of three not interconnected grids, and several isolated systems. The main three systems are associated with the basins of three important rivers; the Kwanza for the northern system; the Catumbela for the central system; and the Cunene for the southern system. These systems supply the main load centers in Angola: Luanda (northern system); Benguela, Lobito and Huambo (central system); and Lubango and Namibe (southern system). The main isolated systems are those of Cabinda, Uige, and Bie. Another important system in the province of Luanda Norte belongs to the mining company ENDIAMA and was mainly used for diamond mining activities.

2.5 The northern system, which covers the capital city of Luanda and its close suburbs, is the biggest consumer and accounts for nearly 80 percent of the total electricity consumed. Electricity consumption has been severely constrained by the war situation and the unceasing supply disruptions. In spite of the booming population growth in Luanda (estimated to have more than doubled since 1987 to about 4 million people today), the growth in electricity demand has been less than 2 percent on an annual basis. The stagnation results from the near total collapse of the industrial activity, which is reportedly presently working at around 10 percent of its nominal capacity.

2.6 Significant portions of the generation and transmission facilities were damaged during the civil war. The central system has been hit repeatedly by the UNITA, which in the 1980s put the Lomaum station and a substation at Alto Catumbela out of commission. Many of the power lines in the central area and in the northwest have also been cut by UNITA. As a consequence of the poor reliability of the power supply, self-generation is widespread in Angola. Many businesses have installed their own generators and produce approximately 20 percent of the total electricity generated in the country (notwithstanding the fact that the cost of generation may be as high as 50-70 cents per kWh, compared to 5-10 cents per kWh for a conventional hydro/thermal plant). Among the few large consumers relying exclusively on their own power generation is the Fina refinery, which is supplied by a 12 MW naphtha-fired gas turbine.

2.7 Of Angola's six dams, only three (Cambambe, Biopo, and Matala) are functioning. GoA has announced plans for a major rehabilitation of its electric sector infrastructure, reaching USD 200 million. Under the recent renovation plan, Cambambe, Biopo and Matala would receive USD 70; 3; and 20 million, respectively, for renovation and upgrades. The other three dams (Mabubas, Lumaun, and Gove) were severely damaged during the war. Thus, most of the present system urgently requires rehabilitation. When Cambambe is upgraded, an additional HV transmission line from Cambambe to Luanda will be required and this scenario leads to a very unbalanced system where all generating units would be located far from the main load center (Luanda), and all along the same axis. The dependence of Luanda on the transmission lines from Cambambe would then become very critical.

2.8 The USD 2 billion, 520-megawatt (4 x 130 MW) Capanda hydroelectric project is reportedly under construction on the Kwanza River, some 200 km east of Cambambe, which is itself about 360 km from Luanda. The first set is not expected to be commissioned before the year 2002. In total, it would generate 2.4 TWh, more than twice the country's current production level.

2.9 GoA, however, should weigh carefully the feasibility of rehabilitating this hydroelectric capacity against the time and cost it would take to put up cheaper and faster alternatives on stream. The rehabilitation of the dams is expected to require more time and investment than would be necessary to build new gas-fired power plants. The new gas plants could also be used during load-shedding periods. The critical factor here is the availability of cost effective gas supplies in the Luanda area.

Preliminary Analysis of Gas Options

2.10 The AGI has conducted a preliminary assessment of the option of developing natural gas (i) for the conversion of existing oil-fired power plants, including the two 56.8 MW gas turbines in Luanda, which currently burn Jet B fuel; and (ii) as an alternative to costly, lengthy hydro-electric schemes. The detailed results of the assessment are given in Chapter 3, and briefly summarized below.

2.11 With regard capital investment required to increase power generation, two main options have been assessed: (i) building new thermal units (gas turbines), and (ii) upgrading the existing Cambambe hydro plant. The latter proves in no case economically competitive, compared with either gas oil- or natural gas-fired gas turbines.

2.12 Thus, adding a new gas turbine in Luanda as soon as possible appears to be the best solution to meet growing demand in the short run. It would also contribute to free the city from its too high dependence on the unreliable Cambambe generation and transmission subsystem. In a first analysis, a typical unit size of 50 MW seems to be best fitted to the system requirements and characteristics.

2.13 The preliminary assessment deals with power options and has not investigated, so far, the feasibility of possible schemes to develop gas supply, which should be one of the objectives of the AGI's second phase. Calculated over the entire period, the economic value (at user's gate) of natural gas for power generation reaches a high USD 3.36/mmbtu, which makes prospects for gas availability quite attractive. The first gas turbine would then serve as a basis for the progressive erection of 2x150 MW combined-cycle plants in the Luanda region. The total discounted saving, compared to the best development programme without natural gas, is over USD 43 million. Gas turbines should be designed for dual-fuel operation, to allow using gas oil or other liquid fuels in the initial years, if necessary, and switching to natural gas as soon as it would become available.

2.14 If no natural gas can be supplied at economic cost, then that first 50 MW gas turbine, fed with gas oil, would be the only thermal unit in the optimal investment programme; it should be followed by the completion of the Capanda hydro plant. The reason is that gas oil-fired thermal units cannot compete, on a pure economic basis, with the completion of the first phase of Capanda. They only find their justification in their short construction time (to fill the initial, short-term gap) and in strategic considerations on supply security for the Luanda area.

2.15 Natural gas consumption, in that least-cost development option, is only a few million cubic meters in the initial year, but increases almost linearly to a peak of about 340 mmcm in 2011.

Conventional Industry

2.16 The market potential for natural gas usage in the industrial sector is not particularly promising in the short term. Among the most acute problems for industrial rehabilitation are shortages of raw materials, unreliable supplies of water and electricity, and labor instability. The decline in domestic production of many raw materials has been especially critical in the decline in local manufacturing. The deterioration of the water supply system has also damaged many industries, especially breweries, as have cut-offs in electricity supply. Furthermore, labor problems, a consequence of a shortage of skilled workers and disincentives to work for wages in an inflated economy, have depleted the local work force. Foreign exchange constraints have also prevented many industries from importing the necessary raw materials and spare parts to maintain or enhance their production capacity.

2.17 The main branches of the heavy industry were the assembly of vehicles; production of steel bars and tubes, zinc sheets, and other metal products; assembly of radio and television sets; and manufacture of tires, batteries, paper, and chemical products. There have been large investments to rehabilitate steel production. In 1983 the government established a company to process scrap metal. The Northern Regional Enterprise for the Exploitation of Scrap Metal, located in Luanda, had the capacity to process 31,000 tons of scrap metal and produced 7,125 tons of processed scrap metal in 1985, its first year of operation. The government planned to establish another company in Lobito, with the financial support of the United Nations Development Programme (UNDP) and the United Nations Industrial Development Organisation (UNIDO).

2.18 The government also controlled the automobile assembly industry through a company founded in 1978 after a Portuguese firm had been nationalized. The company consisted of a factory that assembled light vehicles; a plant, possibly at Viana, that assembled buses and heavy trucks; and a factory at Cunene that built the chassis for all these vehicles. The light vehicle factory was particularly affected by the cutback in imports in 1982, and its output fell in 1983-84 to only 20 percent of capacity. Likewise, the bus and truck plant has experienced shutdowns because of a lack of parts.

2.19 As the industrial sector recovers from the decline due to civil war, these industrial areas would be potential big gas consuming centers. The only other industrial consumers who could theoretically switch to gas and absorb enough gas to justify investments in gathering and transport are the cement factory and the Luanda refinery, both located near the Kwanza field. At the 1989 output (720,000 tpy of clinker) the cement plant's consumption of fuel oil is equivalent to 70 to 100 mmcmy, depending on the route used to produce clinker. With the proposed expansion of the factory to 1.5 million tons of clinker, the fuel demand would about double. However, the cement plant currently uses surplus fuel oil costing about USD 1.8/mmbtu, a value which gas would need to directly compete with, as the technological premium brought by gas in the cement industry is negligible. The same argument applies to the Luanda refinery, whose annual oil requirements are equivalent to approximately 40 mmcmy.

2.20 Other industries, which at present account for only 20 percent of the country's boiler fuel consumption, would annually require 20-50 mmcmy of gas. For a SSA country, such potential is far from negligible, and compares favorably with other mid-size countries. However, the cost of gas delivered at the user's gate depends only to some extent on the cost of gas at wellhead. Gathering and transmission costs may represent a significant component of overall cost, whenever the potential market is located several dozens of kilometers away from the gas source. Therefore, a preliminary survey of a Gas Master Plan is required to assess the actual potential market in the industrial sector, along with the potential for large, stand alone projects that could "drive" the market in lowering transmission cost.

Large scale projects

2.21 Larger projects are outside the scope of the AGI. They are briefly mentioned here to give a comprehensive overview of the current potential market for natural gas.

2.22 ***Ammonia***. In addition to power generation, so far the only large-scale project which could use a sizeable amount of natural gas as feedstock is an ammonia/urea plant proposed for the Soyo area. The project has been under study since the early 1980s. Economies of scale require a minimum capacity of 1.500 t/d of ammonia. World-class plants typically have an installed capacity of 1,500 of ammonia and cost about USD 450 to 500 million. Capacity utilization in these plants typically ranges from 80-90 percent. The maximum output would, therefore, be about 450,000 tpy of ammonia (based on 330 days of production). Given the very limited domestic demand for nitrogen fertilizers (about 12,000 tpy in 1990), the plant would have to sell most of its output abroad. Such plant would potentially require about 400 mmcmy of gas per year. As the normalization process continues in Angola and the agricultural production rises, the domestic demand of nitrogen fertilizers coupled with export potential might justify a plant of this scale, provided that gas may be supplied at very low cost.

2.23 ***LNG Export***. World-wide LNG trade expanded by 44 percent between during the 1990s, rising from 73 bcm in 1990 to 113 bcm in 1998. The region with the largest LNG consumption is Asia, which accounted for 75 percent of LNG imports in 1998. Japan is by far the largest user, importing 58 percent of the world's production, followed by South Korea (12 percent) and France (9 percent). Europe as a whole, the current market closest to Angola, accounts for 21 percent of LNG trade with 24 bcm per year.

2.24 Although LNG trade grew by no more than 1.5 percent in 1998, LNG consumption is expected to increase in the future. New LNG schemes have come in operation in the past few months (Trinidad and Tobago in the Caribbean; Bonny LNG in Nigeria), while Qatar will be able soon to supply both Europe and south Asia. Developing Asia, however, which was expected to experience annual gas consumption increases of almost 8 percent, has been reviewed downwards due to the "Asian Crisis". Much of this growth would have fuelled electricity generation. While the Far East is expected to continue being a major consumer, potential new markets are likely to emerge or to develop in Southeast Asia (China, India, Thailand, and Philippines), in western Europe (Greece, Turkey, Spain, and Portugal), and in isolated markets such as South Africa and Brazil.

2.25 Among the regional markets, South Africa is closest to Angola, which can absorb significant quantities of gas and support a meaningful gas development program. However, considering all potential supply sources, Angola may not be the most cost effective supplier for South Africa's gas needs, since it would have to compete with Mozambique's Pande and Namibia's Kudu gas fields, both of which are located closer to South Africa than is Cabinda. With regard to power generation, coal is still the fuel of choice in power generation and is expected to remain so in the foreseeable future due to low production cost. In these conditions, the need for large, low cost quantities of gas for South Africa, which could draw on Angola's reserves, seems not warranted in the next ten years.

2.26 The option of using offshore cryogenic loading technology for loading LNG, although it is still in the development stage, might provide a significant breakthrough in production as well as loading of LNG offshore. Since the production capacity of the LNG production vessel would be substantially less than that of a typical land based liquefaction plant, this could give a country like Angola significant marketing advantages, such as being able to sell smaller volumes and still have viable production operations. Typical markets for this gas are Brazil, North America and western Europe, all within economic range of present day LNG ships. These are also markets where LNG to gas to power sector demand is growing, with Independent Power Producers seeking innovative ways to supply their projects. LNG would also help diversify exports and export revenues for Angola and Sonangol.

LPG for Households

Main Issues

2.27 A more promising option for associated gas utilization is the production of LPG. At present, the only facility in which associated gas is recovered for LPG production is located offshore of Cabinda and stored on a moored LPG tanker. The output, consisting of a 66:34 mixture of propane and butane, is currently at 2.5 million bpy. Sales on the international market contribute to about 2 percent of the country's earnings from energy exports. The sales of LPG in the domestic market have been about 60,000 t/y in average over the past few years.

2.28 In Angola, as in most central and western African countries, urban development has dramatically increased the demand in household energy, in particular in larger cities. While a large majority of energy needs are currently met by biomass, mostly charcoal and woodfuel, charcoal production is actually responsible for massive deforestation, extending as far as several hundreds of kilometers away from major cities. Substituting LPG for biomass would save 140 kgs of woodfuel or 50 kgs of charcoal for each LPG cylinder of regular size. In addition, ever-increasing distances between production and consumption sites add to the price of biomass, a source of energy highly sensitive to transportation costs. Moreover, hundred of thousands of land mines scattered all over the country make it extremely dangerous, often deadly, for rural populations, in particular children, to collect wood from which charcoal is made. Developing access of urban population to bottled LPG would thus mitigate the adverse consequences of heavy dependence on biomass of rural as well as urban economies.

2.29 Commercial uses; however, most storage and bottling facilities are in poor condition, when not idle, due to war economy and lack of resources. While upside market potential remains very high, LPG production in the province of Cabinda exceed by far the province's needs, and additional quantities could be shipped to the country's major consumption centers, in particular when the gas flaring reduction scheme is implemented. Further development of LPG industry is hampered by institutional, economic and technical issues, including inappropriate administered prices and industry's operating margins, excessive subsidies, and limited receiving, storage, bottling and transportation facilities. Lack of such facilities keep handling and distribution costs high; moreover, it prevents LPG from being widely distributed throughout the country. Thus, LPG consumption is concentrated in Luanda, which typically represents 90 percent of total country' consumption, while other large cities, even when located on the coast or along a railway, are hardly supplied.

