Report No 4511-SU

Sudan: Issues and Options in the Energy Sector

July 1983

Report of the Joint UNDP/World Bank Energy Sector Assessment Program

JOINT UNDP/WORLD BANK ENERGY SECTOR ASSESSMENT PROGRAM

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SUDAN

ISSUES AND OPTIONS IN THE ENERGY SECTOR

July 1983

TITLE: SUDAN: ISSUES AND OPTIONS IN THE ENERGY SECTOR

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ABSTRACT.

Sudan's deteriorating balance of payments position has led to massive overseas borrowing and an acute shortage of foreign exchange. This has resulted more from a decline in exports than an increase in imports. The report argues that Sudan's present economic crisis is in no small measure due to crippling energy shortages in the productive sectors of the economy accompanied by too little emphasis on adequate energy prices and too much reliance on a physical petroleum allocation scheme. Future economic policy must attach a higher priority to supplying energy to the productive sectors -- to promote growth and higher export earnings -- and show a greater willingness to keep energy prices in line with the economic costs of supply and to use pricing as an instrument for resource allocation. At the same time, it must be recognized that Sudan will face serious limits on the extent to which it can increase overall energy supplies and meet expanding energy demands.

The report reviews Sudan's energy resources, including recently discovered oil and gas reserves, hydroelectricity and other renewable resources. The report then goes on to make demand projections over a fifteen-year period for each subsector (petroleum, electricity, firewood, charcoal and other renewable energy resources). Two macroeconomic growth scenarios are used to project the demand for petroleum products. The important issues and options in the energy sector are discussed, including pricing and allocation policies. The report's recommendations focus particularly on investment options and strategies, technical assistance requirements, institutional strengthening and conservation.

CURRENCY EQUIVALENTS

US$1 = LS1.300 (Sudanese Pounds)
LS1 = US$0.769

ACRONYMS AND ABBREVIATIONS

BNG	Blue Nile Grid
CFA	Central Forest Administration
FY	Fiscal Year (July 1 - June 30)
GPC	General Petroleum Corporation
IS	Isolated Systems
KSC	Kenana Sugar Company
LPG	Liquified Petroleum Gas
MEM	Ministry of Energy and Mining
MFC	Mechanized Farming Corporation
n.a.	not available
NEA	National Energy Administration
NEC	National Electricity Corporation
PEWC	Public Electricity and Water Corporation
PSR	Port Sudan Refinery
RTC	River Transport Corporation
SRC	Sudan Railway Corporation
SWD	German Steering Committee for Wind Energy in Developing Countries
USAID	United States Agency for International Development
WECS	Wind Energy Conversion Systems
WNPC	White Nile Petroleum Corporation
bpd	barrels per day
BTU	British Thermal Unit
GJ	Gigajoules
GWh	Gigawatt-hour
Ig	Imperial gallon
kgoe	kilograms of oil equivalent
km	kilometer
m	meter
mt	metric ton
mtpa	metric tons per annum
MCF	thousand cubic feet
MMCF	million cubic feet
MMCFD	million cubic feet per day
MVA	mega-volt-amperes
MW	megawatts
toe	(metric) tons of oil equivalent
W	watt

ENERGY CONVERSION FACTORS

Fuel	Physical Units per TOE	Million Kcal per Unit
Petroleum products (mt):		
- LPG	1.06	10.8
- gasoline	1.03	10.5
- kerosene/jet fuel	1.01	10.3
- gasoil	1.00	10.2
- fuel oil	0.96	9.8
Electricity (MWh)	4.00	86.0×10^{-2}
Biomass (mt)		
- charcoal	0.68	6.9
- fuelwood	0.32	3.3
- other	0.26	2.7

Memo Items

1 TOE = 10.2 million kcal = 40.5 million BTU = 42.7 GJ
1 kcal = 3.968 BTU-6
1 kcal = 4.19 x 10   GJ
1 MWh = 860,000 kcal = 0.248 TOE at 34% efficiency in thermal (oil) generation

This report is based on the findings of an energy assessment mission which visited Sudan in November-December, 1982. The mission comprised N.B. Prasad (Mission Chief, Consultant), R.W. Bates (Deputy Mission Chief, Energy Economist), H.M. Codippily (Country Economist), A. Ody (Ethanol Specialist), W. Kupper (Power Engineer, Consultant), P. Dodd (Forestry Specialist, Consultant), F. Bigache (Petroleum Refinery Specialist, Consultant), T. Ritter (Petroleum Geologist, Consultant) and B. Yates (Bagasse/Ethanol Specialist, Consultant). The principal authors of the report were R.W. Bates and N.B. Prasad.

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KEY ISSUES AND RECOMMENDATIONS

The Energy Sector and the Economy

1. Sudan's present economic crisis is in no small measure due to crippling energy shortages in the productive sectors of the economy during the last few years. The economy has relied too little on energy pricing as a tool of demand management and placed too much emphasis on a physical allocation system for petroleum products. Future economic planning and decision taking must attach a higher priority to supplying energy to the productive sectors of the economy, particularly export - oriented industry and agriculture and show a greater willingness to keep energy prices in line with the economic costs of supply (paras. 1.16-1.18; 4.26;4.29). At the same time, it must be recognized that Sudan will face serious limits on the extent to which it can in fact increase the overall supply of energy.

2. There are some encouraging signs for the short-term and medium-term outlook: power shortages are likely to be relieved during FY84, with a doubling of installed capacity; and domestic crude will augment petroleum supplies and export earnings from FY86 (para. 1.18). However, from a longer-term perspective, it must be recognized that Sudan is poorly endowed with indigenous energy resources in relation to its large land area (para. 2.01). A sustained improvement in economic performance will require much better management of the energy sector and a system of foreign exchange allocation which will permit the Government to plan petroleum imports on a more rational basis (paras. 1.18; 4.31; 5.05). To that extent, energy pricing will assume an even greater importance than usual in restraining overall energy demand and in optimizing the distribution of petroleum products between different consuming sectors and between individual consumers within those sectors. While the impact of energy pricing on demand may take full effect only in the longer-term, by initiating action now the economy will be given the maximum opportunity to adjust to a situation in which energy prices reflect the full economic costs of supply (paras. 4.26-4.29; 4.55 - 4.58).

Options in the Energy Sector - An Overview

3. As in many African countries, fuelwood, charcoal and biomass constitute the main source of energy supply and satisfy about 82% of final consumption. Commercial energy meets the remaining 18%, largely in the form of oil (17%), all of which must be imported, although a small amount of final consumption (1%) is supplied by hydroelectricity (para. 1.07). Sudan's options for the future are comparatively straightforward. Energy conservation offers some scope for reducing imports, although the main potential must lie with the transport sector (para. 4.35); also, as stated above, pricing policy needs careful and immediate attention. On the supply side, several measures are suggested for alleviating the fuelwood problem; furthermore, if decisions are taken now to harness more fully Sudan's hydroelectric resources, hydroelectricity could play a more important role in the long run. However, a number of

new and interesting options have become available in the petroleum sector, following the discovery of oil in the southern part of the country and natural gas in the Red Sea. An export pipeline and a parallel diluent pipeline are to be constructed to transport the oil to the Red Sea; the project has been appraised by IFC. The diluent pipeline could be used to distribute products in the eastern and southern provinces; part of Sudan's entitlement to the crude could be used in a refinery/topping plant at Kosti (although this would probably reduce the benefits of using the diluent pipeline to distribute products), which in turn could make it attractive to locate a power station at Kosti to supply the main grid; alternatively or in addition, some indigenous crude could be blended with imported crude at the existing Port Sudan refinery. Finally, if natural gas is available in sufficient quantities, it could be used in domestic markets; in particular, it could be supplied to power stations to supplement hydroelectric and oil-fired thermal generation.

Energy Supply

A. Petroleum

(i) Oil

4. The discovery of crude in the southern part of Sudan and the construction of an export pipeline has made available certain options, among which a choice must be made (paras. 2.07-2.14). The three principal options are (paras. 4.05; 4.11):

(a) Set up a topping plant at Kosti;

(b) Utilize part of the indigenous crude at Port Sudan Refinery, together with imported crude; and

(c) Set up a new refinery at Kosti or on the Red Sea to process indigenous crude, maximize the production of middle distillates and minimize the production of long residue which requires further processing.

In view of the high capital costs of a new refinery, it seems prudent to pursue options (a) and (b) and to consider (c) only if much higher recoverable reserves are established (para. 4.16); however, technical assistance is recommended for further study of the three options (para. 6.11).

5. The construction of a diluent pipeline parallel to the crude export pipeline presents the option of using the diluent pipeline to deliver products (para. 4.18). It is recommended that the diluent pipeline be designed for an additional pumping station at El Fau at a future date, although the benefits of using the diluent pipeline for product transport should be re-examined in light of a decision on the Kosti topping plant (para. 4.20).

6. All bitumen is currently imported while PSR produces a surplus of long residue. The construction of a bitumen plant in Port Sudan is, therefore, an option (para. 4.21). However, in view of the mission's projection that the surplus of long residue may disappear after 1988, it is recommended that the option of a bitumen plant be re-examined only after a decision on a new refinery is taken (para. 4.22).

(ii) Natural Gas

7. The discovery of natural gas in the Red Sea makes available certain potential options for its utilization in domestic markets (paras. 2.03 - 2.06). Among other options, Sudan should consider using the natural gas in a urea fertilizer plant and -- perhaps more probably -- for power generation (para. 4.42.). Technical assistance is recommended to study both these options, including the possibility of piping the gas to Khartoum (paras. 4.44-4.45; 6.13). The study should include an assessment of gas reserves based on available data, the possibility of a Government "farm-in" with Total and the subject of gas pricing (para. 6.13).

B. Power

8. Despite the numerous studies of hydroelectric projects which have been made for the BNG, none have been completed beyond the prefeasibility stage and no scenario is available from which an order of merit could be prepared based on a least-cost analysis; furthermore, past planning of additions to system capacity in the BNG has been carried out with insufficient lead time to permit the optimal use of Sudan's hydroelectric potential (paras 2.15-2.16; 2.23). Technical assistance is therefore recommended to prepare, as soon as possible, a study to update the long-term power generation development plan for the BNG to the year 2000 (para 6.14). The study should (para. 2.24): (a) define the economic merit order and appropriate timing for the different generating plants recommended; (b) be organized so that it can be repeated at least every two years at low cost; (c) assess the adequacy of existing studies of different generating plants; (d) define further studies necessary to proceed to feasibility and preliminary design; (e) estimate the local and foreign exchange costs of the further studies; and (f) attach a priority and timing to each recommended further study.

9. Outside the BNG, generation studies have been carried out but they are not up-to-date, they lack sufficient detail and they have not been coordinated. PEWC's Electric Power Status Report of March 1982 should be repeated annually by NEC and a mechanism for coordinating past and future studies should be established (para. 4.51).

10. Low-voltage distribution has played a secondary role in past expansion programs in the power sector; distribution systems in the BNG are therefore in poor condition and comprehensive distribution studies have not been made outside Khartoum and Port Sudan. Attention should therefore be given under the proposed Power IV project to distribution planning and investment in the Three Towns. Furthermore, technical assistance is recommended to investigate the condition of distribution

systems within and outside the Three Towns, to assess the requirements for their renovation, improvement and expansion (para. 4.49; 6.16), and to implement a power system loss reduction study (paras. 5.10; 6.15).

11. To a substantial extent, the Power III project should alleviate power shortages in the BNG from the beginning of FY84 (para 4.48); however, plans need to be drawn up for the commissioning of new generation capacity beyond Power III. The only short-term options are thermal, as there are no hydroelectric plants which could be commissioned on time to meet demand growth (para 4.52). If the topping plant is established at Kosti, two thermal options in particular need to be considered (para. 4.53):

(a) Use the residual oil for power generation at Kosti and feed the power into the BNG by strengthening the transmission lines between Kosti and Sennar; and

(b) Transport the residual oil from Kosti to Khartoum for power generation at Khartoum.

Technical assistance is recommended for an urgent study of these options (para. 6.15). In the Port Sudan area, the option of using gas for power generation could be available (para. 4.54) and technical assistance has been recommended (para. 7) for studying this option. With a view to the longer-term, aside from carrying out the study to the year 2000 (recommended in para. 8), a possible Power IV project should consider the inclusion of feasibility studies for the heightening of the Roseires dam and for the Merowe hydroelectric project (para. 4.52).

C. Forestry

12. While some surveys of Sudan's growing stock have been or are about to be conducted in selected areas -- notably in the Blue Nile, Bahr-el-Gazal and El-Buhrat Provinces, with Canadian assistance -- no national forest inventory has been made to provide an accurate estimate of the size of the total forest resource; consequently, there is no reliable basis for planning (paras. 2.30, 4.61). As a matter of high priority, a national forest inventory should be carried out, supported by overseas technical assistance, to extend the Canadian study to all provinces; the inventory would need to be implemented on a continuing basis, in order to assess the rate of deforestation over time and the degree of success encountered by afforestation measures (paras. 4.61, 6.18).