2.30 Against this background, Angola's oil and associated gas production has been increasing rapidly over the last few years. Developing LPG is part of this effort undertaken by GoA to reduce the amount of energy wasted in gas flaring, as stripping and marketing LPG (and condensate) from the gas stream will improve the global economics of any gas recovery scheme, whether gas is marketed for power generation or industrial use, or reinjected.

Scope of the Project

2.31 To promote the use of LPG across the country is one of the AGI's objectives. The scope of a project has been designed, the objective of which is two-fold: (i) to assess the benefits generated by increasing the use of LPG at country level, and (ii) to devise a documented action plan aiming at designing the subsequent steps required to make LPG development achieve the benefits assessed in the first phase. Because the project includes several tasks in various areas, it is broken down into two main phases that include five components that should be carried out in a subsequent manner. The first phase is dedicated to assessing the potential market and the possible sources of supply, and evaluating the requirements in upgrading existing facilities and building additional equipment, as well as estimating the construction and operating costs. The second phase will deal with the institutional matters, including pricing, evaluate the benefits of the project and set up the action plan.

2.32 *Phase 1:* In a first step, *Component 1* would identify the potential market and the existing sources of supply; it includes two Tasks:

- Task a : Analysis of the domestic market, including the small and medium-size commercial market, such as restaurants, bakeries, laundries and workshops. Market assessment would rely on the review of existing market analyses where available, as well as *ad hoc* surveys where required. The analysis would be conducted in Luanda and in a limited number of selected typical cities. The result would consist of medium-term projections (tentatively 7 to 10 years) covering the population, number of households, location of demand, and specific consumption. Competing energy sources would be surveyed and their economic costs and availability would be determined.

- Task b : Identification of existing sources of supply of LPG and forecasted growth in Angola as well as in the sub-region, including access to markets. Review of the availability of transportation means (road, rail, ship), including short-term plans to improve / restore them. Determination of new / additional means that would lead to de-bottlenecking access to the main markets and decreasing transportation costs from supply sources to hubs / receiving terminals. Cost of supply.

2.33 *Component 2.* Once the potential market is assessed and based on the findings, a pre-feasibility study would be conducted of the rehabilitation, the extension and the implementation of the facilities required to make LPG available to the potential users in a selected number of cities, likely candidates to become a distribution hub. At this stage, the pre-feasibility study only needs to provide a rough description of the facilities required and reasonable cost estimates of the distribution chain (storage, bottling, transportation, retail). Completing Task 3 would lead to the determination of the cost of distributing LPG according to the type of container and the location of the market.

2.34 *Phase 2: Component 3* would study the institutional arrangements that should govern the development of the LPG activity, including the structure of the industry; access to supply; access to market; price structure; economic regulation. It would also pay attention to the safety rules that must apply to the industry as well as to the use of LPG.

2.35 *Component 4* would assess the economic benefits deriving from developing LPG, as well as the benefits to the environment generated by substituting LPG for biomass, in particular, in terms of deforestation mitigation and improved health conditions and standard of living.

2.36 *Component 5* would draw a short and medium-term Action Plan to structure the project. In addition to task description, scheduling and phasing, the Action Plan would evaluate specific measures that would make the project sustainable, such as the development of the 6-kg cylinder so as to make LPG more accessible to lower income households, and of cylinder and burner/stove packages, as well as the establishment of credit arrangements for the purchase of packages by households who are equipped with.

Conclusion

2.37 Once recent moves to bring peace are consolidated, Angola has the potential to emerge as a key player in Africa's oil industry both as a major producer and exporter. Once the operations of the IOCs are no longer constrained by security problems, petroleum exploration activity is expected to extend to other unexplored and prospective sedimentary basins, which are estimated to be four times larger than the current producing areas. However, the current flurry of activity is focused on crude production and natural gas continues to be neglected. Over 70 percent of the gas production is flared, which in addition to being a serious waste of a potentially valuable non-renewable resource has been a significant source of environmental pollution. The more than twenty years of civil war continues to hinder the development of on-shore facilities, which are the essential base for any capital intensive gas development facilities. The GoA is expected to make sustained efforts to bring back peace and start economic reconstruction and to win the confidence of the international business community to attract private sector investment in the natural gas upstream as well as downstream sector.

2.38 Gas projects, especially international projects, have a long maturity period from decision time to completion; 5 to 10 years is not uncommon in LNG or similar rigid and capital intensive projects because of the complexity in design, implementation, contract negotiation and commissioning. They do have the advantage, where they are well managed, of providing secure and consistent revenues, albeit lower than for oil. In light of the increasing awareness of the environmental damage resulting from gas flaring and the fact that abundant gas reserves, both associated and non-associated, exist in Angola, gas utilization has a great potential for growth. In addition to diversifying the petroleum export base and hence the export revenues, this development will also lead to increased upstream investments by the participants to expand gas production at various supply points.

3

Gas for Power Generation

Methodology and Assumptions

3.1 In many cases, the power sector appears as the only one capable of absorbing sufficient quantities of gas to make an initial gas infrastructure profitable. This may then serve as a backbone for further gas transmission and distribution projects aimed at supplying other types of consumers such as industrial zones or densely populated residential areas. Accordingly, the objective of the power study is to analyze technical and economical conditions for introducing natural gas within the power system, either in existing or future generating units.

3.2 The question of natural gas availability (reserves estimates, production profiles and costs) is not dealt with in this part of the study. The potential market of natural gas is calculated without consideration to supply limitations, i.e. under the assumption that enough cheap gas can be made available to power plants in the considered zone. For calculation purposes (generating units ranking by merit order), the economic cost of gas at the plant gate is taken as 1.5 USD/GJ[2] in all cases. However, the actual *netback* utilization value of gas is calculated in all cases independently of that assumption. The netback value and the foreseen gas consumption profile will constitute the basis for the final appraisal of the economics of gas use in the power sector.

3.3 A set of possible development scenarios have been established regarding the power generation system. They have been optimized using a computerized linear programming model. The model has been designed for optimizing the development of a generation and transmission system, taking account of investment and operating costs. It is generally applied to problems where geographical aspects are to be considered (plant site comparison, generation or transmission investment balancing, etc) and then features a geographical description of the network topology. In the present case, these network aspects have not been included in the modeling exercise, though they are important and should be covered in a later stage. The model has been used to optimize the choice of generating units and their commissioning years, and the whole system operation (unit commitment) on a yearly and seasonal basis. Finally, the model results are synthesized in

[2] 1 GJ = 0.95 mmbtu. 1.5 USD/GJ = 1.58 USD/mmbtu

economic calculation sheets that will be used to compare the total discounted economic costs and the netback value of gas for all considered scenarios.

3.4 All calculations are made on an economic basis, i.e. aiming at optimizing decisions from the point of view of the national economy. No national taxes, duties or subsidies are therefore included the cost of any commodity. All costs (both investment and operation) incurred to supply electricity over the study period (20 years) are discounted at a uniform rate of 10 %.

3.5 Angola owns significant hydro-electrical resources, that constitute the basis of its power generation system. Thermal units are generally limited to peak load generation, emergency backup and supply to remote areas. Present thermal units are either diesel engines or gas turbines. The future development of thermal generation in these countries will probably face the same limitations, and it is very unlikely that heavy base-load thermal units such as steam generators would be appropriate in this kind of small-scale systems. Therefore, only two types of thermal units have been considered among the options for developing the generation systems: single-cycle gas turbines (GT) and combined-cycle gas turbines (CCGT). The main standard characteristics for these units have been determined on the basis of a market review, as explained below.

3.6 Fig. 3.1 shows the observed relationship between nominal power and unit price (USD/kW), for 76 best-selling gas turbines[3]. The figure also shows a regression curve calculated to best fit the observations. Based on this curve, one may estimate an average equipment cost for different typical sizes of gas turbines. Two typical sizes have been considered here:

- 50 MW: In order to have a real available ("derated") power of 50 MW in running conditions in African countries, one will have to install a unit of, say, 55 MW nominal power. Using the regression curve, the typical cost will be 282 USD/kW, or 310 USD per derated kW. This covers only the equipment itself, FOB factory; it does not include items such as step-up transformers, switchgear, fuel treatment and compression equipments, foundations, freight and insurance, real estate, contingencies, etc. In order to estimate the total turnkey installed plant price, one typically may add between 50 and 100 % to the equipment cost. Assuming 75 % in the present case, this leads to a total installed cost, excluding taxes and duties as well as financial and debt service charges, of 543 USD/derated kW.

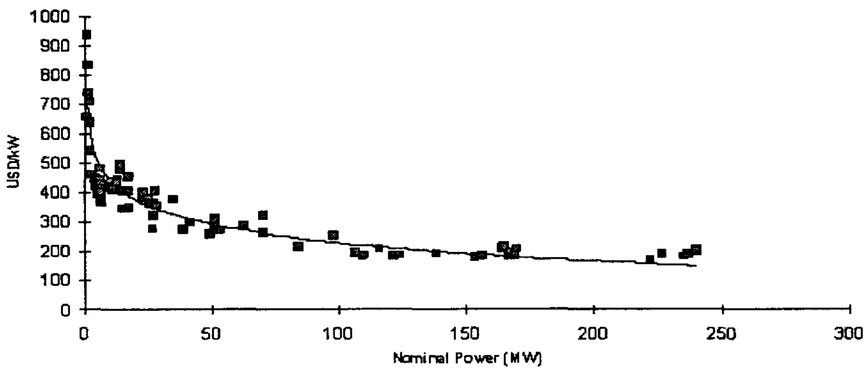
- 100 MW: Similarly, a real 100 MW available power will correspond to some 110 MW installed capacity. The regression curve gives a typical cost of 219 USD/kW, or 241 USD/derated kW. Assuming 75 % non-equipment costs, it gives a total 421 USD/derated kW.

- The investment cost is assumed to be 5 % higher for dual-fired turbines, designed to operate either on a natural gas or on a gas oil basis.

[3] Source: average price data published in the *Gas Turbine World Handbook.*

Figure 3.1: Turbo-generator Price Levels

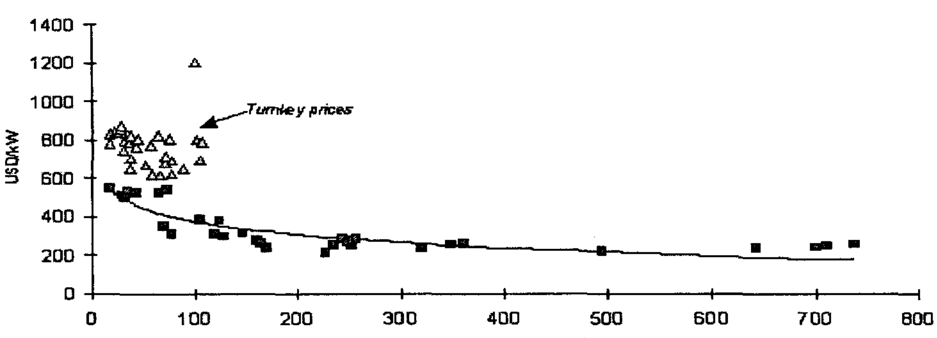
Note: Prices are for equipment only, FOB factory.



Add between 75 and 100% for turnkey prices

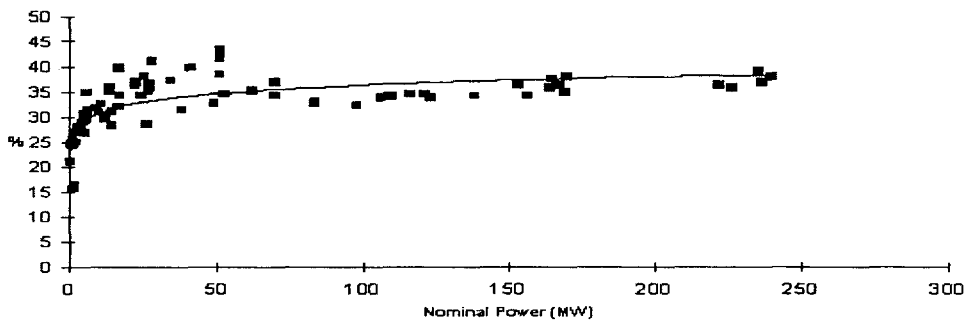
3.7 Fig. 3.2 shows the observed relationship between nominal power and unit price (USD/kW), for 31 commonly marketed combined-cycle packages (same data source as for gas turbines). The regression curve, calculated to best fit the observations, allows to estimate the equipment cost for typical sizes of combined-cycle plants. Taking account of the relatively small size of the studied systems, units of no more than 150 MW have been taken as standard options for the present study. As for single-cycle gas turbines, nominal power has been taken as 10 % higher than derated power. The equipment cost, estimated for a 165 MW (nominal) unit, is 323 USD/kW, i.e. 356 USD per derated kW. Considering the higher degree of uncertainty on the investment cost of combined-cycle plants (due to the greater impact of site requirements, of competitive market conditions), the non-equipment share of the total cost has been taken as 100 % of the equipment cost. Thus, the turnkey investment cost that has been used for calculation purposes is 711 USD per derated kW.

Figure 3.2: Combined Cycle Price Levels



3.8 Fig.3.3 shows the ISO thermal efficiencies (LHV basis) for the same set of 76 single-cycle gas turbines as considered above. Though data dispersion is greater, a similar regression calculation has been performed. For a 50 MW (55 MW nominal) unit, it gives a 34.8 % net efficiency under ISO conditions (15°C, sea level and 60 % relative humidity). Assuming a 10 % degradation under real African climatic and operating conditions, that leads to a 31.3 % net efficiency. For a 100 MW gas turbine, the same calculation results in a 36.3 % ISO efficiency and 32.7 % under actual conditions.

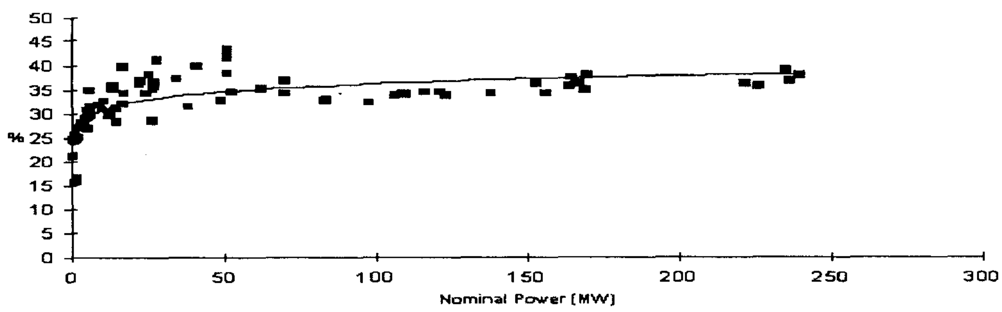
Figure 3.3: Typical Turbo-generator Efficiency



Note: Net efficiencies under ISO conditions (15°Celsius, sea level and 60% relative humidity.

3.9 On the basis of a similar regression analysis (fig.3.4.), the ISO thermal efficiency for a 150 MW combined-cycle package (165 MW nominal) is estimated at 51.7 %; under operating conditions, the actual efficiency is assumed to be 10 % lower, i.e. 46.5 %.

Figure 3.4: Typical Combined Cycle Efficiency



3.10 Assumptions have been made on the cost of competing fuels. As a matter of fact, gas oil is the best alternative to gas for feeding future thermal units (either gas turbines or combined-cycle units) and is used as the reference energy carrier. The price ratio of gas oil over crude oil is based on actual observations of the spot price of gas oil in the NWE market (Rotterdam) vs. the OPEC basket. Over the observation period the index shows at 128. That ratio has thus been adopted for the present study. The future evolution of crude oil price is assumed to be flat, at 21 USD per barrel, FOB loading port. The corresponding gas oil price is 26.88 USD/bl, or 194 USD/ton, FOB Rotterdam.

3.11 For calculation purposes, natural gas is assumed to have a lower calorific value of 37 MJ/cm after treatment (LPG extraction). It is assumed to be supplied at a minimum pressure of 25 bar, which is sufficient for most gas turbines and combined-cycle units.

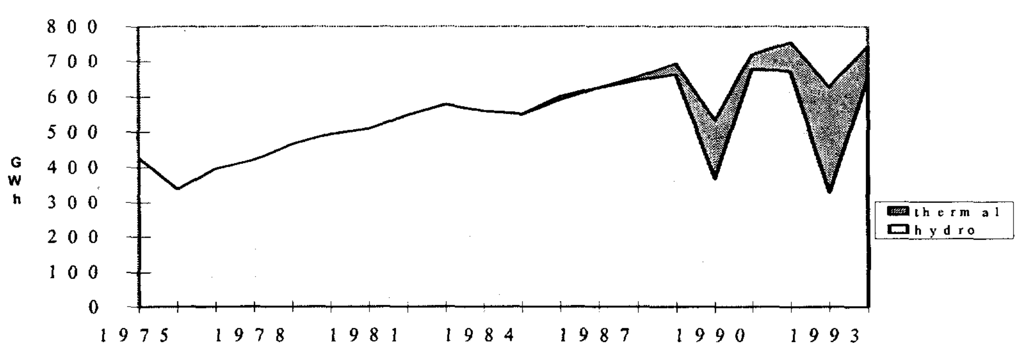
Infrastructure

3.12 The public utility in charge of electricity production and transmission in Angola is the ENE (Empresa Nacional de Electricidade). The former power utility of northern Angola, SONEFE, was integrated into ENE in 1992. Low and medium voltage distribution in Luanda is under the responsibility of EDEL (Empresa de Electricidade de Luanda).

3.13 The Angolan power system is subdivided into three main independent subsystems: one covering the southern region (Namibe, Lubango, Matala); one in the centre of the country (Lobito, Benguela, Huambo), and the northern system supplying Luanda and its surroundings. The latter is by far the most important (79% of total energy sold in 1994), followed by the central and southern systems (10% and 7% respectively, the balance corresponding to Cabinda and other local systems). The project of interconnecting these subsystems has been formulated several times in the past, but the war situation and, as a consequence, the very poor condition of the present infrastructure have risen other priorities. Therefore, only the northern system will be studied here and no interconnection is considered over the study period.

3.14 Angola is endowed with large hydroelectric resources which are well distributed all over the country. Up to the end of the 1980's, hydropower had always accounted for more than 90% of total supply; since then, however, thermal units have been extensively used (see fig. 3.5) to overcome the frequent black-outs mainly due to acts of sabotage on the transmission lines.

Figure 3.5: Northern System: Historical Generation Breakdown



3.15 The largest supplier of the northern system is Cambambe, a run-of-river hydroelectric plant of 4 x 45 MW located 175 km southeast of Luanda, on the Kwanza river. The firm power at the end of the dry season (i.e. between August and October) is 90 MW. The average annual energy is 1,080 GWh, and the firm energy on a dry year is about 900 GWh. Units 1 and 2 (commissioned in 1962 and 1963) have been revised between 1985 and 1990. Units 3 and 4, commissioned 10 years later, have not been revised yet and their operation has now become very critical; one of them may actually be considered as out of order. Table 3.1 summarizes the main characteristics of the Cambambe plant.

Table 3.1: Main Characteristics of the Cambambe Hydro Plant

Commissioning Year	1962-1973
Decommissioning Year	*not planned*
Type	Run-of-river
Normal Water Head (m)	86
Number of Units	4
Installed Power (MW)	180
Firm Power in dry season (MW)	117
Min. Power in extra-dry season (MW) *	90
Availability (%)	83
Average Energy (GWh)	1080
Firm Energy (GWh)	900

(* extra-dry season = minimal flow statistically observed every 20 years)

3.16 The system also comprises a set of three gas-turbine units located in the industrial zone of Luanda (Cazenga):

- GT1 was commissioned in 1979 and completely refurbished in 1995. The available capacity is 24 MW. During more than ten years, that unit has been used exclusively for backup purposes; that explains that its total operation time is only 9,000 hours.

- GT2 is identical to GT1; it was commissioned in 1985 and is presently out of order due to a failure of the fuel injection system. The total operation time is 20,400 hours, which also appears as moderate.

- GT3 is a 40 MW gas turbine which was commissioned in April 1992. It has been intensively used during its first two years of existence but serious problems have occurred as soon as 1993 (maybe due to manufacturing defaults). Its total operation time is now 9,600 hours. The unit is presently used at reduced power (10 to 15 MW max.) and should be totally stopped and overhauled.

3.17 The main technical features of these thermal units are presented on Table 3.2 below. For historical reasons linked to fuel availability at the refinery, all three gas turbines operate on jet fuel B rather than gas oil. In the present situation, the economic value of Jet fuel B is high because it reduces the ability of the refinery to produce jet A1 which has, consequently, to be partly imported to supply the transportation market. Should natural gas be made available in Luanda, it seems that all three turbines could be easily adapted to that fuel, at low cost.

Table 3.2: Technical Data on Existing and Future Thermal Plants

Unit	*Fuel type*	*Installed Power (MW)*	*Net Efficiency (%)*	*Specific Con-sumption (kg/kWh)*	*Lubricant Con-sumption (kg/kWh)*	*Equiv Energy Consum-ption (MJ/kWh)*	*Variable Mainte-nance Cost (USD/ MWh)*	*Total Variable Cost (USD/MWh)*	*Avail abi-lity (%)*
Luanda GT1	Jet B	24	20.1%	0.415	0.01	20.27	10.00	158.45	70
Luanda GT2	Jet B	24	20.1%	0.415	0.01	20.27	10.00	158.45	70
Luanda GT3	Jet B	40	25.5%	0.332	0.005	15.26	10.00	121.76	75
TGGO50	Diesel Oil	50	31.3%	0.27	0.002	11.96	8.00	96.09	82
TGGN50	Natural Gas	100	31.3%		0.002	11.96	8.00	25.94	82
TGGO100	Diesel Oil	50	32.7%	0.26	0.002	11.47	8.00	92.47	82
TGGN100	Natural Gas	100	32.7%		0.002	11.47	8.00	25.21	82
CCGN	Natural Gas	150	46.5%		0.002	8.20	8.00	20.31	82

3.18 On the same site of Cazenga, 5 diesel units, totaling 6 MW, were commissioned in 1995. They are exclusively dedicated to water pumping and are operated separately from the public network.

3.19 As a consequence of the poor reliability of power supply, self-generation is wide-spread in Angola, both in the industry and for commercial and residential uses. In most cases, at least in Luanda, self-generation equipment is used as a backup, by consumers connected to the public grid. Among the few large consumers relying exclusively on their own generation means, one may mention the Fina refinery, which is permanently supplied by a 12 MW naphtha-fired gas turbine installed in the facility in 1986. The public grid does not buy energy from the self-producers.

3.20 The northern HV transmission network is practically limited to the 220 kV line linking the Cambambe dam to Luanda. It was built in 1963 and designed for a maximum 200 MW active power transit. It is operating under precarious conditions, consequence of sabotage and lack of maintenance during the civil war. Frequent interruptions have occurred in the supply of the Luanda region, especially since 1988; they presumably have amounted to some 500 to 600 hours per year on the average.

3.21 A second 220 kV line was built in 1984 linking Cambambe and Luanda via Viana, also with a 200 MW maximum transit capacity. Unfortunately, this line has almost never been in operation and has been completely destroyed by continuous sabotage actions in the late 1980s. Two other HV transmission lines connect Cambambe respetively to the eastern cities of Ndalantado and Malanje, and to Gabela and Sumbe in the south. They have also been partly destroyed several times and have been out of order since 1993.

System Operation

3.22 In a typical year, the northern system peak load reaches 135 MW, with a total energy consumption of 630 GWh. More than 99 % of that consumption is concentrated in the Luanda province (which covers the capital city and its close suburbs). That situation is partly due to the unavailability of transmission lines to most other cities of the northern grid; however, even under better network conditions, the share of Luanda in the total system demand has never been lower than 92 % over the past 25 years.

3.23 The total energy production amounts to 743 GWh, which means that technical and non-technical losses together represent some 15 % of it. Cambambe generates some 88 % of the total energy (652 GWh), while the Luanda gas turbines produce the remaining 91 GWh. Initially designed for peak and backup supply, these gas turbines had never generated more than 10 GWh per year before 1989, when systematic sabotage of the Cambambe lines became the rule. In 1993, which was the most critical year, thermal generation reached 299 GWh or 48 % of the total energy.

3.24 On the basis of sales statistics provided by ENE and EDEL, it has been possible to make a reasonably accurate breakdown of energy sales into the main economic sectors (see Table 3.3 below). Some assumptions had to be made regarding the EDEL sales, since only the proportion of MV and LV sales was available; in first approximation, industry, public services and commercial sector are assumed to represent equal shares of the EDEL MV sales.

Table 3.3: Northern System: Electricity Sales Breakdown Estimates (GWh)

		Industry	Admin./ Publ.serv	Comm	Agric.	House-holds	Total
ENE special customers	EDEL	50	50	50	0	225	375
	Others	58	39	6	25		128
	subtotal	108	89	56	25	225	503
ENE ordinary customers		35	45	7	14	20	122
Total Northern system		143	134	63	40	245	625

Demand Forecast

3.25 Electricity consumption has been severely constrained in the past by the war situation and unceasing supply interruptions. In spite of the booming population growth in Luanda (thought to have more than doubled since 1987), the apparent growth of electricity demand has been very low for the same period (+ 0.8 % on an annual basis). On a longer period, one may observe that the 1994 energy consumption was only 18 % higher than that of in 1974, the last year before independence. Stagnation results from the collapse of the industrial activity (presently working at around 10 % of its nominal capacity) on the one hand, and from the inability of the supply system to meet the potential demand (i.e. strong suppressed demand), on the other hand.

3.26 The estimation of suppressed demand is, as usual, somewhat delicate. However, a rough calculation can be made, assuming that when the Cambambe line is unavailable (i.e. some 600 hours a year on the average), load shedding measures have to be taken in Luanda since the available thermal power can supply only about half of the city's demand. On that basis, non served energy in Luanda was estimated at 22 GWh in 1994. In addition, the potential demand from the cities of the northern system which are presently not supplied may be estimated, on the basis of past consumption records, to about 50 GWh. The total suppressed demand would have been about 72 GWh in 1994 for the whole northern system.

3.27 Considering the prudent optimism currently prevailing regarding the political reconciliation process, it is assumed that the peace situation will take over and allow to carry out urgent infrastructure overhaul works within the next few years. Under this assumption, the national economy is expected to take-off, and energy demand, which was strongly constrained during more than 20 years might then increase very quickly, especially in the industry sector, to recover its natural trend in the medium- and long-term. Accordingly, the demand growth projection adopted here for industry is 12 % per year over the whole period. This may appear very high, but one has to consider that present demand - extremely low – does not represent the real, unconstrained demand.