13. Despite the lack of a comprehensive national forest inventory, the present extent of the deforestation problem and the vital role played by fuelwood in Sudan's energy sector make it clear that urgent measures are necessary to preserve the forest resource as much as possible (paras. 2.48, 4.58-4.60). The following package of overseas technical assistance, administrative action, Government budgetary support and enforcement of regulations is recommended: (a) provide technical assistance to study the feasibility, cost and economic viability of large-scale energy plantations, especially near urban areas (para. 4.62) and to set up

demonstration and pilot projects (para. 6.21); (b) provide technical assistance to study ways of improving the productivity of forests, thereby increasing the annual allowable cut relative to the growing stock volume, through better management practices (including forest protection), the control of cutting, and the improvement and extension of silvicultural practices (paras 4.61, 6.19); (c) increase the central budget allocation to forestry, to implement the recommendations of the study under (b) (para. 2.48); (d) provide Government support and technical assistance to design, test, produce and introduce improved firewood cooking stoves, charcoal stoves and charcoal kilns (paras. 4.63-4.65; 6.20), (e) enforce the requirements that abandoned agricultural land be returned to the Forestry Administration and that 15% of the land area of agricultural schemes be retained under forest (para. 4.66), (f) carry out a program to increase public awareness of the deforestation problem, by establishing village-level committees for environmental protection (para. 4.67), (g) encourage community forestry, through better extension services, community woodlots and homestead plantings (para. 4.67); (h) incorporate the concept of maximum conversion of wood material into charcoal in all land clearance schemes (para. 4.65); and (i) coordinate forestry programs with national energy policy

D. Other

14. Sudan has made only limited use of energy supply sources other than petroleum, power and forestry. Although solar and wind energy, molasses and bagasse can at best make a marginal contribution to the total energy supply in the near future (paras. 2.36, 2.41; 2.44; 2.47), it is recommended that: (a) the Government and University of Khartoum continue to support solar energy research projects, especially for their eventual application to water heating (para. 4.68); (b) further technical assistance be made available to design appropriate windmills for irrigation pumping, identify appropriate sites for these windmills and set up demonstration projects (paras 4.69, 6.22); (c) once the future of the sugar industry is known, the Government reopen discussions with KSC on the possible supply of molasses for ethanol production and choose a suitable agency to develop ethanol production (para. 4.72), and (d) the detailed study of the use of bagasse for power generation proceed as envisaged under IDA's Technical Assistance II project, taking into account appropriate economic values for the costs and benefits of each alternative and determining appropriate institutional and financial arrangements for power and energy exchange between NEC and the sugar factories (para. 4.73).

Energy Demand

A. Pricing

15. The prices of kerosene, diesel and fuel oil are below even the c.i.f. import values of the products; while the price of gasoil exceeds its c.i.f. import value, the margin is insufficient to cover the "inland" costs (i.e. the port, marketing, distribution and transport costs) (para. 4.28). It is recommended that, as a minimum, petroleum product prices be

adjusted to reflect their corresponding values in world markets and, in addition, the "inland" costs be covered. Furthermore, in view of the excess demand for petroleum products, additional price increases would be warranted to generate Government revenues and to keep the relative prices of different petroleum products in line with relative import costs. Although some departure from strict economic pricing might be considered for kerosene -- due to its social implications and its impact on fuelwood consumption -- its official price should at least cover its c.i.f. import value. A study of energy pricing is urgently recommended, which should also take into account the use of energy prices as a vehicle for taxation, resource allocation and related issues (para. 4.29).

16. NEC's average tariff has recently been inadequate from a financial point of view and in relation to the long-run marginal cost of supply. Substantial increases in electricity tariffs are therefore required on both economic and financial grounds and are now being implemented in two steps. However, a number of deficiencies appear to exist in the structure of electricity tariffs and there is a need for a proper tariff study (paras. 4.56 - 4.58). Technical assistance is recommeded to support such a tariff study and the study should cover both the BNG and the isolated systems (para. 6.17).

B. Conservation

17. The growth of road haulage at the expense of rail and river traffic implies an increase in the input of energy per ton-km of traffic carried, taking into account the relative fuel efficiencies of the different transport modes (para 4.36). A beneficial shift in the intermodal allocation of traffic could be realized (paras. 15; 4.29; 4.38) if (a) rail and river freight rates are revised in relation to marginal cost; (b) the price of gasoil is raised at least to the level of its economic cost; and (c) SRC and RTC are reorganized to make them more competitive.

18. Within the road transport sector, the growth of private passenger vehicles has accounted for most of the overall growth of the vehicle fleet since 1970 (para. 4.39). A greater emphasis on public transport could lead to fuel savings. It is recommended (paras. 4.40-4.41) that the Government: (a) continue to support the expansion of Khartoum's bus fleet; (b) rigorously apply the existing regulations concerning the licensing of vehicle imports and exemptions from import duties; and (c) consider setting a ceiling on the import of motor cars.

Institutions

A. The Energy Sector

19. A multiplicity of foreign donor assistance continues to take place in the energy sector; this assistance is uncoordinated and part of it might be better directed towards essential spares and equipment rather than demonstration/pilot projects and studies. An appropriate permanent

mechanism is recommended to evaluate, monitor and coordinate this activity on a regular basis and bilateral assistance is recommended to help MEM set up such a mechanism (para. 6.23).

20. There is insufficient technical expertise in the energy sector to provide the basis for energy planning. A team of technical experts needs to be established in MEM to examine the various pricing and investment options and to make clear recommendations to enable the Government to take prompt decisions (para. 5.01). Similarly, the establishment of energy plantations will require well-trained cadres of forestry specialists (para. 6.24).

B. The Ministry of Mining and Energy

21. The main emphasis of the mission's recommendations for institutional improvement in the commercial energy sector has been given to MEM. World Bank technical assistance is already being directed at improving the performance of NEC and GPC and, furthermore, MEM accounts for many of the gaps which the mission has identified between actual performance and statutory responsibilities (para. 5.03).

22. There is no integrated system for controlling all ongoing activities and projects within MEM and the Minister and State Minister become involved in day-to-day operational affairs. The following areas should be examined (para. 5.05) to make MEM more effective: (a) institutionalize the energy data collection process; (b) establish a mechanism for routinely coordinating the different groups within MEM and for coordinating the activities of MEM with other Ministries and relevant agencies; (c) design follow-up procedures for ministerial decisions; and (d) strengthen the secretariat of MEM with professionals from each of the energy subsectors.

23. Sudan is in the process of awarding a number of new petroleum exploration contracts and is faced or will be faced with certain "buy-in" and "farm-in" options. Technical assistance is recommended (paras. 5.04-5.05; 6.12) to help strengthen the staffing and expertise of the Geology and Mineral Resources Directorate in: (a) contract negotiations; (b) contract monitoring and management; (c) exercising options for "farm-in" and "buy-in"; (d) evolving a long-term strategy for development of the petroleum sector; and (e) compiling and analyzing all geological, geophysical and well-completion data provided by the contractors.

C. General Petroleum Corporation

24. GPC assists the Government in monitoring petroleum exploration contracts; it is also likely to become a partner with the international oil companies in petroleum exploration, through the exercise of the Government's "buy-in" and "farm-in" rights. The Government should, therefore, consider the need to define carefully and limit the contract award, management and monitoring activities of GPC which are the legitimate function of the Geology and Mineral Resources Directorate of MEM (para. 5.13).

D. Forestry

25. The preservation and proper utilization of Sudan's forestry resources is essential and a national coordinated program of forestry management and development is vital (para. 13). Strengthening of the Central Forest Administration (CFA) is therefore recommended. In particular, as a first step, a body should be created within the CFA to be responsible for the planning, coordination, review and monitoring of projects, especially the proposed energy plantation projects (para. 5.19). Technical assistance is recommended to help implement these proposals (including training), to revise forest policy and legislation and to strengthen the administration of the forestry sector (paras. 5.19; 6.19; 6.24). Furthermore, suitable administrative procedures need to be established to coordinate forestry activities with national energy planning and policies (para. 5.20).

Investment

26. There has been under-investment in the energy sector (paras. 6.01-6.03). Tentative mission estimates of public investment requirements for the eight-year period to FY91 -- corresponding to the 'low-growth' scenario for demand on the assumption that the individual investments are shown to be viable -- amount to US$1,730 million in 1983 prices or approaching US$220 million a year. Such a program -- corresponding to about 3.1% of GDP --is not unreasonable compared with the performance of other developing countries (para. 6.08). Specifically, it is recommended that the Government consider: (a) a topping plant at Kosti (paras 4.16; 6.05); (b) participating in the Red Sea natural gas discoveries on a "farm-in" basis and ensuring that the reserves of the Suakin structure are confirmed by additional drilling (paras. 4.46; 6.05); (c) strengthening and expanding the power transmission and distribution facilities in the BNG (para. 6.06); (d) constructing an oil-fired power station at Kosti, in the event that a topping plant is agreed upon (para. 4.53); and (e) increasing investment in the forestry sector, notably through energy plantation programs (paras. 5.19; 6.07). The unfolding debt problem and tighter constraints on scarce foreign exchange make it increasingly likely that the tentative program of energy investments may not be realizable. If half the power investment after Power III is postponed beyond 1991, total public investment in the energy sector could be cut from US$1,730 million to US$1,270 million, about US$160 million a year, corresponding to around 2.25% of GDP (para. 6.09). Such a cut, it must be emphasized, would have very serious implications (paras 1.06; 1.17-1.18; 3.13; 6.09).

I. ENERGY AND THE ECONOMY OF SUDAN

The Country

1.01 Situated in the north-eastern part of Africa, Sudan commands the largest land area on the African continent, stretching over 2,000 km from North to South and 1000 km from East to West. Its land area is a little over 2.5 million km^2 and largely flat, except for a few scattered mountains. Sudan is bordered by eight countries, 1/ and has a shore-line of 640 km at the Red Sea. The River Nile flows through the country, with its main tributaries -- the Blue Nile and the White Nile -- meeting at the historic capital city of Khartoum. The climate in the South is equatorial, while that of the North can be described as desert climate. The average rainfall varies from less than one inch in the North to 80 inches in the South.

1.02 Sudan's present population is estimated at around 19 million. Roughly 25% of the population is classified as urban.

The Economy

1.03 Agriculture is the mainstay of the economy. Its share in GDP is currently around 38%, while that of industry is 13% 2/, the balance (49%) is accounted for by the services sector. Agriculture also accounts for more than 90% of exports and 65% of employment. The economy is heavily dependent on exports of cotton, which is the major commodity produced on irrigated land, and also exports of gum arabic, sesame and groundnuts. The manufacturing sector is relatively small (6% of GDP) and, apart from the processing of such agricultural commodities as cotton, oil seeds and sugar, it is mainly limited to the production of textiles and cement. There have been some exports of chrome ore and further development of these deposits is taking place. The public sector, as in many developing countries, is significant and generates about half the GDP.

Recent Economic Performance

1.04 Following the Addis Ababa accord of 1972, which brought an end to the civil war, the Government directed its attention to rapid economic development through a major public investment effort. GDP growth averaged nearly 8% p.a. from FY73 to FY78 at a time when several other low-income countries barely averaged 4% p.a. This impressive performance, however, was not sustainable for a number of reasons. Although Sudan recorded a trade surplus in FY73, export volumes began to decline (particularly cotton exports), leading to growing annual trade deficits. These

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1/ Egypt and Libya from the North, Chad and Central Africa from the West, Zaire, Uganda and Kenya from the South and Ethiopia from the East.

2/ Industry covers manufacturing, construction, electricity and water.

successive deficits in turn led to massive and uncoordinated borrowing abroad, a large part of it on non-concessional terms. As a result, external debts--which had been less than US$100 million in 1972 -- began to increase sharply. Due to poor project implementation, some debts began to fall due before new projects came into full production. Since FY78, GDP has stagnated in real terms; real per capita income has declined and in FY81 stood at only US$260, placing Sudan within the UN's category of "least developed" countries. 1/

1.05 Sudan's unprecedented external debt problem serves as an indicator of its current economic crisis. The total external debt is estimated at around US$7 billion and the debt service is estimated to exceed the country's export earnings. However, external debt is only one dimension of Sudan's current economic crisis. It is further compounded by weak infrastructure, falling agricultural and industrial outputs, critical energy shortages and an exodus of skilled manpower, mainly to the Gulf States.

1.06 Much of the recovery process now depends upon the extent to which Sudan can obtain debt relief and new aid commitments. Unless critical levels of imports are maintained, particularly petroleum products, domestic production and exports will be further depressed, leaving little or no scope for debt servicing. At least ten years of diligent work and extraordinary external support will be required before Sudan can expect to restore its full economic equilibrium. The Government has prepared a medium-term recovery program and consulted with donors regarding the country's external assistance requirements. Some increase in the capacity to service the debt can be expected in the longer term, through the oil revenues which should be earned from the crude oil export pipeline after 1985. The pipeline is to be constructed from the Unity-Talih oilfield near Bentiu to the Red Sea with an initial design capacity of 50,000 bpd (para. 2.11). At that throughput, the Government's net 'take', after all transport costs, should be at least 16,000 bpd (para. 2.14), equivalent to about half the projected 1991 'low-growth' consumption (Table 3.4). The balance of payments crisis should not be allowed to affect petroleum imports in the short term as this would impair the performance of the energy sector, and the energy sector is crucial to the entire recovery process.