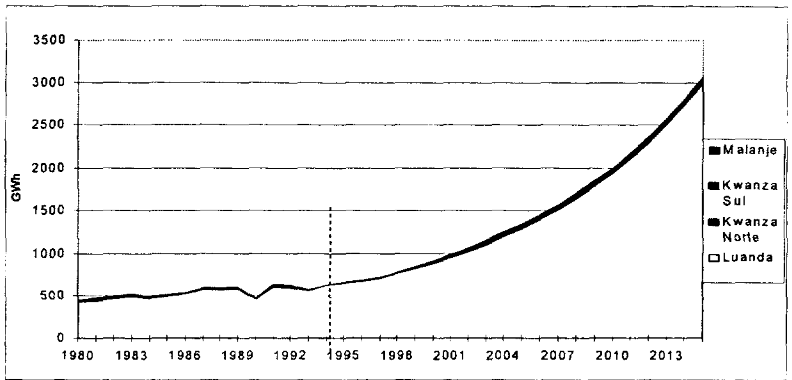
3.28 Demand from the other sectors, however, will probably be negatively influenced, in the next few years, by the much required tariff redefinition, from the present subsidized low prices to prices set on economic bases. In spite of the application of a social price for the first 100 kWh/month, this is expected to have a strong short-term impact especially on the consumption of the residential sector. Therefore, the assumed annual growth rates are, for the first 3-year period, 0 % in the residential sector, 2 % in public services and agriculture and 5 % in the commercial sector; then: 10 % in the commercial sector and 5 % in the other ones.

3.29 The rehabilitation of transmission lines to Malanje and the other cities presently disconnected from the northern grid is expected to be given a lower priority than the re-establishment of a firm supply to Luanda. Accordingly, the restoration of energy consumption up to its historical maximum level is assumed to take 5 years for the Kwanza Norte province, which is close to Cambambe, and 7 years for the provinces of Malanje and Kwanza Sul. After that, a moderate growth rate of 3 % per year has been adopted for those provinces. All details regarding demand projections are given in Table 3.4 and plotted on fig. 3.10. It may be seen that, based on the above considerations, the resulting overall demand growth rate would be, on the average, 4.4 % per year for the first two years and 8.4 % per year afterwards. The average annual growth over the whole period (until 2015) would then be 7.8 %, starting from the actual sales, or 7.3 % if the estimated suppressed demand is added to the current figure.

Table 3.4: Northern System - Power and Energy Demand Forecasts (GWh)

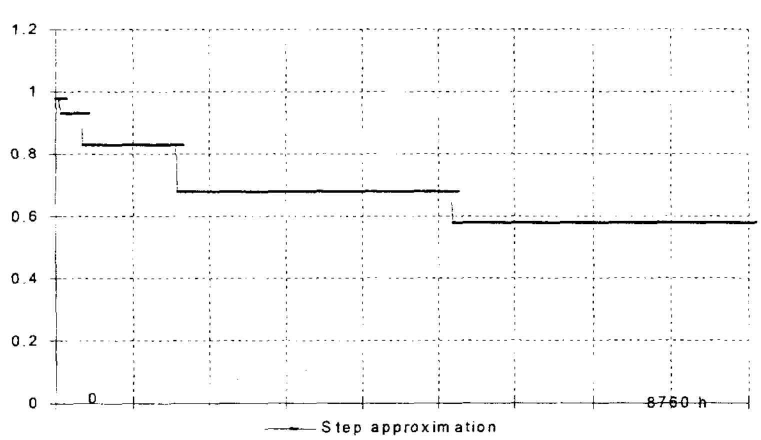
	Luanda Sales Industry	*Luanda Sales Adm./Publ.*	*Luanda Sales Commercial*	*Luanda Sales Agriculture*	*Luanda Sales Households*	*Total Sales Luanda*	*Kwanza Norte*	*Kwanza Sul*	*Malanje*	*Total Energy Sales (GWh)*	*Energy to be Produced (GWh)*	*Growth rate %*	*Annual Utilization (h)*	*Peak (MW)*
1980						423	12	0.7	10	445	494		5683	87
1981						436	24	0.8	11	472	509	2.9%	5987	85
1982						467	13	0.8	11	493	547	7.5%	5526	99
1983						494	13	0.7	12	520	579	5.9%	5680	102
1984						468	12	0.4	13	494	560	-3.4%	6217	90
1985						494	12	0.3	6	513	552	-1.4%	5995	92
1986						520	10	0.6	8	539	602	9.1%	6687	90
1987						569	12	0.5	12	594	627	4.1%	6460	97
1988						569	12	0.5	12	593	655	4.6%	6425	102
1989						578	11	0.3	7	597	694	5.9%	6035	115
1990						449	13	0.1	6	468	533	-23.2%	4674	114
1991						598	14	0.1	19	631	721	35.3%	5678	127
1992						592	11	5.4	21	629	756	4.9%	5818	130
1993						559	6	4.2	1	569	628	-16.9%	4987	126
1994	143	134	63	40	245	625	6	0.0	0	630	745	18.6%	5518	135
1995	161	136	66	40	245	648	7	0	0	656	775	4.0%	5518	140
1996	180	139	70	41	245	674	9	0	1	685	809	4.5%	5518	147
1997	201	142	73	42	245	703	12	0	2	717	847	4.7%	5518	154
1998	226	149	80	44	257	756	15	0	3	774	915	8.0%	5518	166
1999	253	156	88	46	270	814	19	1	5	838	991	8.3%	5518	180
2000	283	164	97	49	283	876	24	1	8	910	1075	8.6%	5518	195
2001	317	172	107	51	298	945	25	3	13	986	1165	8.3%	5518	211
2002	355	181	118	54	313	1020	26	5	21	1072	1267	8.8%	5518	230
2003	398	190	129	56	328	1101	27	6	22	1155	1365	7.8%	5518	247
2004	445	199	142	59	345	1191	27	6	22	1246	1473	7.9%	5518	267
2005	499	209	157	62	362	1288	28	6	23	1346	1590	8.0%	5518	288
2006	559	220	172	65	380	1396	29	6	24	1455	1719	8.1%	5518	312
2007	626	231	190	68	399	1513	30	6	24	1574	1860	8.2%	5518	337
2008	701	242	208	72	419	1642	31	6	25	1705	2014	8.3%	5518	365
2009	785	255	229	75	440	1784	32	7	26	1848	2184	8.4%	5518	396
2010	879	267	252	79	462	1939	33	7	27	2006	2370	8.5%	5518	430
2011	984	281	278	83	485	2110	34	7	27	2179	2574	8.6%	5518	467
2012	1102	295	305	87	509	2299	35	7	28	2369	2799	8.7%	5518	507
2013	1235	309	336	92	534	2506	36	8	29	2578	3047	8.8%	5518	552
2014	1383	325	369	96	561	2734	37	8	30	2809	3320	8.9%	5518	602
2015	1549	341	406	101	589	2986	38	8	31	3063	3620	9.1%	5518	656

Figure 3.6: Historical and Forecasted Energy Demand (Northern System)



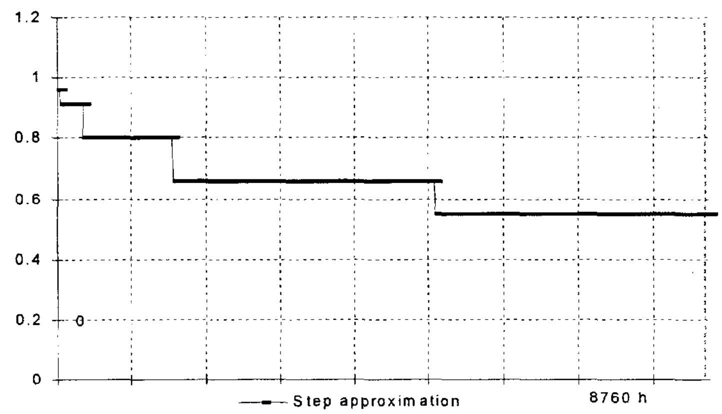
3.30 Two 5-step approximations of the load duration curves have been elaborated for the present study, respectively for the dry season (from June to November, fig. 3.11) and for the wet season (from December to May, fig. 3.12). Their shapes are quite similar, but the peak level is 10 % lower in the dry season. These curves correspond to a constant annual load factor of 63 %, or 5,518 hours of average utilization. Since no detailed historical load curves are available, the proposed curves have been built on the basis of typical load curves, adjusted to the required load factor. This is acceptable a preliminary appraisal, but more precise load curve definitions would be required for later in-depth analyses. Options for Power Generation

Figure 3.7: Dry Season Load Curve (Jun-Nov)



3.31 Most of the present system urgently requires rehabilitation. This is true at all levels: generation, transmission and distribution (not to mention institutional, regulatory, organizational and commercial aspects). The rehabilitation of the Luanda distribution system has already started, financed by several bilateral aid funds. Regarding generation and transmission infrastructures, the first priorities are:

Figure 3.8: Wet Season Load Curve (Dec-May)



Note: For modelling reasons, both curves are presented here on an annual basis (8760 h) and in proportion of the seasonal peak. The seasonal peak in the dry season is approximately 90% of the absolute annual peak.

- overhaul of Luanda's second gas turbine; the cost of fixing the technical problem in the fuel pumping system is estimated at 120,000 USD;
- Rehabilitation of the Cambambe-Luanda 220 kV line. Though it is presently operating, it is reported to be in very poor condition. The link with Cambambe is vital for Luanda since thermal capacity is insufficient to supply the whole city. The estimated rehabilitation cost is 18 million USD.
- Repair of the third (and most recent) gas turbine whose combustor shows fissures and has to be replaced. The estimated cost is 3 million USD, with no consideration to the alleged commercial responsibility of the manufacturer.

3.32 The rehabilitation of the second 220 kV line between Cambambe and Luanda through Viana, which has been destroyed and lies in mined areas, appears in the second rank of priorities. Highly desirable for the security of supply to Luanda, this line becomes absolutely necessary in case of completion of the Capanda hydroelectric project (see below).

3.33 Considering the load growth prospects as above detailed, and even if the urgent rehabilitation works are executed in due time, new power generation capacity is required. The present portfolio of projects focuses on two hydroelectric sites, both located on the same Kwanza river: the completion of the Capanda plant, and the upgrading of the existing Cambambe plant. Their main characteristics are summarized in Table 3.5.

3.34 The Capanda hydroelectric project was initiated in the mid-80s by the Russian-Brazilian-Angolan consortium Gamek (Gabinete de Aproveitamento do Meio Kwanza). It was expected to be completed in 1993. However, due to the war situation, it was stopped at a stage estimated as 60 % of completion. Capanda is located some 200 km east of Cambambe (360 km from Luanda), upstream on the same river. The ultimate plant capacity is set at 520 MW, but only 260 MW are to be installed in the first stage (2 x 130 MW). The cost of completing the first stage was estimated by the Gamek at 307 million USD, including the 220 kV line from Capanda to Cambambe. The technical work duration is said to be between 3 and 4 years.

Table 3.5: Northern System: Considered Hydroelectric Projects Main Data and Assumptions

	*Capanda 1**	*Capanda 2*	*Cambambe upgrade (dam raising)*
Type	*Reservoir*	*Reservoir*	*Run-of-river*
River	*Kwanza*	*Kwanza*	*Kwanza*
Installed Power (MW)	260	260	+80
Firm Power in dry season (MW)	245	245	+52
Min. Power in extra-dry season (MW)	235	235	+40
Availability (%)	82	82	82
Average Energy (GWh)	2170	230	-
Firm Energy (GWh)	1080	230	172
Estimated Investment Cost (million USD)	307	117	150
Cost per kW (USD)	1181	450	1875

Note: Investment costs are given without interests during construction.
(*) Capanda 1 is partly completed; its construction has been suspended in 1992

3.35 Even if the Capanda project was not a least-cost solution when it was initiated, it may be considered a sound economical decision to complete it, since the remaining investment corresponds to 1,180 USD/kW, which is low for a dam-based hydroelectric plant. In addition, it would serve as a regulator for the Cambambe plant and increase its firm annual energy production by 100 GWh. Nevertheless, the investment remains important and may be somewhat under-evaluated because of probable damages and losses in the equipment stored in Capanda and Luanda.

3.36 The Cambambe plant had initially been designed for a 4 x 65 MW installed capacity, but the dam height had subsequently been reduced and the installed power limited to 4 x 45 MW. The project still exists of raising the dam in order to reach the initially planned power, thus adding 80 MW to the installed capacity. The estimated cost is 150 million USD and the works would last a minimum of 3 years. The project faces many constraints and its feasibility is not proven because all units of the power house are now in a poor condition and have no long remaining lifetime, and because the additional power cannot be transported to Luanda without prior rehabilitation of the second line from Cambambe to Luanda.

3.37 Among the possible future generation options, several typical thermal units have been considered: 50 or 100 MW conventional gas turbines, either gas oil or natural gas-fired, and 150 MW combined-cycle units. All of them are assumed to be located in the Luanda region. The main technical and economical features of these units, according to their type and size, have been defined in part 1 of the present document. As also mentioned in that chapter, the *a priori* economic cost of natural gas has been taken as 1.50 USD/GJ. Considering that any new gas oil-fired power plant would put the Luanda refinery in a position of net gas oil importer, the economic cost of gas oil has been caculated as imported from Western Europe. That calculation is detailed in Table 3.6, together with similar estimates for jet fuel and naphtha that are consumed in existing gas turbines. The resulting total economic cost of gas oil is 313 USD/t CIF in Luanda, or 7.36 USD/GJ.

3.38 A last supply option that might be considered consists in establishing a new HV transmission line from the huge hydro plant of Inga, in the Democratic Republic of Congo, located on the River Congo, some 500 km north of Luanda. That project, however, would have to face many problems of political and technical nature, such as those linked to the crossing of one of the heavily mined regions of the country. Therefore, it seems unrealistic to consider that project among the short- to medium-term invesment options. It might be taken into account in the longer term but, due to the absence of any preliminary study and/or data, it has not been considered in the present study.

Table 3.6: Fuel Cost Assumptions (Taxes and Duties Excluded)

		USD/bbl	*USD/ton*	*USD/GJ*
Gasoil Density	0.86			
Gasoil L.H.V. (MJ/kg)	42.5			
Jet B Density	0.83			
Jet B L.H.V. (MJ/kg)	43.2			
Crude OPEC Basket FOB		**21**		
Gasoil economic cost (based on import parity)				
Gasoil FOB Rotterdam		26.88	194	
Europe-Africa Freight Cost			30	
Selling Price on the African Market			224	
Int. Margins Gasoil (%)				
Gasoil CIF Luanda			313	**7.36**
Jet A1 economic cost (based on import parity)				
Jet A1 FOB Rotterdam		29.57	224	
Europe-Africa Freight Cost			30	
Selling Price on the African Market			254	
Int. Margins Jet A1 (%)				
Jet A1 CIF Luanda			356	**8.24**
Naphta economic cost (based on export parity)				
Naphta FOB Rotterdam		22.85	173	
Europe-Africa Freight Cost			30	
Selling Price on the African Market			203	
Regional Freight Cost			15	
Naphta FOB export Luanda			188	
Int. Margins Naphta (%)				
Naphta CIF Luanda			284	**6.58**
Jet B economic cost (based on refinery trade-off: JetB = 30% Jet A1 + 59% Naphta + 11% Gasoil))				
Jet B CIF Luanda			316	**7.32**
Natural Gas (a priori assumption)				**1.50**
Lubricants			**1700**	

Scenarios Without Natural Gas: Definition and Discussion

3.39 As already mentioned, additional generation capacity is required. Since the Capanda hydro plant is not expected to be completed before 2003 at the earliest, the only options for the first generation investment are either new thermal units (gas turbines) or the upgrading of the existing Cambambe hydro plant (raising of the dam to increase the installed capacity by 80 MW). Let us point out that it is quite an optimistic assumption to consider that the Cambambe dam raising could be completed in such a short delay.

3.40 Based on the above considerations, two sets of scenarios (investment plans) have been elaborated and compared on an economic basis: the first set excludes all natural gas-fired thermal units; the scenarios of the second set, on the contrary, are partially or fully based on that kind of units.

3.41 **Scenario 1** is based exclusively on hydro projects; it comprises the upgrading of Cambambe, followed by the first and second stages of Capanda (260 MW each). An additional HV transmission line from Cambambe to Luanda is required when Cambambe is upgraded. The total discounted cost of the system, calculated with a 10 % discount rate, amounts to 281 million USD (see Table 3.7). It must be noted that this scenario leads to a very unbalanced system, with all generating units located far from the main load center (Luanda), and in the same direction. The dependence of Luanda on the transmission lines from Cambambe would then become very critical. This clearly appears on the generation pattern chart at the bottom of Table 3.7.

3.42 **Scenario 2** presents a thermal-hydro variant where a 50 MW gas oil-fired gas turbine is commissioned; the rest of the program is the same as in scenario 1, but somewhat shifted in time. The postponement of investment costs overbalances the increase in operating cost due to thermal generation, and the total discounted cost becomes 275 million USD, i.e. more than 6 million USD below scenario 1 (see Table 3.8). Another comparative advantage of this scenario lies in the reduction of the dependence of Luanda on remote hydro plants.

3.43 **Scenarios 3** and **4** are based on a first gas oil-fired gas turbine (respectively 100 MW and 50 MW), followed by Capanda 1 and 2 (without upgrading of Cambambe). Both scenarios result in an important lowering of total discounted costs, down to 223 million USD with the 100 MW gas turbine, and 213 million USD with the smaller unit (see tables 3.17 and 3.18). The economic advantage of the smallest unit is due to the fact that thermal units are used intensively during a few years only, before completion of Capanda 1. That utilization is too limited to take advantage of the better thermal efficiency of the large-size (100 MW) gas turbines.

3.44 **Scenario 5** is exclusively thermal (gas oil-fired gas turbines) up to the year 2010, when the first unit of Capanda is completed. The disappointing economic result (315 million USD, see Table 3.11) is due to the very high cost of gas oil-based generation.

3.45 To conclude on the comparison of this first set of scenarios, it appears that the best option for the first generation investment, if no natural gas is made available to the Luanda region, is a 50 MW gas oil-fired gas turbine. Afterwards, the completion of the Capanda hydro plant, in two successive phases, appears as the least-cost solution.

Scenarios With Natural Gas: Definition and Discussion

3.46 If natural gas is available at a relatively low cost in the Luanda area (1.50 USD/GJ as a first guess for the present study), the situation changes drastically. **Scenario 6** is based on a 50 MW, natural gas-fired gas turbine followed by the two stages of Capanda.

The resulting discounted cost is 184 million USD (see Table 3.12), i.e. 29 million USD less than the least-cost scenario without gas (scenario 4, which is similar but with a gasoil-fired gas turbine). Not surprisingly, the netback value of natural gas is just below the assumed cost of gas oil (7.30 USD/GJ). However, it must be noted that the new gas turbine only operates significantly during a few years, until Capanda 1 is commissioned. This appears very clearly on the generation pattern chart at the bottom of Table 3.2, where the evolution of natural gas consumption has also been plotted.

3.47 Introducing more natural gas units into the system lead to better economic results, especially when combined cycle units are considered. **Scenario 7** is based on one 150 MW combined cycle plant (constructed by stages, i.e. two 50 MW gas turbines and one 50 MW heat recovery steam turbine) followed by Capanda 1 and 2. The total discounted cost falls down to 172 million USD and the average netback value of gas is 4.50 USD/GJ (see Table 3.13). In this scenario, significant gas quantities are used until the year 2006, with a maximum annual consumption of 171 mmcm in 2004.

3.48 The share of natural gas in the system is increased again in **scenario 8**, with the construction of two 150 MW combined-cycle units instead of one. This lowers the total cost by an additional 2.8 million USD compared to scenario 7 (see Table 3.14) and thus becomes the least-cost solution among those considered here. The total gas consumption is higher than in scenario 7 (up to 343 mmcmy in 2011), and it is spread over a longer period. As a consequence, the average netback value of gas is lower (3.20 USD/GJ) but still very satisfactory.

3.49 A scenario exclusively based on natural gas units (without completion of Capanda even in the long-term) has also been envisaged (**scenario 9**, see Table 3.15). The investment program then consists in 3 combined-cycle plants of 150 MW each and one additional 50 MW gas turbine. Quite logically, natural gas consumption is higher than for all other scenarios (up to 560 mmcmy at the end of the period). The total discounted cost of the system, however, is 4.7 million USD higher than in scenario 8, which thus remains the least-cost option.

3.50 It must be pointed out that, in all considered scenarios, replacing 50 MW gas turbines by larger-size (100 MW) units results in a slight but not negligible economic cost increase. That was already the case when considering gas oil-fired turbines. For open-cycle gas turbines, the explanation is again to be found in their low average utilization, and is reinforced by the low fuel cost in the case of natural gas. For combined-cycle units, the problem lies more in the fact that such 300 MW plant do not fit satisfactorily the system size, leading to temporary over-capacity.

Table 3.7: Economic Calculation Sheet - Scenario 1

Country: Angola

Scenario: Cambambe upgrade in 1998
Capanda 1 in 2004
Capanda 2 in 2013

Monetary Unit:	MUSD	
Discount Rate:	10%	
DDO Cost:	7.36	USD/GJ
Natural Gas Cost:	**1.50**	USD/GJ
GT Inv.cost:		USD/kW
CC Inv.cost:		

	Generation Investments			*Transmission Investments*	*Operating*	*Total*	*Natural Gas*	*G.T.*	*Natural Gas*	*TG50*	*TG100*	*CC*	*Tot.gaz*	*Hydro*	*Old GT*
	Cambambe Upgrade	*Capanda 1*	*Capanda 2*	*New line Cambambe-Luanda*	*Cost*		*Consumption (Mm3/y)*	*Aver. Oper. Time (h)*	*Consumption (Million GJ/y)*	*GWH*	*GWH*	*GWH*			
Invest.Cost	*150*	*307*	*117*	*26.3*											
1995	38					**37.5**			0.0						
1996	38			6.6	0.3	**44.3**	0						0	800	2
1997	38			17.1	0.6	**55.1**	0						0	835	5
1998	**38**			**2.6**	0.0	**40.1**	0	0		0			0	905	
1999					0.0	**0.0**	0	0		0			0	982	
2000					0.1	**0.1**	0	0		0			0	1063	1
2001		55			9.4	**64.5**	0	0		0			0	1072	78
2002		111			21.7	**132.4**	0	0		0			0	1072	182
2003		99			33.3	**131.9**	0	0		0	0		0	1072	275
2004		**43**			0.0	**43.1**	0	0		0	0		0	1456	0
2005					0.0	**0.0**	0	0		0	0		0	1571	0
2006					0.0	**0.0**	0	0		0	0		0	1701	0
2007					0.0	**0.0**	0	0		0	0		0	1838	0
2008					0.0	**0.0**	0	0		0	0		0	1991	0
2009					0.0	**0.0**	0	0		0	0		0	2160	0
2010			17.5		0.0	**17.5**	0	0		0	0		0	2346	0
2011			29.1		0.0	**29.2**	0	0		0	0		0	2547	0
2012			58.3		0.8	**59.1**	0	0		0	0		0	2760	4
2013			**11.7**		0.0	**11.7**	0	0		0	0		0	3011	0
2014					0.0	**0.0**	0	0		0	0		0	3283	0
2015					0.0	**0.0**	0	0		0	0		0	3578	0
Res. Value	*-73*	*-202*	*-106.6*	*-7*		***-389***									

Total Discounted Cost: **281.4** MUSD

Average Netback Value Of Gas: #Div/0! USD/GJ

Table 3.8: Economic Calculation Sheet - Scenario 2

Monetary Unit:	MUSD	
Discount Rate:	10%	
DDO Cost:	7.36	USD/GJ
Natural Gas Cost:	**1.50**	USD/GJ
GT Inv.cost:	543	USD/kW
CC Inv.cost:		

Country: Angola

Scenario: 50 MW GO.GT in 1998
Cambambe upgrade in 2003
Capanda 1 & 2 in 2006 & 2014

	Generation Investments				*Transmission*	*Operating*	*Total*	*Natural Gas*	*G.T.*	*Natural Gas*	*TG50*	*TG100*	*CC*	*Tot.gaz*	*Hydro*	*Old GT*
	50 MW GT	*Cambambe Upgrade*	*Capanda 1*	*Capanda 2*	*New line Cambambe-Luanda*	*Cost*		*Consumption (Mm3/y)*	*Aver. Oper. Time (h)*	*Consumption (Million GJ/y)*	*GWH*	*GWH*	*GWH*			
Invest.Cost	*27.2*	*150*	*307*	*117*	*26.3*											
1995							**0.0**			0.0						
1996	4.1					0.3	**4.3**	0						0	800	2
1997	13.6					0.6	**14.2**	0						0	835	5
1998	**9.5**					1.3	**10.8**	0	280		14			14	892	
1999						7.9	**7.9**	0	1640		82			82	900	
2000		38				15.8	**53.3**	0	3240		162			162	900	1
2001		38			6.6	24.3	**68.3**	0	4900		245			245	900	6
2002		38			17.1	34.6	**89.1**	0	6660		333			333	900	21
2003		**38**	55		**2.6**	26.4	**121.7**	0	5480		274			274	1072	1
2004			111			37.5	**148.1**	0	7180		359			359	1073	25
2005			99			51.2	**149.7**	0	7180		359			359	1072	139
2006			**43**			0.0	**43.1**	0	0					0	1702	
2007						0.0	**0.0**	0	0					0	1838	
2008						0.0	**0.0**	0	0					0	1991	
2009						0.0	**0.0**	0	0					0	2160	
2010						0.0	**0.0**	0	0		0			0	2345	
2011				17.5		0.0	**17.5**	0	0		0			0	2547	0
2012				29.1		0.5	**29.6**	0	100		5			5	2761	0
2013				58.3		4.8	**63.1**	0	340		17			17	2993	
2014				**11.7**		0.0	**11.7**	0	0					0	3284	
2015						0.0	**0.0**	0	0					0	3578	
Res.Value	*-3*	*-94*	*-219*	*-110*	*-13*		***-439***									

Total Discounted Cost:	**275.1**	MUSD
Average Netback Value Of Gas:	#DIV/0!	USD/GJ

Table 3.9: Economic Calculation Sheet - Scenario 3

Country: Angola

Scenario: 100 MW GO.GT
Capanda 1 in 2004
Capanda 2 in 2013

Monetary Unit:	MUSD
Discount Rate:	10%
DDO Cost:	7.36 USD/GJ
Natural Gas Cost:	**1.50** USD/GJ
GT Inv.cost:	421 USD/kW
CC Inv.cost:	

	Generation Investments			*Transmission Investments*	*Operating Cost*	*Total*	*Natural Gas Consumption (Mm3/y)*	*G.T. Aver. Oper. Time (h)*	*Natural Gas Consumption (Million GJ/y)*	*TG50 GWH*	*TG 100 GWH*	*CC GWH*	*Tot.gaz*	*Hydro*	*Old GT*
	100 MW GT	*Capanda 1*	*Capanda 2*	*New line Cambambe-Luanda*											
Invest.Cost	*42.1*	*307*	*117*	*26.3*											
1995						**0.0**			0.0						
1996	6.3				0.3	**6.6**	0						0	800	2
1997	21.1				0.6	**21.6**	0						0	835	5
1998	**14.7**				1.3	**16.0**	0	140			14		14	892	
1999					7.6	**7.6**	0	820			82		82	900	
2000					15.1	**15.1**	0	1640			164		164	900	
2001		55			23.2	**78.4**	0	2510			251		251	900	
2002		111		6.6	32.8	**150.0**	0	3540			354		354	900	
2003		99		17.1	41.4	**157.0**	0	4460			446		446	900	1
2004		**43**		**2.6**	0.0	**45.7**	0	0					0	1456	
2005					0.0	**0.0**	0	0					0	1571	
2006					0.0	**0.0**	0	0					0	1702	
2007					0.0	**0.0**	0	0					0	1838	
2008					0.0	**0.0**	0	0					0	1991	
2009					0.0	**0.0**	0	0					0	2161	
2010			17.5		0.2	**17.7**	0	30			3		3	2343	
2011			29.1		1.0	**30.2**	0	110			11		11	2536	
2012			58.3		3.6	**61.9**	0	390			39		39	2727	
2013			**11.7**		0.0	**11.7**	0	0					0	3011	
2014					0.0	**0.0**	0	0					0	3284	
2015					0.0	**0.0**	0	0					0	3578	
Res.Value	*-4*	*-202*	*-107*	*-14*		***-326***									