Overview of the Energy Sector

1.07 In 1981, Sudan's final energy consumption totalled 6.1 million toe, of which 82% was in the form of fuelwood, charcoal and biomass and the balance of 18% was provided by imported oil and hydro-electricity (see Table 1.1). The largest consuming sector was households (77.8%),

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1/ Based on GNP of LS4333.9 million in FY81 and the exchange rate of US$1 = LS0.90.

followed by transport (11.0%) and industry (5.8%). The per capita consumption of all forms of energy in 1981 amounted to about 324 kgoe and is comparable to levels in other developing countries at similar levels of per capita income. The gross supply of primary energy in 1981, on the other hand, amounted to 9.7 million toe, made up as follows (in thousands of toe): fuelwood, 7,765 (80.2%); biomass, 526 (5.4%); hydroelectricity, 188 (1.9%); crude oil, 874 (9.0%); and imported petroleum products, 334 (3.5%). A significant part of the difference between final consumption and gross supply was accounted for by the high level of losses involved in the production of charcoal from fuelwood, estimated at 3.2 million toe; every ton of charcoal produced requires 6 tons of dry fuelwood. By comparison, losses in the case of petroleum refining amounted to only 42 thousand toe. The energy balance in Annex 1 gives the gross supply, conversion losses, stock changes and net domestic consumption of energy for 1981.

Table 1.1

Final Energy Consumption (1981)
(10^3 toe)

	Fuel-wood	Char-coal	Bio-mass	Elec-tricity	Petro-leum	Total	Share (%)
Agriculture				7	98	105	1.7
Industry	75		100	22	161	358	5.8
Transport					674	674	11.0
Households	2591	1686	426	23	55	4781	77.8
Public/Other	85	92		8	45	230	3.7
Total	2751	1778	526	60	1033	6148	100.0
Share (%)	44.7	28.9	8.6	1.0	16.8	100.0	

Source: Mission estimates, based on 1980 data provided by NEA, using Bank suggested conversion factors.

Commercial Energy

(a) General

1.08 In Sudan, commercial energy is obtained from hydroelectricity and imported petroleum and amounted to 58 kgoe per capita or 18% of total energy consumption in 1981. 1/ Imported petroleum accounted for 94.5% of commercial energy consumption while hydroelectricity contributed only 5.5%, indicating the high degree of reliance on imported energy. The largest consumer of commercial energy was transport (62%), followed by industry (17%) and agriculture (10%). The household sector consumed only 7% of commercial energy, reflecting partly restrictions on the availability of kerosene and limited access to electricity. 2/ The balance (4%) is accounted for by consumption by the public/other category.

(b) Petroleum

1.09 The consumption of petroleum products recorded a modest increase during the 1970s of 4% p.a. (see Table 1.2), when GDP was growing at 2.6% p.a. in real terms, giving an elasticity of a little over 1.5. The increase in the consumption of gasoline and gasoil was well above this average rate reflecting the high growth rate of the transport sector during the decade. The inter-city surfaced road network went through a rapid expansion from virtually nothing in the early 1960s to 1750 km in 1982, and thus encouraged road transport; road freight haulage increased from 920 million ton-km to 3570 million ton-km between 1971 and 1980 -- an increase of 16% p.a. Furthermore, passenger vehicles and taxis increased at an average rate of around 11% p.a. over the decade; the number of licensed motor cars increased from about 25,000 in 1970 to about 85,000 in 1980--an annual rate of increase of 13%. The mission has not been able to obtain a breakdown of the consumption of petroleum products by sectors but the above figures indicate that a substantial part of the increase in consumption is accounted for by the transport sector and the consumption of petroleum products by the industrial and agricultural sectors was either stagnant or increased only marginally. The consumption of petroleum products by the residential sector (mainly kerosene) actually declined.

1/ This definition of commercial energy may be misleading, in so far as large quantities of fuelwood and charcoal are traded commercially in urban areas, but it is retained in accordance with convention and to facilitate intercountry comparisons.

2/ The consumption of kerosene in 1981 was 20 thousand toe as against an estimated demand in the order of 70 thousand toe, based on past consumption patterns.

Table 1.2

Consumption of Petroleum Products, 1970 and 1980
(toe)

Product	1970	1980	Increases 1970-80 (%)
LPG	-	5,550	-
Gasoline	100,823	206,955	105
Kerosene and Jet	58,285	64,792	11
Gasoil	310,140	551,839	78
Fuel Oil	199,392	163,647	-18
Total	668,640	992,782	48

Source: NEA.

1.10 As there is no indigenous production, the entire increase in the consumption of petroleum products was met by increased imports of petroleum; crude oil imports remained roughly at a level of about one million mt, partly conditioned by refining capacity and the desired product mix, while petroleum product imports rose from 11,000 mt in 1973 to 334,000 mt in 1981. Petroleum imports rose in value from LS6.7 million in FY73 to LS30.5 million in FY75 and to LS162.8 million in FY81 while total imports had gone up from LS126.7 million to LS319.7 million and LS781.4 million respectively. Petroleum product exports rose from LS5.9 million in FY75 to LS17.6 million in FY81. While the total imports as a percentage of GDP rose marginally from 18 to 21, the percentage of petroleum products in total imports rose from 4 to 21. Therefore, the net commercial energy imports rose from a little less than 1% of GDP in FY73 to about 4% in FY81.

(c) Electricity

1.11 NEC's electricity generation in FY81 was 965 GWh and provided about 65% of Sudan's total electricity consumption; the balance was generated by individual enterprises to meet their own requirements. NEC's total generation capacity in 1982 was 311 MW, of which 160 MW was hydroelectric and the remainder thermal. However, due to age, lack of spares, major overhauls and other constraints, the serviceable (or reliable) capacity was in the order of 220 MW. Private self-generation capacity (excluding the sugar industry) is estimated to have grown at an annual rate of about 70% since 1978 and is now equivalent to half NEC's generation capacity. 1/ Public electricity operations are divided into eight regions, mostly served by isolated diesel systems. The only interconnected system is the Blue Nile Grid (BNG), which serves about 85% of customers receiving a public supply. Table 1.3 shows the growth of generation and maximum demand in the BNG over the ten-year period FY72 to FY81 and the growth of generation in NEC's isolated systems (IS) in the seven-year period FY75 to FY81.

Table 1.3

NEC's Electricity Generation and Maximum Demand in the BNG (FY72 to FY81)

FY	BNG	Electricity Generation (GWh) Isolated Systems	Total NEC	Maximum Demand in the BNG (MW)
72	379	n.a.	n.a.	74.0
73	418	n.a.	n.a.	81.6
74	452	n.a.	n.a.	86.0
75	489	100	589	93.6
76	528	104	632	96.0
77	576	106	682	104.0
78	667	111	778	126.0
79	742	112	854	136.9
80	819	113	932	144.7
81	841	124	965	157.8
		Growth Rates FY75 to FY81 (%)		
	9.5	3.7	8.6	9.1

Source: NEC.

1/ The rapid expansion of private generation facilities is due in large measure to the low level of public investment in the power sector, which averaged less than 5% of total development expenditure over the seven-year period FY76 to FY82. As a percentage of GDP, power investment has never exceeded 0.5% in the same period (see para. 6.1).

1.12 For the country as a whole, per capita consumption of electricity in 1981 is estimated at around 60 kWh. While access to electricity is limited and only about 8% of the population has access to a public supply, the residential sector accounted for nearly 38% of NEC's consumption. Industry and agriculture accounted for 37% and 12% respectively. The balance (13%) was accounted for by the public/other category. There has been a severe constraint in the supply of power to the industrial and agricultural sectors, which is likely to be relieved in the near future, as the components of Power III are commissioned in FY84.

Economic Losses due to Energy Shortages

1.13 Past studies of the suppressed demand for petroleum products in Sudan suggest that about 28% of real demand is suppressed; no studies exist in regard to other forms of energy. The mission therefore attempted to develop its own view of the extent of energy shortages and their impact upon the Sudanese economy. Although useful insights into the problem were gained, it was concluded that there is no satisfactory way of quantifying the extent and impact of energy shortages for two reasons. First, the national income statistics do not permit sufficient disaggregation by sub-sectors within each major sector to estimate the impact of energy shortages for a recent year. Secondly, production losses in agriculture and industry are due to a multiplicity of constraints, whose separate effects cannot be disentangled.

1.14 In the case of agriculture, production losses are caused by a number of factors, including: delays and inadequacies in land preparation; inadequate rainfall in certain years; shortages of irrigation; non-availability of agricultural equipment for one reason or another; and shortages of fertilizer. There is no clear-cut way of quantifying the loss due to energy shortages alone. 1/ Agriculture in Sudan is more dependent on commercial energy than in many developing countries and lack of timely energy supplies could be responsible for some of the factors listed above. In addition, non-availability of energy at the right time leads to delayed planting and/or harvesting and transport of crops after harvesting. While the output of sorghum more than doubled during FY82, harvesting in one of the MFC farms was delayed due to fuel shortages and this delayed land preparation for the next season. Losses have also been incurred due to inadequate transport facilities for crops, particularly in the western region. For example, it was reported that nearly half a million tons of sorghum deteriorated due to lack of transport from the west.

1.15 In the case of industry, seven industrial plants were visited and it was evident that output was constrained by shortages of raw materials, energy, skilled manpower and spares. It was again not possible to

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1/ However, it is estimated that interruptions in energy supplies to pumped irrigation schemes at critical times during the last two years caused production losses of at least US$60 million.

disentangle the separate effects of these shortages. In several cases, the shortage of raw materials appeared to be the main production constraint (e.g. of cotton seed due to a drop in cotton production), or imported raw materials due to a shortage of foreign exchange. On the other hand, it was noticeable that there was a marked drop in monthly production during the summer months (May - July), when supply from the BNG was restricted. For example, Sudan Textile Mills experienced a complete power cut between May 3 and July 3, 1982 and thus suffered a production loss despite a standby capacity of 6.2 MW (as against a requirement of 9 MW). In addition, frequent power cuts and voltage drops led to equipment damage and hence the need for more spares. Studies carried out by the NEA have indicated a markedly low capacity utilization in Sudanese industry. While capacity utilization in industries operating in the Port Sudan area was of the order of 65%, in the rest of the country it averaged around 40%. The high capacity utilization in the Port Sudan area was mainly attributable to a greater degree of self-reliance in electricity generation and easier access to petroleum supplies from the Port Sudan refinery, imported raw materials, spares and other inputs.

1.16 In many developing countries, rising oil prices have imposed severe burdens on the economy and imports as a percentage of GDP have gone up substantially. In the case of Sudan, imports as a percentage of GDP have increased only marginally and net energy imports amounted to about 4% of GDP in FY81. 1/ At a time when the transport sector was growing at a high rate, petroleum products import growth was held to only 4% p.a. and the Government sought to meet the growing needs of the agricultural, industrial and residential sectors by an allocations system. This may have led to severe distortions; for example, due to a reduction in the allocation of kerosene to the residential sector (from 66,000 mt in 1972 to 20,000 mt in 1981) some gasoil was diverted for lighting, presumably from the agricultural sector. The net result was that the productive sectors may have been allocated less than they would normally require and may in fact have consumed less than they were actually allocated.

1.17 Import allocation priorities do not seem to have been optimal and a greater percentage devoted to the import of petroleum products may have resulted in higher agricultural and industrial production and more buoyant exports. For example, a 25% increase in petroleum product imports in the three-year period FY79-FY81 would have cost about LS88 million or around 5% of the total import bill for this period, but would have assured adequate supplies to all productive sectors of the economy, rendered unnecessary an inefficient allocation system and probably resulted in much higher export earnings. It may be noted that the foreign exchange crisis which Sudan faces is a result of exports declining rapidly

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1/ By comparison, the ratio of net fuel imports to GDP for all oil-importing developing countries in 1980 was 5.2% (see World Development Report 1981, Table 2.5).

rather than imports increasing sharply as a percentage of GDP. 1/ The fortunes of the Sudanese economy have always been closely related to agriculture and in particular cotton. A substantial part of the decline in exports was caused by a decline in cotton production. One of the keys to Sudan's economic recovery, therefore, must lie in making energy available in adequate quantities to the productive sectors of the economy and ensuring that there is little or no incentive for the diversion of these supplies to other sectors.

Conclusions

1.18 It appears that the present economic crisis faced by Sudan is in no small measure due to the massive energy shortages experienced in the last few years and future energy supplies are critical to Sudan's economic recovery. The short- to medium-term outlook is encouraging: power shortages are likely to be relieved during FY84 with a doubling of installed capacity; and domestic crude will augment petroleum supplies and export earnings from FY86. However, improved economic performance will require better management of the energy sector and a system of allocation of foreign exchange which will permit the Government to plan petroleum imports on a more rational basis to assist development in the major energy-using sectors.

1/ Between FY71 and FY81, imports rose from 18% of GDP to 21%; exports fell from 16% to 9% during the same period.