Total Discounted Cost: **223.0** MUSD

Average Netback Value Of Gas: #DIV/0! USD/GJ

Table 3.10: Economic Calculation Sheet - Scenario 4

Monetary Unit:	MUSD	
Discount Rate:	10%	
DDO Cost:	7.36	USD/GJ
Natural Gas Cost:	**1.50**	USD/GJ
GT Inv.cost:	543	USD/kW
CC Inv.cost:		

Country: Angola

Scenario: 50 MW GO.GT in 1998
Capanda 1 in 2003
Capanda 2 in 2013

	Generation Investments			*Transmission Investments*	*Operating Cost*	*Total*	*Natural Gas Consumption (Mm3/y)*	*G.T.Aver. Oper. Time (h)*	*Natural Gas Consumption (Million GJ/y)*	*TG50 GWH*	*TG100 GWH*	*CC GWH*	*Tot gaz*	*Hydro*	*Old GT*
	50 MW GT	*Capanda 1*	*Capanda 2*	*New line Cambambe-Luanda*											
Invest.Cost	*27.2*	*307*	*117*	*26.3*											
1995						**0.0**			0.0						
1996	4.1				0.3	**4.3**	0						0	800	2
1997	13.6				0.6	**14.2**	0						0	835	5
1998	**9.5**				1.3	**10.8**	0	280		14			14	892	
1999					7.9	**7.9**	0	1640		82			82	900	
2000		55			15.8	**70.9**	0	3240		162			162	900	1
2001		111		6.6	24.3	**141.5**	0	4900		245			245	900	6
2002		99		17.1	34.6	**150.2**	0	6660		333			333	900	21
2003		**43**		**2.6**	0.0	**45.7**	0	0					0	1347	
2004					0.0	**0.0**	0	0					0	1457	
2005					0.0	**0.0**	0	0					0	1571	
2006					0.0	**0.0**	0	0					0	1702	
2007					0.0	**0.0**	0	0					0	1838	
2008					0.0	**0.0**	0	0					0	1991	
2009					0.0	**0.0**	0	0					0	2160	
2010			17.5		0.2	**17.7**	0	60		3			3	2343	
2011			29.1		1.1	**30.2**	0	220		11			11	2536	1
2012			58.3		4.5	**62.8**	0	620		31			31	2727	8
2013			**11.7**		0.0	**11.7**	0	0					0	3011	
2014					0.0	**0.0**	0	0					0	3284	
2015					0.0	**0.0**	0	0					0	3578	
Res.Value	-3	*-193*	*-107*	*-13*		***-315***									

Total Discounted Cost:	**212.9**	MUSD
Average Netback Value Of Gas:	#Div/0!	USD/GJ

Table 3.11: Economic Calculation Sheet - Scenario 5

Monetary Unit:	MUSD	
Discount Rate:	10%	
DDO Cost:	7.36	USD/GJ
Natural Gas Cost:	**1.50**	USD/GJ
50 MW GT Inv.cost:	543	USD/kW
100 MW GT Inv.cost:	421	

Country: Angola

Scenario: 50 MW GO.GT in 1998
2 x 100 MW GO.GT in 2003 & 2007
Capanda 1 in 2010

	Generation Investments				*Transmission New line Cam-bambe-Luanda*	*Operating Cost*	*Total*	*Natural Gas Consumption (Mm3/y)*	*G.T. Aver. Oper. Time (h)*	*Natural Gas Consumption (Million GJ/y)*	*TG50 GWH*	*TG100 GWH*	*CC GWH*	*Tot gaz*	*Hydro*	*Old GT*
	50 MW GT	*100 MW GT*	*100 MW GT*	*Capanda 1*												
Invest.Cost	*27.2*	*42.1*	*42.1*	*307*	*26.3*											
1995							**0.0**			0.0						
1996	4.1					0.3	**4.3**	0						0	800	2
1997	13.6					0.6	**14.2**	0						0	835	5
1998	**9.5**					1.3	**10.8**	0	280		14			14	892	
1999						7.9	**7.9**	0	1640		82			82	900	
2000						15.8	**15.8**	0	3240		162			162	900	1
2001		6.3				24.3	**30.6**	0	4900		245			245	900	6
2002		21.1				34.6	**55.6**	0	6660		333			333	900	21
2003		**14.7**				41.4	**56.1**	0	2973		0	446		446	900	1
2004						51.5	**51.5**	0	3713		8	549		557	900	0
2005			6.3			62.1	**68.5**	0	4467		22	648		670	900	0
2006			21.1			74.6	**95.6**	0	5307		78	718		796	900	6
2007			**14.7**	55		86.8	**156.7**	0	3752			938		938	900	
2008				111	6.6	100.9	**218.1**	0	4364		6	1085		1091	900	
2009				99	17.1	116.6	**232.2**	0	5036		17	1242		1259	900	1
2010				**43**	**2.6**	0.2	**45.9**	0	12		0	3		3	2343	
2011						1.0	**1.0**	0	44		0	11		11	2536	0
2012						3.6	**3.6**	0	156		0	39		39	2727	0
2013						8.6	**8.6**	0	372		0	93		93	2918	
2014						17.1	**17.1**	0	736			184		184	3099	
2015						39.2	**39.2**	0	1668		8	409		417	3161	
Res.Value	*-3*	*-15*	*-23*	*-254.4*	*-20*		***-315***									

Total Discounted Cost: **315.0** MUSD

Average Netback Value Of Gas: #DIV/0! USD/GJ

Table 3.12: Economic Calculation Sheet - Scenario 6

Country: Angola

Scenario: 50 MW NG.GT in 1998
Capanda 1 in 2003
Capanda 2 in 2013

Monetary Unit:	MUSD	
Discount Rate:	10%	
DDO Cost:	7.36	USD/GJ
Natural Gas Cost:	**1.50**	USD/GJ
GT Inv.cost:	570	USD/kW
CC Inv.cost:		

	Generation Investments			*Transmission Investments*	*Operating Cost*	*Total*	*Natural Gas Consumption (Mm3/y)*	*G.T.Aver. Oper. Time (h)*	*Natural Gas Consumption (Million GJ/y)*	*TG50 GWH*	*TG100 GWH*	*CC GWH*	*Tot gaz*	*Hydro*	*Old GT*
	50 MW GT	*Capanda 1*	*Capanda 2*	*New line Cambambe-Luanda*											
Invest.Cost	*28.5*	*307*	*117*	*26.3*											
1995						**0.0**			0.0						
1996	4.3				0.3	**4.6**	0		0.0				0	800	2
1997	14.3				0.6	**14.8**	0		0.0				0	835	5
1998	**10.0**				0.4	**10.3**	4	280	0.2	14			14	892	
1999					2.1	**2.1**	25	1640	0.9	82			82	900	
2000		55			4.4	**59.5**	50	3240	1.9	162			162	900	1
2001		111		6.6	7.1	**124.3**	76	4900	2.8	245			245	900	6
2002		99		17.1	11.2	**126.8**	104	6660	3.8	333			333	900	21
2003		**43**		**2.6**	0.0	**45.7**	0	0	0.0	0			0	1347	0
2004					0.0	**0.0**	0	0	0.0				0	1457	0
2005					0.0	**0.0**	0	0	0.0				0	1571	0
2006					0.0	**0.0**	0	0	0.0				0	1702	0
2007					0.0	**0.0**	0	0	0.0				0	1838	0
2008					0.0	**0.0**	0	0	0.0				0	1991	0
2009					0.0	**0.0**	0	0	0.0				0	2160	0
2010			17.5		0.2	**17.7**	1	60	0.0	3			3	2343	0
2011			29.1		1.1	**30.2**	3	220	0.1	11			11	2536	1
2012			58.3		4.5	**62.8**	10	640	0.4	32			32	2727	7
2013			**11.7**		0.0	**11.7**	0	0	0.0				0	3011	0
2014					0.0	**0.0**	0	0	0.0				0	3284	0
2015					0.0	**0.0**	0	0	0.0				0	3578	0
Res.Value	*-3*	*-193*	*-107*	*-13*		***-315***									

Total Discounted Cost: **183.6** MUSD

Average Netback Value Of Gas: 7.3 USD/GJ

Table 3.13: Economic Calculation Sheet - Scenario 7

Country: Angola
Scenario: 2 x 50 MW NG.GT in 1998 & 2003

+ 50 MW ST (CC) in 2005
Capanda 1 & 2 in 2007 & 2014

Monetary Unit:	MUSD	
Discount Rate:	10%	
DDO Cost:	7.36	USD/GJ
Natural Gas Cost:	**1.50**	USD/GJ
GT Inv.cost:	570	USD/kW
CC Inv.cost:	711	

	Generation Investments					*Transmission*	*Operating Cost*	*Total*	*Natural Gas Consumption (Mm3/y)*	*G.T. Aver. Oper. Time (h)*	*Natural Gas Consumption (Million GJ/y)*	*TG50 GWH*	*TG100 GWH*	*CC GWH*	*Tot.gaz*	*Hydro*	*Old GT*
	50 MW GT	*50 MW GT*	*50 MW ST*	*Capanda 1*	*Capanda 2*	*New line Cambambe-Luanda*											
Invest.Cost	*28.5*	*28.5*	*49.65*	*307*	*117*	*26.3*											
1995								**0.0**			0.0						
1996	4.3						0.3	**4.6**	0		0.0				0	800	2
1997	14.3						0.6	**14.8**	0		0.0				0	835	5
1998	**10.0**						0.4	**10.3**	4	280	0.2	14			14	892	
1999							2.1	**2.1**	25	1640	0.9	82			82	900	
2000							4.4	**4.4**	50	3240	1.9	162			162	900	1
2001		4.3					7.1	**11.4**	76	4900	2.8	245			245	900	6
2002		14.3					11.2	**25.5**	104	6660	3.8	333			333	900	21
2003		**10.0**	7.4				11.7	**29.1**	139	4460	5.1	446			446	900	1
2004			24.8	55			15.2	**95.1**	171	5490	6.3	549			549	900	8
2005			**17.4**	111		6.6	13.7	**148.2**	140	4473	5.2			671	671	900	0
2006				99		17.1	16.9	**132.5**	167	5307	6.2			796	796	900	6
2007				**43**		**2.6**	0.0	**45.7**	0	0	0.0				0	1838	0
2008							0.0	**0.0**	0	0	0.0				0	1991	0
2009							0.0	**0.0**	0	0	0.0				0	2160	0
2010							0.1	**0.1**	1	20	0.0			3	3	2343	0
2011					17.5		0.2	**17.7**	2	73	0.1			11	11	2536	0
2012					29.1		0.8	**29.9**	8	260	0.3			39	39	2727	0
2013					58.3		2.2	**60.5**	19	620	0.7			93	93	2918	0
2014					**11.7**		0.0	**11.7**	0	0	0.0				0	3284	0
2015							0.0	**0.0**	0	0	0.0				0	3578	0
Res.Value	*-3*	*-10*	*-22*	*-228*	*-110*	*-17*		***-390***									

Total Discounted Cost:	**172.5**	MUSD
Average Netback Value Of Gas:	4.5	USD/GJ

Table 3.14: Economic Calculation Sheet - Scenario 8

Monetary Unit:	MUSD	
Discount Rate:	10%	
DDO Cost:	7.36	USD/GJ
Natural Gas Cost:	**1.50**	USD/GJ
GT Inv.cost:	570	USD/kW
CC Inv.cost:	711	

Country: Angola

Scenario: 3 x 50 MW NG.(GT-CC) in 1998-2005
3 x 50 MW NG.(GT-CC) in 2007-2010
Capanda 1 in 2012

	Generation Investments					*Transmission*	*Operating Cost*	*Total*	*Natural Gas Consumption (Mm3/y)*	*G.T.Aver. Oper. Time (h)*	*Natural Gas Consumption (Million GJ/y)*	*TG50 GWH*	*TG100 GWH*	*CC GWH*	*Tot.gaz*	*Hydro*	*Old GT*
	2 x 50 MW GT	*50 MW ST*	*2 x 50 MW GT*	*50 MW ST*	*Capanda 1*	*New line Cambambe-Luanda*											
Invest.Cost	*28.5*	*49.65*	*28.5*	*49.7*	*307*	*26.3*											
1995								**0.0**			0.0						
1996	4.3						0.3	**4.6**	0		0.0				0	800	2
1997	14.3						0.6	**14.8**	0		0.0				0	835	5
1998	**10.0**						0.4	**10.3**	4	280	0.2	14			14	892	
1999							2.1	**2.1**	25	1640	0.9	82			82	900	
2000							4.4	**4.4**	50	3240	1.9	162			162	900	1
2001	4.3						7.1	**11.4**	76	4900	2.8	245			245	900	6
2002	14.3						11.2	**25.5**	104	6660	3.8	333			333	900	21
2003	**10.0**	7.4					11.7	**29.1**	139	4460	5.1	446			446	900	1
2004		24.8					15.2	**40.0**	171	5490	6.3	549			549	900	8
2005		**17.4**	4.3				13.7	**35.3**	140	4473	5.2			671	671	900	0
2006			14.3				16.9	**31.1**	167	5307	6.2			796	796	900	6
2007			**14.3**				19.2	**33.4**	198	4690	7.3	14		924	938	900	0
2008			14.3	7.4			23.0	**44.7**	231	5425	8.6	43		1042	1085	900	6
2009			**10.0**	24.8	55		26.7	**116.7**	282	5036	10.4	182		1077	1259	900	1
2010				**17.4**	111	6.6	29.4	**164.0**	302	4817	11.2			1445	1445	900	0
2011					99	17.1	34.2	**149.8**	343	5470	12.7			1641	1641	900	6
2012					**43**	**2.6**	0.8	**46.5**	8	130	0.3			39	39	2726	0
2013							1.9	**1.9**	19	310	0.7			93	93	2918	0
2014							3.8	**3.8**	39	617	1.4			185	185	3099	0
2015							8.5	**8.5**	87	1393	3.2			418	418	3161	0
Res.Value	*-13*	*-22*	*-34*	*-35*	*-272*	*-22*		***-398***									