II. ENERGY RESOURCES

Introduction

2.01 In relation to its large land area, Sudan is poorly endowed with energy resources. Commercial energy resources are limited to hydroelectricity and the recent discoveries of oil and gas. Taking into account the fact that the River Nile traverses the entire length of Sudan, hydroelectric resources are more modest than would be expected, due to the low river gradient. The recent discoveries of oil and gas are also not large but they will have a useful role to play in the Sudanese economy. Sudan is, however, blessed with a considerable forestry resource; as this is the most abundant resource and is also renewable, it will continue to play an important role in the economy even after commercial energy resources have been developed. Due to its geographical position, Sudan receives high solar insolation which could be a valuable energy resource when appropriate technologies are developed. The wind regime is favorable in the northern part of Sudan and may be expected to contribute marginally towards meeting Sudan's energy needs. A discussion of each of these resources follows, including the likely contribution of the sugar industry to meeting the energy needs of Sudan.

A. Petroleum

Exploration Activities and Hydrocarbon Resources

2.02 Exploration activities have taken place in Sudan for several years in three broad areas: the northwestern corner, bordering Egypt, Libya and Chad; the Red Sea coast and areas immediately offshore; and the interior, especially the southern part of the country. The northwest corner has not, so far, shown any promising results, although exploration licences have been granted since 1959, first to Shell and B.P. and later to Continental Oil and Total. It is the Red Sea area and the interior which have shown the most encouraging results.

2.03 Interest in the Red Sea area started in 1959, concurrent with the interest shown in the northwest corner. Since that time, Agip, General Exploration Company of California, Digna, Chevron, Burmah/Eastern Petroleum, Total, Texas Eastern and Union Texas have all received licences. Photogeologic, aeromagnetic and seismic studies have been carried out. Nine wells have been drilled, of which six are located in the Tokar Delta region, south of Suakin; only two have tested gas and one of these (Chevron's Bashayer 1) is apparently non-commercial. The other (Chevron's Suakin 1) is a wet gas discovery but has not yet been confirmed and the concession was relinquished in 1976 without additional drilling. Based on data from the first well and later seismic interpretations, it could have 130-385 billion cubic feet of gas and 9-29 million barrels of condensate. The gas has a high heating value (1300 BTU per cu. ft.) and no sulfur, which makes it an excellent fuel. Additional drilling on the Suakin structure is required to firm up the reserve figures. There are two smaller structures in the area which may be worthy of drilling if the Suakin structure appears commercial after one or two more wells.

2.04 Burmah/Eastern Petroleum, Total and Texas Eastern obtained production sharing contracts along the Red Sea in 1979. The first two contract areas are in the Tokar Delta and adjacent offshore while the latter is in the north from about Ras Abu Shagara northward to the Egyptian border. All of these companies carried out seismic programs in 1980 with recorded totals in 1980 and 1981 as follows: Texas Eastern, 2100 km; Total, 3064 km; and Burmah, 390 km.

2.05 Total drilled an exploratory well on the Bashayer structure on which Chevron had found non-commercial gas. The well was low and dry. Total is now trying to "farm out" its contract area, which will require the "farm-in" partner to drill a delineation well on the Suakin structure, where Chevron had drilled the Suakin 1 gas-condensate discovery well. Total believes there may be a light oil ring present that could be commercial and enhance the prospect of the Suakin structure.

2.06 The Burmah-Eastern Petroleum contract area was farmed out to Union Texas Petroleum, which completed the Digna 1 exploratory well early in 1982. The area will probably be relinquished in 1983, as the well was dry and gave little encouragement for additional exploration on the offshore portion of the tract. Texas Eastern began its Halaib 1 exploratory well in the north portion of its contract area on October 1, 1982. It is the most northerly location yet to be drilled in the Sudan offshore and for that reason is important. It has been programmed to a depth of 11,300 feet, which is expected to be into basement. A second location has been selected by Texas Eastern but the final decision to drill has not been made.

2.07 The first exploration licences to be granted in the <u>interior of Sudan</u> covered almost the entire sedimentary outcrop area of the country south of latitude 15° north and were granted to Chevron in 1974. Aeromagnetic, gravity and seismic work was carried out. The first exploratory well was begun in late 1977 and the first discovery was made in 1979. By early November, 1982, three drilling rigs and four seismic crews were operating, with a fourth drilling rig to begin in 1983; 35,000 line km of seismic had been recorded. In September 1982, total expenditures had exceeded US$500 million and were taking place at a rate of about US$15 million per month. Chevron had drilled 50 wells as of November, 1982, in two of the three sedimentary basins; of the thirty-three wells on which results are available, nine had tested oil, i.e. a success ratio in excess of one in four. However, to date only one discovery seems to be of commercial interest, namely the Unity-Talih Trend which is 16 km long by about 2 km wide. Recoverable reserves appear to be at least 150 million barrels, which are present in ten individual reservoirs, some of which are less than ten feet thick. The oil is very waxy with a paraffin base and has a high pour point of 80°F. These characteristics will cause difficulty in handling, which in turn will increase the cost of the oil. In addition, as there is no dissolved gas in the oil and no apparent water drive in the reservoir, water flooding will be required immediately upon the commencement of production, which again will increase the cost. To some extent, these increases in cost will be offset by an expected higher price due to the low sulfur content and the excellent lube qualities of the crude.

2.08 Unfortunately, reliable estimates on the size of recoverable reserves in the Unity-Talih field are not available. The figure of 150 million barrels is based upon a knowledge of the field's geology and information gathered from the wells tested to date. On the other hand, the known plans of the Government and Chevron for the exploitation of Sudan's petroleum resources suggest that total reserves may be considerably higher. A senior Chevron official has stated that discovered oil reserves amounted to 200 million barrels and Chevron was optimistic that they would continue to make significant discoveries. 1/

2.09 In November, 1979, Total, along with two minority partners, entered onshore exploration by obtaining rights over large areas that had previously been released by Chevron, along with a block in the northwest portion of the country. Total has recorded 1,000 km of seismic and has interpreted it along with 500 km of Chevron data which was recorded earlier. An aeromagnetic program has been completed and 1500 km of seismic is planned for 1983 to explore further two long, narrow basins that have been located.

2.10 In 1981, both Sun and Phillips obtained contract areas in the northwestward extension of the Blue Nile graben. They have completed a joint aeromagnetic survey, which was reported to be indecisive as to basement depth. However, experimental seismic work will be undertaken in 1983. A number of small independent companies have made applications for contract areas adjacent to the major holdings noted above, so that by now all areas with any sedimentary thickness are either under contract or have been applied for.

Crude Oil Export Pipeline

2.11 After considering various alternatives, including the construction of a refinery at Kosti, the Government and Chevron signed an agreement in January, 1983 providing for the construction of a 1,425 km crude oil pipeline from the Unity-Talih oilfield near Bentiu to a marine terminal at Marsa Nimeri, 20 miles south of Port Sudan. The pipeline diameter is to be 22" - 24", with an initial design capacity of 50,000 bpd. By adding pumping stations, the capacity can be increased to about 200,000 bpd. Given the waxy nature of the crude, several alternatives were examined to make its transportation by pipeline feasible. These alternatives included heating the crude and the addition of different types of cutter stock (or diluent). It was decided to use a middle distillate as a diluent (e.g. naphtha) and to transport the diluent

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1/ Middle East Economic Survey 26:14, January 17, 1983. The higher figure would appear to include the nearby Heglig field.

inland from the coast in a parallel diluent pipeline. The diluent would be blended with the crude oil in a ratio of up to 1 in 5. Since the diluent will remain in the crude after it is sold, to make continued transport possible, the crude should fetch a higher price but not enough to cover the cost of buying and transporting the diluent. 1/

2.12 Bids for the pipeline project were invited in January 1983, from six prequalified consortia and the award of a turnkey contract is expected in September, 1983. The project is scheduled for completion towards the end of 1985. Construction of the oil terminal will be handled under a separate contract to be let in 1984.

2.13 The estimated cost of the pipeline and marine terminal is about US$910 million (including working capital and interest during construction) and, although it should be possible to arrange the financing, the terms will need to be examined carefully. The pipeline will be owned by the White Nile Petroleum Corporation (WNPC) and operated as a common carrier for any oil discovered by other exploration contractors. Most of the financing will be arranged through borrowing against the proceeds of the crude oil exports. Chevron has declared that it is prepared to arrange the necessary financing for the construction of the pipeline. WNPC is owned by the Government (one-third), Chevron (one-third), IFC (one-sixth) and APICORP (one-sixth). The pipeline is expected to be financed 25% by equity, which will mean increasing the capital of WNPC to US$225 million. The Government intends to increase its share of the re-capitalized WNPC to 44%, with Chevron also holding 44%, and IFC and APICORP the remaining 12%. Agreement has been reached in principle for Chevron to prefinance the Government's equity share. IFC has appraised the project and will take a decision soon on its participation.

2.14 As a substantial part of the crude has to be exported to recover the cost of exploration, field development and the pipeline, the amount of crude likely to be available to Sudan at a production level of 50,000 bpd is estimated to be at least 16,000 bpd. 2/ Under its agreement with Chevron, the Government has the option to take up to 5,000 bpd at the oil fields or at any point along the proposed crude oil export pipeline. Apart from its direct share in the output of the Unity-Talih field, the Government, as a shareholder in WNPC, should also receive a dividend on part of the transportation fees which are paid to WNPC. 3/ However, it must be emphasized that these estimates of Sudan's net benefits are

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1/ A further possibility would be to construct a parallel gas pipeline instead of a diluent pipeline, to use the natural gas which has been discovered in the Red Sea to heat the crude and to supply local markets (see para 4.42).

2/ Based on a crude oil price of US$30 per barrel in 1983 prices.

3/ Estimated at 2,000 bpd, again based on a crude oil price of US$30 per barrel in 1983 prices.

conditional upon the eventual terms which are arranged for financing the pipeline. Nevertheless, the quantities of crude which are likely to be available to Sudan provide some new options, which are examined in Chapter IV.

B. Hydroelectricity

2.15 A complete inventory of Sudan's hydroelectric resources is not available. 1/ Nevertheless, it is evident that, for large scale developments, Sudan will have to depend on the Nile and its major tributaries. Detailed discharge records covering over fifty years are available and the potential water uses have been studied extensively; a computer model has been developed by consultants for the Government and NEC. Irrigation requirements largely dictate the water release patterns of the existing hydroelectric plants and the nature of the rivers requires long but low-head dams and large reservoirs to ensure water availability for irrigation during the dry season. Reservoirs have been created at Roseires and Sennar on the Blue Nile and at Khasm el Girba on the Atbara River.

2.16 A number of studies have been carried out for the BNG, to varying levels of detail; potential hydroelectric sites have been identified, but follow-up studies have not been completed beyond the pre-feasibility stage to ascertain their technical feasibility, particularly with respect to siting. Consequently, no scenario is available from which an order of merit scheme could be prepared resulting from a least-cost analysis. It should be noted that the large hydroelectric schemes in the south, such as the plants on the Bedden and Fola Rapids near the border with Uganda, cannot be considered as generation sources for the BNG as they are too remote from the consumption centers and transmission costs would be high. Such information as exists on the various hydroelectric possibilities which have been identified for the BNG and which could in principle be included in the long-run development plan is summarized in the following paragraphs.

2.17 The addition of 2X7.5 MW at Sennar could generate on average 72 GWh in addition to the 109 GWh average capability of the existing plant; it would not add to firm capacity. 2/ It appears that the plant would be economically justified only if the Roseires dam is heightened and until then only as a substitute for thermal energy.

2.18 The installation of a seventh unit at Roseires would add on average 120 GWh per annum by 1990 or about 10% of generation by the first six sets. The heightening of Roseires dam (by 9 m) would increase plant capacity outside but not during the flood season. The additional mean generation would be 500 GWh. A low-head power plant (4X30 MW) could also

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1/ A study is being financed by the Italian Government, covering the southern part of the country.

2/ The feasibility of adding 2 x 15 MW is also being studied.

be added at Roseires, using canal works already completed but not expected to be fully utilized. The station would operate throughout the flood season, add some 100 MW of firm capacity during the flood season and generate a mean 368 GWh p.a. The possibility exists of adding a 35 MW power station at the existing Jebel Aulia dam on the White Nile, 40 km south of Khartoum. The gross head at this dam varies from 6.3 m in March to practically zero during the flood season. No contribution would be made to the system's firm capacity but 166 GWh could be generated on average to substitute for thermal energy. The technical viability of the project has yet to be established, as operation at a decreasing low head becomes more and more difficult and would impose further constraints on the plant's generating capability. The installation of bulb-type turbine generators has been studied but there are doubts as to whether or not this type of machine can be used, for reasons of system stability and maintenance.

2.19 The potential exists for a 20 MW plant at Rumela, on the Atbara river upstream from Khasm el Girba. The dam would extend the life of the Khasm el Girba reservoir by providing additional storage for siltation. In the early years, generation would not depend on irrigation requirements and mean generation could be about 58 GWh per annum.

2.20 Although no detailed information exists, there is the possibility of installing a dam and power facilities at Burdana, on the Setit River, a tributary to the Atbara between Khasm el Girba and Rumela. Further studies are required to establish the potential generating capacity.