Total Discounted Cost:	**169.7**	MUSD
Average Netback Value Of Gas:	3.2	USD/GJ

Table 3.15: Economic Calculation Sheet - Scenario 9

Monetary Unit:	MUSD	
Discount Rate:	10%	
DDO Cost:	7.36	USD/GJ
Natural Gas Cost:	**1.50**	USD/GJ
GT Inv.cost:	570	USD/kW
CC Inv.cost:	711	

Country: Angola

Scenario: 3 x 50 MW NG.(GT-CC) in 1998-2005
3 x 50 MW NG.(GT-CC) in 2007-2010
3 x 50 MW NG.(GT-CC) in 2012
50 MW NG.GT in 2014

	Generation Investments						*Operating Cost*	*Total*	*Natural Gas Consumption (Mm3/y)*	*G.T.Aver. Oper. Time (h)*	*Natural Gas Consumption (Million GJ/y)*	*TG50 GWH*	*TG100 GWH*	*CC GWH*	*Tot gaz*	*Hydro*	*Old GT*
	2 x 50 MW GT	*50 MW ST*	*2 x 50 MW GT*	*50 MW ST*	*150 MW CC*	*50 MW GT*											
Invest.Cost	*28.5*	*49.65*	*28.5*	*49.7*	*106.7*	*28.5*											
1995								**0.0**			0.0						
1996	4.3						0.3	**4.6**	0		0.0				0	800	2
1997	14.3						0.6	**14.8**	0		0.0				0	835	5
1998	**10.0**						0.4	**10.3**	4	280	0.2	14			14	892	
1999							2.1	**2.1**	25	1640	0.9	82			82	900	
2000							4.4	**4.4**	50	3240	1.9	162			162	900	1
2001	4.3						7.1	**11.4**	76	4900	2.8	245			245	900	6
2002	14.3						11.2	**25.5**	104	6660	3.8	333			333	900	21
2003	**10.0**	7.4					11.7	**29.1**	139	4460	5.1	446			446	900	1
2004		24.8					15.2	**40.0**	171	5490	6.3	549			549	900	8
2005		**17.4**	4.3				13.7	**35.3**	140	4473	5.2			671	671	900	0
2006			14.3				16.9	**31.1**	167	5307	6.2			796	796	900	6
2007			**14.3**				19.2	**33.4**	198	4690	7.3	14		924	938	900	0
2008			14.3	7.4			23.0	**44.7**	231	5425	8.6	43		1042	1085	900	6
2009			**10.0**	24.8			26.7	**61.5**	282	5036	10.4	182		1077	1259	900	1
2010				**17.4**	16.0		29.4	**62.8**	302	4817	11.2			1445	1445	900	0
2011					53.3		34.2	**87.6**	343	5470	12.7			1641	1641	900	6
2012					**37.3**	4.3	37.9	**79.5**	390	4147	14.4			1866	1866	900	0
2013						14.3	42.9	**57.1**	442	4691	16.3			2111	2111	900	0
2014						**10.0**	48.4	**58.4**	499	4768	18.5	3		2381	2384	900	0
2015							57.6	**57.6**	562	5356	20.8	17		2661	2678	900	0
Res.Value	*-13*	*-22*	*-34*	*-35*	*-85*	*-26*		***-215***									

Total Discounted Cost:	**174.4**	MUSD
Average Netback Value Of Gas:	2.6	USD/GJ

Joint UNDP/World Bank
ENERGY SECTOR MANAGEMENT ASSISTANCE PROGRAMME (ESMAP)

LIST OF REPORTS ON COMPLETED ACTIVITIES

Region/Country	*Activity/Report Title*	*Date*	*Number*
	SUB-SAHARAN AFRICA (AFR)		
Africa Regional	Anglophone Africa Household Energy Workshop (English)	07/88	085/88
	Regional Power Seminar on Reducing Electric Power System Losses in Africa (English)	08/88	087/88
	Institutional Evaluation of EGL (English)	02/89	098/89
	Biomass Mapping Regional Workshops (English)	05/89	--
	Francophone Household Energy Workshop (French)	08/89	--
	Interafrican Electrical Engineering College: Proposals for Short- and Long-Term Development (English)	03/90	112/90
	Biomass Assessment and Mapping (English)	03/90	--
	Symposium on Power Sector Reform and Efficiency Improvement in Sub-Saharan Africa (English)	06/96	182/96
	Commercialization of Marginal Gas Fields (English)	12/97	201/97
	Commercilizing Natural Gas: Lessons from the Seminar in Nairobi for Sub-Saharan Africa and Beyond	01/00	225/00
	Africa Gas Initiative – Main Report: Volume I	02/01	240/01
Angola	Energy Assessment (English and Portuguese)	05/89	4708-ANG
	Power Rehabilitation and Technical Assistance (English)	10/91	142/91
	Africa Gas Initiative – Angola: Volume II	02/01	240/01
Benin	Energy Assessment (English and French)	06/85	5222-BEN
Botswana	Energy Assessment (English)	09/84	4998-BT
	Pump Electrification Prefeasibility Study (English)	01/86	047/86
	Review of Electricity Service Connection Policy (English)	07/87	071/87
	Tuli Block Farms Electrification Study (English)	07/87	072/87
	Household Energy Issues Study (English)	02/88	--
	Urban Household Energy Strategy Study (English)	05/91	132/91
Burkina Faso	Energy Assessment (English and French)	01/86	5730-BUR
	Technical Assistance Program (English)	03/86	052/86
	Urban Household Energy Strategy Study (English and French)	06/91	134/91
Burundi	Energy Assessment (English)	06/82	3778-BU
	Petroleum Supply Management (English)	01/84	012/84
	Status Report (English and French)	02/84	011/84
	Presentation of Energy Projects for the Fourth Five-Year Plan (1983-1987) (English and French)	05/85	036/85
	Improved Charcoal Cookstove Strategy (English and French)	09/85	042/85
	Peat Utilization Project (English)	11/85	046/85
	Energy Assessment (English and French)	01/92	9215-BU
Cameroon	Africa Gas Initiative – Cameroon: Volume III	02/01	240/01
Cape Verde	Energy Assessment (English and Portuguese)	08/84	5073-CV
	Household Energy Strategy Study (English)	02/90	110/90
Central African Republic	Energy Assessement (French)	08/92	9898-CAR
Chad	Elements of Strategy for Urban Household Energy The Case of N'djamena (French)	12/93	160/94
Comoros	Energy Assessment (English and French)	01/88	7104-COM
	In Search of Better Ways to Develop Solar Markets: The Case of Comoros	05/00	230/00
Congo	Energy Assessment (English)	01/88	6420-COB

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Congo	Power Development Plan (English and French)	03/90	106/90
	Africa Gas Initiative – Congo: Volume IV	02/01	240/01
Côte d'Ivoire	Energy Assessment (English and French)	04/85	5250-IVC
	Improved Biomass Utilization (English and French)	04/87	069/87
	Power System Efficiency Study (English)	12/87	--
	Power Sector Efficiency Study (French)	02/92	140/91
	Project of Energy Efficiency in Buildings (English)	09/95	175/95
	Africa Gas Initiative – Côte d'Ivoire: Volume V	02/01	240/01
Ethiopia	Energy Assessment (English)	07/84	4741-ET
	Power System Efficiency Study (English)	10/85	045/85
	Agricultural Residue Briquetting Pilot Project (English)	12/86	062/86
	Bagasse Study (English)	12/86	063/86
	Cooking Efficiency Project (English)	12/87	--
	Energy Assessment (English)	02/96	179/96
Gabon	Energy Assessment (English)	07/88	6915-GA
	Africa Gas Initiative – Gabon: Volume VI	02/01	240/01
The Gambia	Energy Assessment (English)	11/83	4743-GM
	Solar Water Heating Retrofit Project (English)	02/85	030/85
	Solar Photovoltaic Applications (English)	03/85	032/85
	Petroleum Supply Management Assistance (English)	04/85	035/85
Ghana	Energy Assessment (English)	11/86	6234-GH
	Energy Rationalization in the Industrial Sector (English)	06/88	084/88
	Sawmill Residues Utilization Study (English)	11/88	074/87
	Industrial Energy Efficiency (English)	11/92	148/92
Guinea	Energy Assessment (English)	11/86	6137-GUI
	Household Energy Strategy (English and French)	01/94	163/94
Guinea-Bissau	Energy Assessment (English and Portuguese)	08/84	5083-GUB
	Recommended Technical Assistance Projects (English & Portuguese)	04/85	033/85
	Management Options for the Electric Power and Water Supply Subsectors (English)	02/90	100/90
	Power and Water Institutional Restructuring (French)	04/91	118/91
Kenya	Energy Assessment (English)	05/82	3800-KE
	Power System Efficiency Study (English)	03/84	014/84
	Status Report (English)	05/84	016/84
	Coal Conversion Action Plan (English)	02/87	--
	Solar Water Heating Study (English)	02/87	066/87
	Peri-Urban Woodfuel Development (English)	10/87	076/87
	Power Master Plan (English)	11/87	--
	Power Loss Reduction Study (English)	09/96	186/96
	Implementation Manual: Financing Mechanisms for Solar Electric Equipment	07/00	231/00
Lesotho	Energy Assessment (English)	01/84	4676-LSO
Liberia	Energy Assessment (English)	12/84	5279-LBR
	Recommended Technical Assistance Projects (English)	06/85	038/85
	Power System Efficiency Study (English)	12/87	081/87
Madagascar	Energy Assessment (English)	01/87	5700-MAG
	Power System Efficiency Study (English and French)	12/87	075/87
	Environmental Impact of Woodfuels (French)	10/95	176/95
Malawi	Energy Assessment (English)	08/82	3903-MAL
	Technical Assistance to Improve the Efficiency of Fuelwood Use in the Tobacco Industry (English)	11/83	009/83

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Malawi	Status Report (English)	01/84	013/84
Mali	Energy Assessment (English and French)	11/91	8423-MLI
	Household Energy Strategy (English and French)	03/92	147/92
Islamic Republic of Mauritania	Energy Assessment (English and French)	04/85	5224-MAU
	Household Energy Strategy Study (English and French)	07/90	123/90
Mauritius	Energy Assessment (English)	12/81	3510-MAS
	Status Report (English)	10/83	008/83
	Power System Efficiency Audit (English)	05/87	070/87
	Bagasse Power Potential (English)	10/87	077/87
	Energy Sector Review (English)	12/94	3643-MAS
Mozambique	Energy Assessment (English)	01/87	6128-MOZ
	Household Electricity Utilization Study (English)	03/90	113/90
	Electricity Tariffs Study (English)	06/96	181/96
	Sample Survey of Low Voltage Electricity Customers	06/97	195/97
Namibia	Energy Assessment (English)	03/93	11320-NAM
Niger	Energy Assessment (French)	05/84	4642-NIR
	Status Report (English and French)	02/86	051/86
	Improved Stoves Project (English and French)	12/87	080/87
	Household Energy Conservation and Substitution (English and French)	01/88	082/88
Nigeria	Energy Assessment (English)	08/83	4440-UNI
	Energy Assessment (English)	07/93	11672-UNI
Rwanda	Energy Assessment (English)	06/82	3779-RW
	Status Report (English and French)	05/84	017/84
	Improved Charcoal Cookstove Strategy (English and French)	08/86	059/86
	Improved Charcoal Production Techniques (English and French)	02/87	065/87
	Energy Assessment (English and French)	07/91	8017-RW
	Commercialization of Improved Charcoal Stoves and Carbonization Techniques Mid-Term Progress Report (English and French)	12/91	141/91
SADC	SADC Regional Power Interconnection Study, Vols. I-IV (English)	12/93	--
SADCC	SADCC Regional Sector: Regional Capacity-Building Program for Energy Surveys and Policy Analysis (English)	11/91	--
Sao Tome and Principe	Energy Assessment (English)	10/85	5803-STP
Senegal	Energy Assessment (English)	07/83	4182-SE
	Status Report (English and French)	10/84	025/84
	Industrial Energy Conservation Study (English)	05/85	037/85
	Preparatory Assistance for Donor Meeting (English and French)	04/86	056/86
	Urban Household Energy Strategy (English)	02/89	096/89
	Industrial Energy Conservation Program (English)	05/94	165/94
Seychelles	Energy Assessment (English)	01/84	4693-SEY
	Electric Power System Efficiency Study (English)	08/84	021/84
Sierra Leone	Energy Assessment (English)	10/87	6597-SL
Somalia	Energy Assessment (English)	12/85	5796-SO
Republic of South Africa	Options for the Structure and Regulation of Natural Gas Industry (English)	05/95	172/95
Sudan	Management Assistance to the Ministry of Energy and Mining	05/83	003/83
	Energy Assessment (English)	07/83	4511-SU
	Power System Efficiency Study (English)	06/84	018/84
	Status Report (English)	11/84	026/84