2.21 A 120 MW station at Sabaloka, on the Main Nile, 90 km north of Khartoum, has a potential annual mean generation of 700 GWh, which again would be largely free from irrigation constraints. A major problem, however, could arise in extreme hydrological conditions, when floodwater from the tailrace apparently could flood Khartoum; the cost of protecting Khartoum has not been studied.

2.22 Some 2000 MW can be developed at four sites along the Main Nile, downstream from Sabaloka, up to Lake Nubia and the Egyptian border: 240 MW at Shereik, downstream of the confluence with the Atbara; 450 MW at Shirri Island, downstream from Shereik; up to 750 MW at Merowe, downstream from Shirri Island; and 600 MW at Dal, near the Egyptian border. No efforts have been made to study these projects beyond the prefeasibility stage. Discussions are underway with the Swedish Government for financing a study of the Merowe plant, which could be built in one or two stages.

2.23 Despite the numerous studies which have been made of the Nile and its tributaries, the planning of additions to system capacity in the BNG has been carried out with insufficient lead time to permit the optimum use of Sudan's hydroelectric resources; in practice, optimisation has normally been confined to a choice between the thermal alternatives which could be constructed in time to meet anticipated demand.

2.24 As soon as possible, therefore, a study should be prepared which would update the long-term power development program to the year 2000. The study should: (a) define the economic merit order of plant, taking into account a range of uncertainties in irrigation development and, consequently, define the appropriate timing for the plant; (b) be organized in such a way that it can be repeated rapidly and at low cost at least every two years; (c) assess the adequacy of studies already made for each plant; (d) define further studies and surveys necessary to proceed to the stages of feasibility and preliminary design; (e) estimate the local and foreign exchange cost of the studies and surveys; and (f) attach a priority to each of the studies and define its timing in the light of assumed financial and physical constraints.

2.25 In updating the long-term power development program for the BNG, an important objective is to lay the foundations for a consistent approach towards regular updating, so that the reliability of the findings would increase through time. The hydroelectric capability of the Sudan (2,000-3,000 MW) is large enough to justify executing studies in an orderly and expeditious manner.

C. Renewables

(1) Forestry

Climate

2.26 Sudan consists essentially of an extensive plain bounded on the north by desert, on the east by the Red Sea Hills and the Ethiopian foothills in the south by the line of the Acholi, Smatang and Didinga Mountains and, on the southwest and west, as far as 9°N latitude by the higher ground of the Nile-Congo watershed. Lying within the tropics, the climate is dominated by the seasonal movement of the inter-tropical convergency zone, except for the local influence of the Red Sea on the climate of the Port Sudan coastal plain.

2.27 Three climatic zones may be recognized. The first is north of about latitude 19° N. This is a desert region, with prevailing northerly winds throughout the year, and minimal rain. The second climatic zone is south of about latitude 19° N, where the climate is dominated by north-south movement of the inter-tropical convergence zone of the dry northerly and southerly winds. The duration of the rainy season is determined by the period during which the moist southerly winds predominate; hence short, sparse rains occur in the northern limits and longer, heavier rains in the Southern Region. Rainfall intensity is determined by the shower or thunderstorm type falling in the afternoons and evenings. In the semi-arid north, duststorms are common. The third climatic zone is along the Red Sea coast, which is influenced by the Red Sea maritime factors, and most of the rainfall occurs in the winter, with a secondary rainy season in the summer.

2.28 The mean annual rainfall isohyets are remarkably parallel across the country from west to east. There is thus a steady progression of increasing rainfall from north to south; this pattern of distribution determines the natural vegetation divisions, which in consequence tend to lie in broad belts across the country.

The Forest Resource

2.29 Early estimates made in the 1950's to the 1960's indicated a productive forest area of 455,000 km^2. A further revision indicated limits of 455,000 to 585,000 km^2. The lower figure was estimated to carry a growing stock volume of 1,280 million m^3 of firewood and building poles and 52 million m^3 of timber, i.e. a total growing stock of 1.3 billion m^3. The overall stocking based on these figures would be of the order of 22.2 m^3 to 28.6 m^3 per hectare of productive forest, with actual values ranging from 150 m^3 per hectare in the mentano forest of the Southern Region to less than 1 m^3 per hectare in the desert areas.

2.30 No national forest inventory has been made to verify these figures and only limited surveys for specific purposes, generally resource estimation for the sawmilling industry, have been carried out. As a result of this uncertainty, no reliable data base exists for forestry planning purposes. A national forestry inventory should therefore have a high priority. The National Energy Administration (NEA) did commission a study, executed by the Forestry Administration, using 1972 Landsat imagery, to revise the estimates summarized in para. 2.29. The satellite imagery was visually interpreted in thirteen strata covering the country from the Luratong mountains in the Southern Region to the arid areas of the Northern Region.

2.31 A growing stock inventory at low intensity to provide ground truth was carried out in selected areas including the Blue Nile, White Nile and Kassala Provinces in April and May 1982. The results of these activities indicate an increase in total growing stock to 1,994 million m^3 due to both larger forest area and higher growing stock volume per hectare. However, analysis of the ground truth data reveals severe reduction in growing stock volumes, particularly in the once heavily forested areas of the Blue Nile Province, where the growing stock is presently estimated to be only one-third of previous estimates, i.e. less than 9 m^3 per hectare. Preliminary data from these surveys are in Annex 2, which also indicates a total annual allowable cut of 15.1 million m^3 of wood for the Northern Region and 29.3 million m^3 for the Southern Region.

Distribution of Forest and Population

2.32 The available growing stock resource is unevenly distributed both between the Northern and Southern Regions and between Provinces within the Regions. Thus, 33% of the total growing stock occurs in the Northern Region and 67% in the Southern Region. Furthermore, within the twelve Northern Region Provinces, 93% of the total available growing stock occurs in the two Provinces of Southern Darfur and Southern Kordofan combined. By contrast, the Northern Province probably has less than 3% of the growing stock of the Region. In the Southern Region, the Provinces of Bahr El Ghazal and West Equatoria together carry 63% of the

Region's growing stock, with the smallest resource of 3% occurring in the Jonglei Province.

2.33 The population distribution pattern between the Northern and Southern Regions presents the opposite case. In 1980, 78% of the total population was concentrated in the Northern Province, whereas the Southern Region had only 22% of the total population. There is thus a considerable imbalance between fuelwood resources and population.

2.34 In terms of available growing stock and annual allowable cut in m^3 of roundwood per capita, 1980 average figures for the Northern Region were 50 and 1 respectively; for the Southern Region, the figures were 322 and 7 respectively. These numbers emphasize both the uneven distribution of the resource and, as far as the Northern Region is concerned, the inability of its resource to provide a sustainable supply adequate to meet consumer requirements for firewood and charcoal, quite apart from other demands on the resource for commerce, industry, poles and timber.

(ii) Solar

2.35 Sudan has been maintaining records of solar radiation since 1957 and the data base is extensive. Solar radiation, measured horizontally, ranges between 6.9 GJ/m^2 p.a. in the south to 10.1 GJ/m^2 p.a. in the north, equivalent to a sizable 436-639 W/m^2.

2.36 At the present state of development, solar energy could be used in Sudan for the following purposes: (a) water heating for low-temperature commercial and industrial applications; (b) drying of agricultural products; (c) stills for water desalination, and (d) photovoltaic cells for remote small-scale application. These combinations were submitted by the NEA to ten Sudanese and in-country foreign experts involved in the study of renewable energy developments. The panel concluded that only item (a) could have substantial utilization and market potential in the country. NEA itself has identified several hotels and industries as potential customers for converting to solar heating and made an analysis of a typical, locally produced solar water heating system, which would have an internal rate of return of 8.8% when substituted for fuel oil.

(iii) Wind

2.37 Wind speed has been measured in 23 meteorological stations throughout the country, mostly for more than 20 years, at a height of 15.2 m above ground, as well as at ground level. NEA has analysed and refined the available data to identify wind characteristics for the design of wind energy conversion systems (WECS). The wind energy potential generally increases from south to north with the area around Dongola (in the northern part) showing a density in excess of 400 W/m^2. In the Khartoum area, wind power density ranges between 285 W/m^2 and 380 W/m^2.

2.38 About 250 windmills of American design were installed in the Gezeira province in the early 1950's for pumping drinking water for dispersed small communities. They were progressively replaced (the last one was dismantled by 1965) by diesel and electric driven pumps because their operating and maintenance cost were high, spares were lacking and the design was inadequate for Sudanese conditions.

2.39 Research in windmill design, construction and testing is underway at the University of Khartoum in collaboration with Reading University (UK). The Australian government has agreed to supply five windmills which are expected to be installed shortly in the Khartoum, Kordofan, and Darfur areas.

2.40 A wind energy program is presently being studied by the German Steering Committee for Wind Energy in Developing Countries (SWD), in collaboration with the Sudanese Institute of Energy Research. The two-phase, five-year program would establish a wind energy department within the Institute to develop and introduce a wind energy technology appropriate for the Sudan. The first phase would initiate pilot projects of locally designed and manufactured pumping windmills. In the next phase, both water pumping and electricity generating systems would be installed at selected sites to collect data on problems and suitability of equipment.

2.41 In view of the high wind density in the northern part of the country, mostly in excess of 150 W/m^2, and the fact that some 12,500 diesel driven pumps are operating in the agricultural areas, with an installed capacity of about 125 MW, potential for developing WECS' for pumping are large. Even at a load factor as low as 25%, these diesel driven pumps would represent some 175 GWh of energy, equivalent to a consumption of 82,000 mt of gasoil.

(iv) Molasses and Bagasse

Sugar Industry

2.42 There are two distinct sectors in the Sudan sugar industry. The first is the wholly government-owned sector, comprising four mills (Guneid, New Halfa, Sennar and Assalaya) with a combined design capacity of about 340,000 mtpa. The second is semi-private and consists of the Kenana Sugar Company (KSC), whose mill has a design capacity of 330,000 mtpa at a single location. KSC is owned by the governments of Sudan, Kuwait and Saudi Arabia, the Arab Investment Company, the Sudan Development Corporation and various private foreign investors. It commenced production in FY80. The publicly-owned sugar sector has performed poorly and exhibited declining production for several years. As a result, proposals for the rehabilitation of the public sector have been prepared by Tate and Lyle Technical Services (TLTS) and a Sugar Rehabilitation Project is now under consideration by the Government and the Bank. Kenana is a sophisticated project, which is technically successful, but there are financial aspects of its future which remain to be resolved.

Molasses

2.43 The possibility of substituting part of Sudan's domestic consumption of gasoline by ethanol produced from molasses has been under consideration for several years. A project proposal was submitted by

TLTS in 1980; at the time of the energy assessment mission, TLTS was updating relevant ethanol project data, while preparing its recommendations on the rehabilitation of the publicly-owned sugar schemes. It is understood that KSC has also commissioned an independent review of fuel ethanol potential.

2.44 Assuming that the full rehabilitation proposals are implemented, TLTS has estimated molasses availability (in mtpa) in the public sector at full capacity as follows: Sennar, 43,800; Assalaya, 40,800; New Halfa, 26,400; and Guneid, 25,600. Kenana might reach 130,000 mtpa rather than 105,000 mtpa, as assumed by TLTS. The potential for ethanol production from this total quantity of molasses is estimated at 45,000 mt.

Bagasse

2.45 Throughout the world, bagasse is potentially a source of primary energy after meeting the needs of the cane sugar industry. Provided that a sugar factory is well-designed, well-operated and functions at or near its design throughput, the bagasse availability will normally be surplus to its own steam and power requirements. In Sudan, the ratio of fibre to cane (18%) is higher than in most countries so that a potentially large quantity of bagasse is available. Nevertheless, the sugar industry in Sudan is a net energy consumer as it uses significant quantities of petroleum products (see Annex 3) and in addition is supplied with electricity from the public grid.

2.46 There are six reasons for this heavy reliance on external energy supplies: (i) the factories are poorly managed and operate intermittently; (ii) cane supplies are insufficient, due in part to an unreliable public power supply for irrigation; (iii) steam and power demand are high as a result of the production of refined rather than mill white sugar; (iv) all mills (except New Halfa) have high electric demands from their irrigation systems; (v) the mill operations are generally highly mechanized; and (vi) cane haulage distances are long, resulting in a high usage of gasoil and gasoline.

2.47 However, the industry is unlikely to become a net energy exporter and the best that may be expected is that it would not be a net power consumer. Consumption of petroleum products would continue.

Conclusions

2.48 In the short- to medium-term, the fuelwood resource will continue to be the most important resource for Sudan and more managerial effort and a higher budgetary allocation should be devoted to its preservation. Oil and gas resources proven to date will have a limited impact on the overall energy supply situation, but exploration activity has been stepped up substantially in the last five years or so and there is a real possibility that additional discoveries of oil and gas will be made. Southern Sudan is held to be the most promising area and the Government of Sudan and Chevron are wisely planning a pipeline with a capacity in excess of the presently planned production. If these new discoveries can sustain an additional production of 50,000 bpd or more Sudan could well become self-sufficient in energy for some period of time. Solar and wind energy and additional hydroelectric generation are expected to make a contribution only in the longer term.

III. SUPPLY AND DEMAND FORECAST SCENARIOS

Introduction

3.01 The 1981 energy balance shown in Annex 1 and discussed in Chapter I makes extensive use of data compiled by NEA, particularly regarding the consumption of fuelwood, charcoal and biomass. The conversion of these fuels from original units to oil equivalents is based on the Bank's suggested conversion factors rather than those used by NEA. Electricity data was obtained from NEC records. There are discrepancies in the petroleum product data: consumption figures provided by GPC are at variance with refinery crude throughput, product output and product import figures. In order to achieve a material balance in the petroleum sector, these discrepancies have been shown as stock changes. This indicates the need for preparing material balances in the petroleum sector on an annual basis. It should also be noted that the consumption of all forms of energy in 1981 was constrained by limitations on supply, which were reflected only partially, if at all, in the prices charged. Nevertheless, Annex I represents the best data available to the mission and has been used as a basis for the mission's projections of energy supply and demand for 1986, 1991 and 1996. Separate projections are made for fuelwood, charcoal, biomass, electricity and petroleum products, as discussed in the following paragraphs.

Non-Commercial Energy

3.02 Studies indicate that the consumption of fuelwood in rural households is higher than in urban households. Among rural households, consumption appears to be higher in provinces with more abundant fuelwood supplies. On the other hand, urban households have a higher per capita consumption of charcoal. The detailed breakdown of the consumption of fuelwood and charcoal in different provinces are in Annexes 4 and 5 respectively and summarized in Table 3.1. Table 3.2 shows projected increases in the demand for fuelwood and charcoal corresponding to the anticipated growth rates in population to the year 1995 on the assumption that there is a continuation of the present levels of per capita consumption and that very little inter-fuel substitution takes place in the household sector. The derived forecasts of demand for fuelwood and charcoal separately, in terms of m^3 of roundwood, are given in Annexes 6 and 7 and for fuelwood and charcoal combined in Annex 8.

Table 3.1

Average Consumption of Fuelwood and Charcoal in Urban and Rural Areas, 1980
(m^3 roundwood equivalent per capita)

	Fuelwood	Charcoal
Urban	0.85	3.70
Rural	1.50	1.80

Table 3.2

Five-Year Growth Rates in Urban, Rural and Total Population and in Fuelwood and Charcoal Consumption in the Household Sector, 1980-1995
(%)

	1980-1985	1985-1990	1990-1995
Urban population	40.6	38.2	35.6
Rural population	5.8	7.0	3.8
Total population	14.2	16.9	14.9
Fuelwood consumption	9.3	10.7	9.3
Charcoal consumption	16.4	24.8	21.9

3.03 Limited quantities of fuelwood and charcoal are also used in industry and commerce. Fuelwood use in industry is largely confined to wakeries and brickmaking, which account for 83% of total industrial use. Industrial and commercial consumption of fuelwood and charcoal is projected to grow at 3% per annum.

3.04 In the case of other biomass energy sources - bagasse, groundnut shells, crop residues and animal wastes - a simpler approach is adopted. Allowance is made for a substantial increase in availability and utilization of bagasse, due to rehabilitation of the sugar industry by 1985. Use of biomass in the household sector is assumed to grow at a rate slightly below the total population growth rate, to reflect the increasing degree of urbanization.

Electricity

3.05 The approach adopted for the electricity subsector was dictated by the fact that its growth will be constrained by the available supply throughout the projection period. Until 1991, supply will be based on the completion of Power III and the possible implementation of Power IV. Between 1991 and 1996, the supply options are confined within a narrow range, given the long lead time for hydroelectric projects. The forecasts of demand for electrical energy are, therefore, more properly regarded as the mission's best estimate of the consumption which is likely to be met, given an expected upper limit on NEC's ability to supply. Separate estimates were made for the BNG and the isolated systems. In the former case, it was estimated that consumption could grow by 7.5% in FY83 and that the implementation of Power III in late FY83 and FY84 would permit consumption to grow by 30% in FY84; after FY84 electricity demand in the BNG was held to a growth of 9% p.a., i.e. the average rate recorded in the decade FY71 to FY81. 1/ In the case of the isolated systems, the historical growth rate of 4% p.a. in consumption since 1974 is entirely misleading, but little objective basis exists for future projections. More or less arbitrarily, it is assumed that demand in the isolated systems will grow at 15% in FY83 and 10% p.a. thereafter. The demand projections for the BNG and isolated systems were then combined and generation forecasts obtained on the assumption that transmission and distribution losses would fall from the present level of 27% to 17% by FY86. Finally, the consumption of petroleum products by the electricity subsector (NEC) was estimated by projecting the generation mix between hydroelectric and thermal power generation and by anticipating a significant shift from the use of gasoil to fuel oil. 2/

Petroleum Products

3.06 While the demand for electricity was treated as supply constrained, the demand for petroleum products was derived on the assumption that additional supplies could be imported. The conventional approach was, therefore, adopted in which the growth in the demand for petroleum products was related to the growth in GDP. As noted in Chapter I, the future recovery of the economy of Sudan and its subsequent growth will

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1/ NEC is projecting a growth rate of 12% p.a. after FY84.

2/ New thermal units will be of larger size and suitable for the use of residual fuel oil.

depend on a high level of external assistance so that Sudan can maintain critical imports of oil, raw materials and intermediate goods, to this end, the Government has prepared a medium-term recovery program to serve as a basis for consultation with overseas donors. 1/ Economic recovery will also entail better management of domestic resources and a revitalization of exports. In view of these uncertainties, the forecasts of the demand for petroleum products has been predicated on the basis of two alternative scenarios related to the underlying growth of the economy. Under Scenario A, GDP grows at an average rate of 2% p.a. from 1981 to 1986 and 3% p.a. from 1986 to 1991. The aggregate final demand for petroleum products (excluding electricity generation, see para. 3.04) assumes an elasticity of 1.5 with respect to aggregate GDP growth, the figure during the decade 1970-1980 (para. 1.09). Under Scenario B, GDP grows at 4% p.a. from 1981 to 1986 and 5% p.a. from 1986 to 1991. The aggregate demand elasticity for petroleum products under Scenario B is assumed to be 1.5 for the period 1981-1986, falling to 1.2 in the period 1986-1991. Under both scenarios, demand grows after 1991 at the rate calculated for the period 1986-1991. Lump-sum provisions have been made for individual large-scale plants, as yet unidentified. These would be plants with high energy requirements, e.g. cement, bitumen and fertilizers. The projections of the consumption of fuel oil include 100,000 mt in 1986 and 150,000 mt in 1991 and 1996 for these purposes.

3.07 In making the projections for the individual petroleum products, a neutral assumption was employed, in which present consumption patterns continue. This tends to overstate the growth in gasoline consumption and understate the growth of LPG and kerosene consumption. In the urban areas, there is likely to be some inter-fuel substitution in the household sector, particularly of charcoal by kerosene and LPG. An increase in the emphasis on public transport and a greater degree of restraint on the growth of private transport (motor cars) will also tend to increase gasoil and suppress gasoline consumption. The energy balances do not reflect these likely shifts and provide only a general indication of the aggregate petroleum product demand for the purpose of discussing some of the issues and options in the petroleum sector.

The Energy Balances

3.08 The demand projections, in terms of oil equivalents, are in Annex 9 (Scenario A) and Annex 10 (Scenario B). Supply projections are also included, based on the following assumptions: (a) consumer demand for non-commercial energy will be fully met, in spite of a declining fuelwood resource; (b) no substantial improvements in the conversion efficiency of fuelwood to charcoal; and (c) PSR would work at full capacity and the remaining demand for petroleum products would be met by imports. Table 3.3 summarizes the results in terms of final energy consumption. The same information is expressed in conventional units in

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1/ "Prospects, Programmes and Policies for Economic Development (1982/83 - 1984/85)".

Table 3.4, along with annual growth rates. The net imports of petroleum products which would be required to meet these consumption e e s, including the intermediate consumption of the electricity industry (NEC), are in Table 3.5.

Table 3.3

Final Energy Consumption 1981, 1986, 1991 and 1996
(10^3 toe)

	Base Year	Scenario A			Scenario B		
	1981	1986	1991	1996	1986	1991	1996
Fuelwood	2751	3020	3345	3685	3020	3345	3685
Charcoal	1778	2137	2610	3180	2137	2610	3180
Other biomass	526	823	937	1066	823	937	1066
Total biomass	5055	5980	6892	7931	5980	6892	7931
LPG	6	7	9	11	8	11	14
Gasoline	262	304	379	472	351	470	629
Kerosene-Jet	65	75	93	116	87	116	156
Gasoil	566	656	817	1018	757	1013	1356
Fuel oil	134	255	343	391	279	390	471
Total petroleum	1033	1297	1641	2008	1482	2000	2626
Electricity (NEC)	60	115	183	286	115	183	286
Total all energy	6148	7392	8716	10,225	7577	9075	10,843

Note: The figures show final energy consumption and therefore do not include NEC's consumption of petroleum products.

Table 3.4

Final Energy Consumption and Growth Rates 1981-1996

	Base Year 1981	Scenario A 1986	Scenario A 1991	Scenario A 1996	Scenario B 1986	Scenario B 1991	Scenario B 1996
A. Consumption (Conventional Units)							
1. Non-commercial energy (10^3 mt)							
Fuelwood	8503	9335	10,339	11,390	9335	10,339	11,390
Charcoal	2628	3159	3,858	4,701	3159	3,858	4,701
Other biomass	1986	3110	3,538	4,025	3110	3,538	4,025
2. Commercial energy							
(a) Petroleum products (10^3 mt)							
LPG	6	7	9	10	8	10	13
Gasoline	254	295	368	459	341	457	611
Kerosene-Jet	64	74	92	114	86	114	154
Gasoil	566	656	817	1,018	757	1,013	1,356
Fuel Oil	140	267	359	409	292	408	493
Total Petroleum	1,030	1,299	1,645	2,010	1,484	2,002	2,627
(b) Electricity (GWh)	706	1,291	1,988	3,115	1,291	1,988	3,115
B. Growth rates (% p.a. for each 5-year period)							
1. Non-commercial energy							
Fuelwood		1.9	2.1	2.0	1.9	2.1	2.0
Charcoal		3.8	4.1	4.0	3.8	4.1	4.0
Other biomass		9.4	2.6	2.6	9.4	2.6	2.6
Total biomass		3.4	2.9	2.9	3.4	2.9	2.9
2. Commercial energy							
(a) Petroleum products		4.8	4.8	4.1	7.6	6.2	5.6
(b) Electricity		12.8	9.0	9.1	12.8	9.0	9.4

Table 3.5

Imports (Exports) of Petroleum Products, 1981-1996
(10^3 mt)

	Base Year	Scenario A			Scenario B		
	1981	1986	1991	1996	1986	1991	1996
LPG	1	2	4	6	3	6	9
Gasoline	72	99	172	262	144	260	415
Kerosene-Jet	13	15	32	55	27	55	95
Gasoil	248	262	437	625	363	633	963
Fuel oil	(147)	(156)	104	386	(131)	153	470
Net product imports	187	222	749	1334	406	1107	1952

Conclusions

3.09 In both scenarios, electricity consumption has been held to grow at the same annual rates. The result is a per capita consumption of 100 kWh, 137 kWh and 186 kWh for the years FY86, FY91 and FY96 respectively. It could be argued that the electricity consumption growth should be related to GDP growth and the projections for Scenario A should be lower than for Scenario B. It should be noted, however, that: (a) during the period FY72 - FY81, electricity consumption in the BNG area grew at an annual rate of 9.5%; (b) during the three-year period FY78 - FY81, when GDP stagnated in real terms and real per capita income declined, consumption grew by 26%; and (c) these growth rates were recorded despite severe supply constraints. As noted earlier, only 8% of the population had access to electricity in 1981 and the demand for new connections far exceeds NEC's ability to accept new consumers. There are ambitious plans to electrify irrigation pump systems in the Rahad, Kenana and Gezeira schemes and agricultural consumption is likely to grow substantially. Sudan has plans to commission relatively power-intensive industries such as cement and fertilizer and it appears prudent to plan for consumption growth rates as projected.

3.10 Non-commercial energy consumption grows at a rate nearly equal to projected population growth. The major initiatives in the non-commercial energy sector are expected to be on the supply side, where energy plantations and improved charcoal kilns may be expected to reduce the aggregate demand in the forestry sector.

3.11 Petroleum product consumption is expected to grow at about 4.8% under Scenario A and a slightly higher rate under Scenario B. Fuel oil consumption should grow at an even higher rate, partly due to increasing reliance on fuel oil for power generation and the lump-sum provision for individual large scale plants with high energy requirements. The import of petroleum products in Table 3.5 does not reflect the domestic use of Unity-Talih crude. Use of domestic crude under the various options examined in Chapter IV would reduce product imports. For the longer term, if additional oil discoveries are made and production reaches a level of 100,000 bpd, all imports could cease. Finally, the energy balances do not take into account the production or direct use of crude from domestic sources.