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Sudan	Wood Energy/Forestry Feasibility (English)	07/87	073/87
Swaziland	Energy Assessment (English)	02/87	6262-SW
	Household Energy Strategy Study	10/97	198/97
Tanzania	Energy Assessment (English)	11/84	4969-TA
	Peri-Urban Woodfuels Feasibility Study (English)	08/88	086/88
	Tobacco Curing Efficiency Study (English)	05/89	102/89
	Remote Sensing and Mapping of Woodlands (English)	06/90	--
	Industrial Energy Efficiency Technical Assistance (English)	08/90	122/90
	Power Loss Reduction Volume 1: Transmission and Distribution SystemTechnical Loss Reduction and Network Development (English)	06/98	204A/98
	Power Loss Reduction Volume 2: Reduction of Non-Technical Losses (English)	06/98	204B/98
Togo	Energy Assessment (English)	06/85	5221-TO
	Wood Recovery in the Nangbeto Lake (English and French)	04/86	055/86
	Power Efficiency Improvement (English and French)	12/87	078/87
Uganda	Energy Assessment (English)	07/83	4453-UG
	Status Report (English)	08/84	020/84
	Institutional Review of the Energy Sector (English)	01/85	029/85
	Energy Efficiency in Tobacco Curing Industry (English)	02/86	049/86
	Fuelwood/Forestry Feasibility Study (English)	03/86	053/86
	Power System Efficiency Study (English)	12/88	092/88
	Energy Efficiency Improvement in the Brick and Tile Industry (English)	02/89	097/89
	Tobacco Curing Pilot Project (English)	03/89	UNDP Terminal Report
	Energy Assessment (English)	12/96	193/96
	Rural Electrification Strategy Study	09/99	221/99
Zaire	Energy Assessment (English)	05/86	5837-ZR
Zambia	Energy Assessment (English)	01/83	4110-ZA
	Status Report (English)	08/85	039/85
	Energy Sector Institutional Review (English)	11/86	060/86
	Power Subsector Efficiency Study (English)	02/89	093/88
	Energy Strategy Study (English)	02/89	094/88
	Urban Household Energy Strategy Study (English)	08/90	121/90
Zimbabwe	Energy Assessment (English)	06/82	3765-ZIM
	Power System Efficiency Study (English)	06/83	005/83
	Status Report (English)	08/84	019/84
	Power Sector Management Assistance Project (English)	04/85	034/85
	Power Sector Management Institution Building (English)	09/89	--
	Petroleum Management Assistance (English)	12/89	109/89
	Charcoal Utilization Prefeasibility Study (English)	06/90	119/90
	Integrated Energy Strategy Evaluation (English)	01/92	8768-ZIM
	Energy Efficiency Technical Assistance Project: Strategic Framework for a National Energy Efficiency Improvement Program (English)	04/94	--
	Capacity Building for the National Energy Efficiency Improvement Programme (NEEIP) (English)	12/94	--
	Rural Electrification Study	03/00	228/00

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	EAST ASIA AND PACIFIC (EAP)		
Asia Regional	Pacific Household and Rural Energy Seminar (English)	11/90	--
China	County-Level Rural Energy Assessments (English)	05/89	101/89
	Fuelwood Forestry Preinvestment Study (English)	12/89	105/89
	Strategic Options for Power Sector Reform in China (English)	07/93	156/93
	Energy Efficiency and Pollution Control in Township and Village Enterprises (TVE) Industry (English)	11/94	168/94
	Energy for Rural Development in China: An Assessment Based on a Joint Chinese/ESMAP Study in Six Counties (English)	06/96	183/96
	Improving the Technical Efficiency of Decentralized Power Companies	09/99	222/999
Fiji	Energy Assessment (English)	06/83	4462-FIJ
Indonesia	Energy Assessment (English)	11/81	3543-IND
	Status Report (English)	09/84	022/84
	Power Generation Efficiency Study (English)	02/86	050/86
	Energy Efficiency in the Brick, Tile and Lime Industries (English)	04/87	067/87
	Diesel Generating Plant Efficiency Study (English)	12/88	095/88
	Urban Household Energy Strategy Study (English)	02/90	107/90
	Biomass Gasifier Preinvestment Study Vols. I & II (English)	12/90	124/90
	Prospects for Biomass Power Generation with Emphasis on Palm Oil, Sugar, Rubberwood and Plywood Residues (English)	11/94	167/94
Lao PDR	Urban Electricity Demand Assessment Study (English)	03/93	154/93
	Institutional Development for Off-Grid Electrification	06/99	215/99
Malaysia	Sabah Power System Efficiency Study (English)	03/87	068/87
	Gas Utilization Study (English)	09/91	9645-MA
Myanmar	Energy Assessment (English)	06/85	5416-BA
Papua New Guinea	Energy Assessment (English)	06/82	3882-PNG
	Status Report (English)	07/83	006/83
	Energy Strategy Paper (English)	--	--
	Institutional Review in the Energy Sector (English)	10/84	023/84
	Power Tariff Study (English)	10/84	024/84
Philippines	Commercial Potential for Power Production from Agricultural Residues (English)	12/93	157/93
	Energy Conservation Study (English)	08/94	--
Solomon Islands	Energy Assessment (English)	06/83	4404-SOL
	Energy Assessment (English)	01/92	979-SOL
South Pacific	Petroleum Transport in the South Pacific (English)	05/86	--
Thailand	Energy Assessment (English)	09/85	5793-TH
	Rural Energy Issues and Options (English)	09/85	044/85
	Accelerated Dissemination of Improved Stoves and Charcoal Kilns (English)	09/87	079/87
	Northeast Region Village Forestry and Woodfuels Preinvestment Study (English)	02/88	083/88
	Impact of Lower Oil Prices (English)	08/88	--
	Coal Development and Utilization Study (English)	10/89	--
Tonga	Energy Assessment (English)	06/85	5498-TON
Vanuatu	Energy Assessment (English)	06/85	5577-VA
Vietnam	Rural and Household Energy-Issues and Options (English)	01/94	161/94

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Vietnam	Power Sector Reform and Restructuring in Vietnam: Final Report to the Steering Committee (English and Vietnamese)	09/95	174/95
	Household Energy Technical Assistance: Improved Coal Briquetting and Commercialized Dissemination of Higher Efficiency Biomass and Coal Stoves (English)	01/96	178/96
	Petroleum Fiscal Issues and Policies for Fluctuating Oil Prices In Vietnam	02/01	236/01
Western Samoa	Energy Assessment (English)	06/85	5497-WSO
	SOUTH ASIA (SAS)		
Bangladesh	Energy Assessment (English)	10/82	3873-BD
	Priority Investment Program (English)	05/83	002/83
	Status Report (English)	04/84	015/84
	Power System Efficiency Study (English)	02/85	031/85
	Small Scale Uses of Gas Prefeasibility Study (English)	12/88	--
India	Opportunities for Commercialization of Nonconventional Energy Systems (English)	11/88	091/88
	Maharashtra Bagasse Energy Efficiency Project (English)	07/90	120/90
	Mini-Hydro Development on Irrigation Dams and Canal Drops Vols. I, II and III (English)	07/91	139/91
	WindFarm Pre-Investment Study (English)	12/92	150/92
	Power Sector Reform Seminar (English)	04/94	166/94
	Environmental Issues in the Power Sector (English)	06/98	205/98
	Environmental Issues in the Power Sector: Manual for Environmental Decision Making (English)	06/99	213/99
	Household Energy Strategies for Urban India: The Case of Hyderabad	06/99	214/99
	Greenhouse Gas Mitigation In the Power Sector: Case Studies From India	02/01	237/01
Nepal	Energy Assessment (English)	08/83	4474-NEP
	Status Report (English)	01/85	028/84
	Energy Efficiency & Fuel Substitution in Industries (English)	06/93	158/93
Pakistan	Household Energy Assessment (English)	05/88	--
	Assessment of Photovoltaic Programs, Applications, and Markets (English)	10/89	103/89
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	Lighting Efficiency Improvement Program Phase 1: Commercial Buildings Five Year Plan (English)	10/94	--
Sri Lanka	Energy Assessment (English)	05/82	3792-CE
	Power System Loss Reduction Study (English)	07/83	007/83
	Status Report (English)	01/84	010/84
	Industrial Energy Conservation Study (English)	03/86	054/86
	EUROPE AND CENTRAL ASIA (ECA)		
Bulgaria	Natural Gas Policies and Issues (English)	10/96	188/96
Central and Eastern Europe	Power Sector Reform in Selected Countries	07/97	196/97

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	The Future of Natural Gas in Eastern Europe (English)	08/92	149/92
Kazakhstan	Natural Gas Investment Study, Volumes 1, 2 & 3	12/97	199/97
Kazakhstan & Kyrgyzstan	Opportunities for Renewable Energy Development	11/97	16855-KAZ
Poland	Energy Sector Restructuring Program Vols. I-V (English)	01/93	153/93
	Natural Gas Upstream Policy (English and Polish)	08/98	206/98
	Energy Sector Restructuring Program: Establishing the Energy Regulation Authority	10/98	208/98
Portugal	Energy Assessment (English)	04/84	4824-PO
Romania	Natural Gas Development Strategy (English)	12/96	192/96
Slovenia	Workshop on Private Participation in the Power Sector (English)	02/99	211/99
Turkey	Energy Assessment (English)	03/83	3877-TU
	Energy and the Environment: Issues and Options Paper	04/00	229/00

MIDDLE EAST AND NORTH AFRICA (MNA)

Arab Republic of Egypt	Energy Assessment (English)	10/96	189/96
	Energy Assessment (English and French)	03/84	4157-MOR
	Status Report (English and French)	01/86	048/86
Morocco	Energy Sector Institutional Development Study (English and French)	07/95	173/95
	Natural Gas Pricing Study (French)	10/98	209/98
	Gas Development Plan Phase II (French)	02/99	210/99
Syria	Energy Assessment (English)	05/86	5822-SYR
	Electric Power Efficiency Study (English)	09/88	089/88
	Energy Efficiency Improvement in the Cement Sector (English)	04/89	099/89
	Energy Efficiency Improvement in the Fertilizer Sector (English)	06/90	115/90
Tunisia	Fuel Substitution (English and French)	03/90	--
	Power Efficiency Study (English and French)	02/92	136/91
	Energy Management Strategy in the Residential and Tertiary Sectors (English)	04/92	146/92
	Renewable Energy Strategy Study, Volume I (French)	11/96	190A/96
	Renewable Energy Strategy Study, Volume II (French)	11/96	190B/96
Yemen	Energy Assessment (English)	12/84	4892-YAR
	Energy Investment Priorities (English)	02/87	6376-YAR
	Household Energy Strategy Study Phase I (English)	03/91	126/91

LATIN AMERICA AND THE CARIBBEAN (LAC)

LAC Regional	Regional Seminar on Electric Power System Loss Reduction in the Caribbean (English)	07/89	--
	Elimination of Lead in Gasoline in Latin America and the Caribbean (English and Spanish)	04/97	194/97
	Elimination of Lead in Gasoline in Latin America and the Caribbean - Status Report (English and Spanish)	12/97	200/97

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LAC Regional	Harmonization of Fuels Specifications in Latin America and the Caribbean (English and Spanish)	06/98	203/98
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	National Energy Plan (English)	12/87	--
	La Paz Private Power Technical Assistance (English)	11/90	111/90
	Prefeasibility Evaluation Rural Electrification and Demand Assessment (English and Spanish)	04/91	129/91
	National Energy Plan (Spanish)	08/91	131/91
	Private Power Generation and Transmission (English)	01/92	137/91
	Natural Gas Distribution: Economics and Regulation (English)	03/92	125/92
	Natural Gas Sector Policies and Issues (English and Spanish)	12/93	164/93
	Household Rural Energy Strategy (English and Spanish)	01/94	162/94
	Preparation of Capitalization of the Hydrocarbon Sector	12/96	191/96
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Colombia	Energy Strategy Paper (English)	12/86	--
	Power Sector Restructuring (English)	11/94	169/94
	Energy Efficiency Report for the Commercial and Public Sector (English)	06/96	184/96
Costa Rica	Energy Assessment (English and Spanish)	01/84	4655-CR
	Recommended Technical Assistance Projects (English)	11/84	027/84
	Forest Residues Utilization Study (English and Spanish)	02/90	108/90
Dominican Republic	Energy Assessment (English)	05/91	8234-DO
Ecuador	Energy Assessment (Spanish)	12/85	5865-EC
	Energy Strategy Phase I (Spanish)	07/88	--
	Energy Strategy (English)	04/91	--
	Private Minihydropower Development Study (English)	11/92	--
	Energy Pricing Subsidies and Interfuel Substitution (English)	08/94	11798-EC
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Guatemala	Issues and Options in the Energy Sector (English)	09/93	12160-GU
Haiti	Energy Assessment (English and French)	06/82	3672-HA
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Honduras	Energy Assessment (English)	08/87	6476-HO
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	Energy Efficiency Standards and Labels Phase I (English)	03/88	--
	Management Information System Phase I (English)	03/88	--
	Charcoal Production Project (English)	09/88	090/88
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Jamaica	Energy Sector Strategy and Investment Planning Study (English)	07/92	135/92
Mexico	Improved Charcoal Production Within Forest Management for the State of Veracruz (English and Spanish)	08/91	138/91
	Energy Efficiency Management Technical Assistance to the Comision Nacional para el Ahorro de Energia (CONAE) (English)	04/96	180/96
Panama	Power System Efficiency Study (English)	06/83	004/83
Paraguay	Energy Assessment (English)	10/84	5145-PA
	Recommended Technical Assistance Projects (English)	09/85	--
	Status Report (English and Spanish)	09/85	043/85
Peru	Energy Assessment (English)	01/84	4677-PE
	Status Report (English)	08/85	040/85
	Proposal for a Stove Dissemination Program in the Sierra (English and Spanish)	02/87	064/87
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