3.12 In arriving at gross supply, it was necessary to incorporate conversion losses, which occur in the conversion of fuelwood to charcoal, in the generation of electricity and in refinery processing. Some loss of energy also occurs in the transmission and distribution of electricity. The conversion losses in the production of charcoal account for over 90% of the total losses so that there is substantial scope for their reduction.

3.13 The major difficulty underlying all the demand forecast scenarios discussed above and summarized in Table 3.4 is the uncertainty surrounding the development of the Sudanese economy as a whole. It has been emphasized (in paras 1.07 and 3.06) that economic recovery will depend on the achievement of a number of favorable outcomes; for this reason, two scenarios were predicated. However, as the magnitude of Sudan's debt problem continues to unfold, it becomes increasingly likely that even the 'low-growth' Scenario A may be optimistic -- not, it must be emphasized, because the underlying energy demand has been overestimated, but rather because constraints on foreign exchange and investment may become so tight that even the high priority energy sector cannot receive the resources it needs. For example, if limitations on investment in the power sector over the five-year period 1986-1991 -- i.e., after the completion of Power III -- hold the growth of electricity consumption to 4.5% p.a. rather than 9.0% p.a. as in Table 3.4, then electricity consumption would be cut from about 2,000 GWh to about 1,600 GWh in 1991. Similarly, the demand for petroleum products in Table 3.4 will not be satisfied by imports (as assumed in para. 3.06) if the requisite amounts of foreign exchange are not made available. For example, by restraining the increase in supply of petroleum products in the ten-year period 1981 - 1991 to 2.4% p.a. -- half the rate underlying Scenario A in Table 3.4 — the aggregate consumption of petroleum products in 1991 would be 1.3 million m.t. rather than 1.6 million m.t. In effect, the 1986 forecasts of petroleum and power consumption corresponding to Scenario A would be postponed by five years. The result, of course, of constraining foreign exchange and investment in the energy sector in this way -- and the result must be weighed carefully in any decision to impose such constraints -- is that it will be even more difficult to achieve a satisfactory growth of GDP and exports and to resolve Sudan's economic difficulties, at least in the short - and medium-term future.

IV. ISSUES AND OPTIONS IN THE ENERGY SECTOR

Introduction

4.01 The Sudanese economy has been characterized by severe energy shortages in the past few years which have affected all economic activity. Although the transport sector is allocated the largest share of the supply of petroleum products, long queues of trucks, cars and buses persist for gasoline and gasoil at the pumps. Allocation of petroleum products to the agricultural and industrial sectors seems inadequate in relation to their needs and the problem is compounded by an inefficient and unreliable public power supply. There are frequent power interruptions and power supply to industry is curtailed drastically for a two to three month period when hydroelectric generation drops. The supply of petroleum products to the household sector, mainly in the form of kerosene, has also been reduced drastically over the past seven years, with the result that quantities of gasoil, allocated to other sectors, is diverted to lighting. There is also a growing fuelwood shortage leading to deforestation of large tracts of land in the northern region and to haulage of fuelwood and charcoal supplies over hundreds of kilometers from the Southern region.

4.02 As noted earlier, Sudan must import nearly all its commercial energy and in so doing it is seriously limited by the current foreign exchange crisis. Nevertheless, unless adequate supplies of commercial energy are made available, economic recovery does not seem possible. This is the single most important issue that Sudan faces and the recent discoveries of oil and gas are not likely to have any major impact in alleviating these energy shortages in the short term. One redeeming feature is that substantial electrical generating capacity is likely to be commissioned in the near future and the availability of power to industry and agriculture is likely to improve.

A. Petroleum

(i) Oil Sector

Recent Supply/Demand Situation

4.03 The demand for petroleum products in Sudan is met partly by the domestic processing of imported crude and partly by the direct import of products. As the refinery output pattern does not follow the domestic product consumption pattern, some petroleum products are imported while large quantities of fuel oil are exported. In recent years, Sudan has been importing about 0.9 million mt of crude per annum and in addition 0.3 million mt of products while exporting 0.2 million mt to 0.3 million mt of fuel oil. PSR has not operated at its rated capacity of 1.2 million mt, due to lack of regular supplies of crude, but even when it does, some product imports will be required. Fuel oil surpluses are likely to keep decreasing as larger quantities are utilized for power generation. Some of the issues and options in the supply and demand sides of the petroleum sector are discussed below.

Oil Resources, Issues and Options

4.04 As noted in Chapter II, oil has been discovered in commercial quantities in the southern part of Sudan and the Government has announced plans for the construction of a pipeline to a point on the Red Sea for export of the crude. Plans call for commissioning of the pipeline by 1985 at a capacity of 50,000 bpd initially. The pipeline has a design throughput capacity of up to 200,000 bpd to provide for additional discoveries. The pipeline and marine terminal are estimated to cost around US$910 million and will be owned and operated by WNPC, which will receive a fee for the transport of the crude, probably payable in kind. WNPC would export the crude thus received towards amortization of the debt. Present plans call for a debt: equity ratio of about 3:1, so the debt is expected to be about US$685 million.

4.05 It is understood that, according to the contractual arrangements between the Government, Chevron, and WNPC, the Government's share of oil production would be 24,500 bpd at a producton level of 50,000 bpd. After paying for transport of the crude in kind, the net crude available to the Government for domestic use or for export should amount to over 16,000 bpd. Out of this quantity, the Government could take up to 5,000 bpd at the oil fields or at any point along the export pipeline. Crude is likely to be available in these quantities by 1986 and would provide Sudan with the following options:

(a) Set up a topping plant at Kosti with a capacity of 4000 to 5000 bpd;

(b) Utilize part of the indigenous crude at PSR, together with imported Arabian Light; and

(c) Set up a new refinery, with a capacity of 25,000 bpd or about 1.2 million mtpa, at Kosti or near the export terminal on the Red Sea to process indigenous crude.

If options (a) and (b) are pursued, Sudan will have about 5,000 bpd of crude available for export. These three options are discussed below:

(a) Topping Plant at Kosti

4.06 Under its agreement with Chevron, the Government has the option to take 5,000 bpd from the proposed crude oil export pipeline or at the oilfields. This crude could be used in a topping plant to meet the demand for middle-distillates in the southern part of the country and provide heavy fuel oil, which is likely to be in short supply for power generation. An estimate of the consumption of petroleum products in the Southern Region (Equatoria and Upper Nile Provinces) in 1986 and 1991 is given in Table 4.1, based upon the mission's estimates of the overall national consumption of each product (Annex 9) and the percentage of the national consumption which will occur in the Southern Region. The annual consumption of middle distillates is expected to be in the order of 50,000 mt by 1986 and 60,000 mt by 1991, including gasoil consumption for petroleum exploration. Taking a 30% yield of middle distillates by weight for Sudanese crude, consumption would be satisfied with a topping plant of about 180,000 mtpa. For example, a 4,000 bpd skid-mounted topping plant might be considered, with the material balance shown in Table 4.2.

Table 4.1

Southern Region Consumption of Petroleum Products, 1985 and 1990
(metric tons)

	1986	1991
LPG	70	90
Gasoline	12,768	15,918
Kerosene - Jet	4,200	5,208
Gasoil	45,920	57,190
Fuel oil	5,355	7,203

Table 4.2

Material Balance for 4,000 bpd Topping Plant

	Percent (by weight)	mtpa	bpd
Losses	0.6	1,070	40
Unstabilized Naptha	7.8	13,900	360
Kerosene-Jet	5.7	10,160	260
Gasoil Product	22.4	33,910	940
Gasoil Fuel	2.0	3,560	80
Long Residue	61.5	109,600	2,320
Crude Oil	100.0	172,200	4,000

Source: Mission estimates.

4.07 Marketable products (kerosene and gasoil of about 50,000 mtpa) would be stored while other products (unstabilized naphtha and long residue) would be either returned to the oilfield facilities, to be blended with the crude oil, or used for power generation close to the topping plant. The excess production of kerosene and jet fuel over the anticipated consumption could be reduced by blending with gasoil production (of which there is a deficit relative to anticipated consumption) if allowed by the gasoil flash point. The gasoil distillation cut points might also be modified to match consumption more closely. Blending of the non-marketable products with the crude oil is feasible only if crude oil production is maintained at a level sufficient to avoid degradation of the export crude oil quality. If diluent is mixed with crude oil, the corresponding volume of diluent will be recovered by distillation of the crude oil, thus reducing the crude quantity required to be processed for meeting the demand for middle distillates.

4.08 A topping plant would require, apart from the distillation unit, investment in steam boilers, an electric power generator, a compressed air package, a control room, laboratory, workshop and offices. Storage tanks for kerosene, jet fuel and gas oil would also have to be erected. A preliminary estimate of the investment cost is US$ 20 million (in 1982 prices), including material and equipment, transportation to the site, engineering costs, erection of the topping plant, utilities generation and distribution, product storage, buildings and site preparation. Owner expenses, such as project management, financial charges, contingencies etc., are excluded.

(b) Utilization of Indigenous Crude Oil at PSR

4.09 Little attention has been given to the possibility of using indigenous crude as a feedstock at the existing refinery in Port Sudan. In particular, the management of PSR has not been approached by the Government to carry out feasibility studies. Nevertheless, Shell International has made some preliminary studies on its own initiative, which indicate that a portion of local crude oil could be processed at PSR if blended with imported Arabian Light. 1/

4.10 The refinery might process an amount of crude equivalent to 25% - 30% of its capacity, say 300,000 - 350,000 mtpa. It is assumed that: (a) the available processing capacity of PSR is 3660 mt per standard day or about 1.2 million mtpa; (b) the throughput of Arabian Light remains at the present level of about 870,000 mtpa (i.e. 2,635 mt per standard day); and (c) the indigenous crude is an equal mixture of Unity and Talih crudes. 2/ The distillation yields, expressed as percentages of the crude in terms of weight, would be: gas, 0.53; butane, 0.37; full-range naphtha, 7.51; kerosene-jet, 5.71; gasoil, 24.37; and long residue, 61.51. Due to its low naphthenic and aromatic content, the naphtha is not suitable for further processing in the catalytic reformer but could be sold as petrochemical naphtha, for example to the Sudan-Ren fertilizer plant in Khartoum. Having a low sulfur content (0.02% by weight), the

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1/ Without blending, problems arise due to the high residue content and waxiness of indigenous oil. PSR would not be equipped to handle this type of crude as its normal feedstock.

2/ With APIs of 30.9 and 39.5 respectively.

gasoil can be used in the final gasoil blend to match the Sudanese sulfur gasoil specifications without adding kerosene. The present production of fuel oil 1500 is assumed to remain constant and to be blended according to the present refinery practice. The remaining quantity of long residue ex-Arabian Light crude, long residue ex-indigeneous crude and kerosene are assumed to be blended to make fuel oil 3500. Table 4.3 summarises the overall material balances when processing a mixture of indigenous and imported crude oil and for comparison shows the additional products which are obtained relative to the processing of imported crude alone at the present level of around 870,000 mt.

Table 4.3

Material Balances using Blend of Indigenous and Imported Crudes (mtpa)

	Indigenous/Imported Crude Blend	Imported Crude Only	Difference
Crude input			
Arabian Light crude oil	869,616	869,616	-
Unity-Talih 50-50 mix	338,184	-	338,184
Total crude input	1,207,800	869,616	338,184
Products Output			
L.P.G.	4,343	3,090	1,253
Gasoline	136,230	136,230	-
Naphtha	25,397	-	25,397
Kerosene-Jet	103,910	43,352	60,558
Gasoil	299,310	271,053	28,257
Fuel oil (1500)	175,019	175,019	-
Fuel oil (3500)	402,600	198,377	204,223
Refinery fuel and losses	60,991	42,495	18,496
Total products output	1,207,800	869,616	338,184

Source: Mission estimates

(c) New Refinery

4.11 The forecast of petroleum products in Chapter III shows that Sudan will face a shortage of refined products by 1986 even if the "low-growth" scenario materialises and the existing refinery operates at full capacity. The deficit will be acute for middle distillates -- kerosene, jet fuel and gasoil -- amounting to nearly 300,000 mtpa by 1986 under the "low-growth" scenario. One option to tackle the projected shortage is:

(a) to construct a new refinery, utilizing indigenous crude; (b) to maximize the production of middle distillates; and (c) to minimize the production of fuel oil requiring secondary processing of the long residue.

4.12 From available data, it appears that indigenous crude oil has the following characteristics: (a) high paraffin content and high pour point; (b) low sulfur content; (c) high nitrogen content; (d) low metals and asphaltenes content; and (e) a high fuel oil yield (61.5% by weight) with a high pour point. Due to (a), thermal cracking such as coking could lead to a high gasoil yield. Due to (d), more sophisticated processing techniques, such as hydrocracking of the long residue, could also be utilized to maximize the gasoil production.

4.13 The refinery should be located at a site which can be supplied with crude oil from the oil fields in the south and from which products could be shipped to the rest of the country using, as far as possible, the existing infrastructure. Two locations offer themselves: at Kosti and on the Red Sea. The Kosti area is traversed by the Nile, a railway runs from the west to the north-east and a main road provides links to the Khartoum, Gezeira and Kassala provinces. The crude oil pipeline is planned to cross the Nile river near Kosti. Plans exist for a crude oil export terminal on the Red Sea, in the Port Sudan-Suakin area. A product pipeline, roads and a railway link this area to Khartoum and other provinces, while the planned diluent pipeline could deliver diluent to the southern oilfields and be used for the shipment of middle distillates to the Western and Southern provinces. Blending low sulfur gasoil produced from domestic crude with products from the existing refinery will be easier if the new refinery is located on the Red Sea. It would also be possible to export from a coastal refinery any product surplus arising out of an imbalance between the market structure and the structure of the refinery output or from a temporary unavailability of process units treating the long residue.

4.14 Since the market structure requires maximization of middle distillate production while Sudanese crude oil will have a high fuel oil yield, two processing schemes were envisaged: a coker scheme and a hydrocracking scheme. A refinery capacity of 25,000 bpd or about 1.2 million mtpa was chosen in order to meet the market requirements by 1990 in the case of the coker scheme. The same capacity was utilized in the case of the hydrocracking scheme for the purposes of comparison. Possible production slates for the two schemes are in Table 4.4.

Table 4.4

	Coker Scheme mtpa	%	Hydrocracking Scheme mtpa	%
Butane	11,730	0.9	10,570	0.8
Gasoline	214,010	17.4	179,440	14.6
Kerosene-Jet	70,290	5.7	70,290	5.7
Gasoil	598,160	48.6	844,780	68.6
Fuel oil	124,340	10.1	-	
Coke	137,060	11.1	-	
Refinery use and losses	76,060	6.2	126,570	10.3
Crude oil intake	1,231,650	100.0	1,231,650	100.0

Source: Mission estimates.

4.15 The Coker scheme would produce a high quality (low sulfur and metal) coke which might be exported. The plant's capital cost is estimated at US$430 million (in 1982 prices), excluding contingencies, the cost of land and interest during construction. The hydrocracking scheme would be technically more elaborate, involving a unit which combines residuehydrodemetallization and the hydrocracking of vacuum distillates. To some extent, the production of kerosene could be increased at the expense of hydrocracking gasoil production. Refinery use and losses are high due to the hydrogen production unit and to the high energy consumption of the hydrocracking unit. The plant's estimated capital cost is US$590 million (in 1982 prices), excluding contingencies, the cost of land and interest during construction.

(d) Conclusions

4.16 The net imports of petroleum products by 1991 are estimated at 0.75 million mt and 1.1 million mt under Scenarios A and B respectively (Table 3.5), if none of the three options is exercised. Net crude imports would be about 0.45 million mt, i.e. 1.2 million mt for PSR minus 0.75 million mt of crude exports (at 15,000 bpd). If options (a) and (b) are exercised, product imports would be reduced by 0.17 million mt to 0.58 million mt and 0.93 million mt under the two alternative scenarios, while net crude imports would correspondingly rise to about 0.62 million mt. In view of the capital costs of a new refinery, it seems prudent to pursue options (a) and (b) and to consider option (c) only if a much higher production potential is established for the oil fields in the south.

Other Issues

4.17 Two other issues which need to be examined in the petroleum sector are: (a) use of the proposed diluent pipeline for products; and (b) the setting up of a bitumen plant at Port Sudan. These are discussed in paras. 4.18 and 4.22.

(a) Use of Diluent Pipeline for Products

4.18 The construction of a diluent pipeline from the Red Sea to the Unity-Talih field near Bentiu - parallel to the crude oil export pipeline - raises the possibility of using the diluent pipeline to deliver kerosene and gasoil to the eastern and southern provinces, thus meeting some of the demand for kerosene and gasoil in the provinces of Kassala, Blue Nile, White Nile, Kordofan, Darfur, Equatoria and Upper Nile. 1/ Estimated demands from these provinces in 1985 and 1990 are in Table 4.5. 2/

Table 4.5

Consumption of Kerosene and Gasoil in Eastern and Southern Provinces, 1985 and 1990
(metric tons)

	1985		1990	
	Kerosene	Gasoil	Kerosene	Gasoil
Kassala	2,240	41,500	2,840	52,000
Blue Nile	960	59,300	1,220	74,300
White Nile	720	45,100	910	56,500
Kordofan	2,180	24,600	2,760	37,200
Darfur	960	23,700	1,220	29,700
Equatoria and Upper Nile	2,240	41,500	2,840	52,000

1/ Other provinces could be supplied from the existing Port Sudan-Khartoum pipeline.

2/ These are mission estimates -- used for the diluent pipeline hydraulics calculations in para. 4.19 -- and take into account forecasts of the provincial distribution of consumption made by the NEA and by Pencol. The latest mission forecasts of total petroleum products demand in Annex 9 imply demands for individual provinces in Table 4.5 which could be higher by 3% for kerosene and 5% for gasoil.

4.19 For product supply to Kassala and Blue Nile provinces, a depot could be built with a take-off at El Fau, where the pipeline crosses the new all-weather Wad Medani-El Gedaref road; products could then be dispatched to the Kassala and Blue Nile provinces by road tankers. Product supply to the White Nile, Kordofan and Darfur provinces is assumed to pass through Kosti, from which point products could be sent by rail, road and river. Product supply to the southern provinces of Equatoria and Upper Nile would be effected by river and road from a new depot in the city of Bentiu. If the crude oil pipeline produces 50,000 bpd and uses a 1 in 10 dilution ratio, 5,000 bpd or about 233,000 mt per annum of diluent would be required. Combined with the estimated product demands at each take-off point, the following throughputs for each section are implied: Kosti to Bentiu, 287,300 mt in 1990; El Fau to Kosti 415,600 mt; and Red Sea to El Fau, 546,000 mt. Pipeline hydraulic calculations show that an additional pumping station would be required at El Fau. The cost -- including new storage facilities at El Fau, Kosti and Bentiu and other related facilities -- is estimated at US$5 million (in 1982 prices), excluding contingencies, interest during construction and the cost of land.

4.20 In view of the above, the design of the diluent pipeline should provide for installing an additional pumping station at El Fau at a later date. However, the benefits of the use of the diluent pipeline for moving products inland should be re-examined in the light of a decision on the topping plant at Kosti.

(b) Bitumen Plant

4.21 All bitumen is currently imported. At the same time, PSR produces a surplus of long residue. The feasibility of a bitumen plant has therefore been the subject of past studies, e.g. by Shell and Agip. GPC statistics show that annually about 20,000 mt of bitumen are imported. GPC forecasts of future consumption or the period 1982-1990, as reported in the Pencol study, are 26,700 mt for 1982, increasing to 41,400 mt for 1989.

4.22 Using the Agip study of November, 1981, as a basis, Table 4.6 sets down the possible characteristics of a 40,000 mtpa bitumen plant, in terms of plant facilities, capital costs (in 1982 prices) and material balances. Major factors in the economic justification of a bitumen plant would be: the future demand, the amount of long residue that will be required and the future opportunity cost of long residue (in relation to the export price of residual fuel oil or the value of the reduced supply of residual fuel oil to the local market, e.g. for power generation). However, in view of the projection that long residue is not likely to be surplus and Sudan may have to import fuel oil beyond 1988 unless a new refinery is built, the option of setting up a bitumen plant needs to be re-examined only after a decision on a new refinery is taken.

Table 4.6

Possible Characteristics of 40,000 mtpa Bitumen Plant

1. Facilities

Storage

Long residue	15,000 mt	80/100 Bitumen	2 X 1600 mt
Short residue	1,000 mt	Naphtha	2 X 500 mt
Blown bitumen	4 X 1,500 mt	Kerosene	800 mt

Utilities

Sea water desalination	8 cm/h	Air service	800 m^3/h
Boiler 12 kg/cm^2 steam	5.5 mt/h	Sea water treatment	200 m^3/h
Electric power generator	1 MVA	Cooling water	15 m^3/h

2. Material Balances
(mtpa)

Input (from PSR)		Output (from plant)	
Long Residue Arabian Light	109,500	Vacuum gasoil to PSR	72,900
Kerosene (for 80/100 cutback)	3,460	60/70 Pen Bitumen	24,000
Naphtha (for RC 250 cutback)	564	80/100 Cutback	12,800
Total input	113,524	RC 250 Cutback	3,230
		Plant use and losses	594
		Total output	113,524

3. Capital Costs
(LS thousands)

	Bitumen Plant	Drum Factory	Total
Buildings	3,400	1,400	4,800
Plant & Equipment	10,400	2,200	12,600
Sundry	300	-	300
Transport	-	100	100
Total	14,100	3,700	17,800

Source: Mission estimates.

Transport, Distribution and Storage of Petroleum Products

4.23 The physical movement of petroleum products from Port Sudan to the rest of the country takes place by railway, road, pipeline and river. Table 4.7 shows the distribution of traffic between these modes in FY82 and it can be seen that the largest single carrier of products is the railways. However, a greater volume of petroleum products could and should be transported by pipeline than is currently the case; the reasons for this need to be studied. Furthermore, as can be seen from Table 4.8, the overall share of the railways has declined substantially, from nearly 90% of the traffic (by weight) in 1973 to less than 40% in 1981. Indeed, the absolute volume of products carried by the railways has also declined, in total and for each product category, with the exception of gasoline.

Table 4.7

Transportation of Petroleum Products by Mode FY82
(metric tons)

	Road	Rail	River	Pipeline	Total
Gasoil	233,405	77,503	14,831	327,481	653,220
Gasoline	45,189	144,740	718	14,348	204,995
Kerosene	8,740	361		3,062	12,163
Diesel	5,385	10,455			15,840
Fuel Oil	8,985	148,171			157,156
Jet	5,100	33,643	335		39,078
LPG	341	4,502			4,843
Total	307,145	419,375	15,884	344,891	1,087,295
Distribution (%)	28.2	38.6	1.5	31.7	100.0

Table 4.8

Transportation of Petroleum Products
by Railways, 1973-1981
(metric tons)

	1973	1978	1980	1981
Gasoline	95,455	152,286	177,025	144,740
Kerosene	43,377	7,284	2,484	361
Gasoil	229,274	180,303	192,355	77,503
Diesel Oil	12,833	14,177	12,673	10,455
Fuel Oil	206,646	137,148	141,827	148,171
Total	637,585	491,195	326,364	381,230
Share of Railways in total (%)	88.6	59.7	57.8	36.5

4.24 The split of the traffic in petroleum products between the different transport modes has been directly influenced by the policy and actions of the GPC in a number of ways. First, the official selling prices of petroleum products are based upon railway freight rates, so that the consumer pays a premium if road tankers are used. Secondly, GPC's monthly plan for the allocation of products determines the geographical distribution of each petroleum product and also the means by which products are moved from Port Sudan to their respective destinations. Normal movement is to take place by railway and product pipeline. Nevertheless, the four marketing companies are allowed, in exceptional cases, to accept the delivery of products in Port Sudan and to make their own arrangements for shipment by road tanker. In these cases, the final consumer pays a premium, subject to agreement by the regional governor.

4.25 Current deficiencies in the transport and storage of petroleum products are masked by the severe overall supply shortages. Although transport and storage problems contribute to supply shortages at particular times and in particular places, it is not possible to assess their true extent. In the case of transport, the basic problems are not peculiar to the transport of petroleum products but are part of the broader transport problem in Sudan -notably serious inadequacies in the rail and river systems (see para. 4.37). In the case of storage, the question of capacity is almost entirely academic; the stores are normally empty, aside from the minimum stocks which inevitably exist in moving products from Port Sudan to the final consumer. While the national storage capacity of about 60 days of 1981 consumption (see Table 4.9) may be regarded as adequate for a developing country such as Sudan, 1981 consumption was seriously suppressed. In any case, a national average is misleading. More than half the national capacity is in the Red Sea province, which accounted for less than 20% of 1981 consumption. Outside the Red Sea province, storage capacity is equivalent to 30 days of 1981 consumption. The situation for individual products can be quite acute in some cases.

Table 4.9

National Storage Capacity for
Petroleum Products, by Province

Province	1981 Consumption (mt)	Storage Capacity Quantity (mt) 1/	Storage Capacity Equivalent Days of 1981 Consumption 2/
Nile	55,619	4,568	30.0
Northern	10,822	2,779	93.7
White Nile	74,379	5,233	25.7
Khartoum	524,970	42,893	29.8
Blue Nile	28,020	3,677	47.9
Kordofan	26,392	2,580	35.7
Darfur	6,658	1,225	67.2
Equatoria	9,038	1,253	50.6
Upper Nile	2,052	690	122.7
Gezira	45,877	2,202	17.5
Kassala	43,986	3,713	30.8
Sub-total	827,813	70,813	31.2
Red Sea	198,514	98,543 3/	181.2
Total	1,026,327	169,356	60.2

Notes:

1/ Includes: the "LPG project" (1100 mt) in Khartoum, Wad Medani, Atbara, El Obeid and Kassala; and the component of the "Romanian project" for the storage of gasoil, gasoline and LPG in Port Sudan (22,483 mt) and Haiya (2,245 mt), both in the Red Sea Province.

2/ Based on 365 days per year.

3/ Excludes the component of the "Romanian project" for the storage of crude oil (42,835 mt) and residual fuel oil for export (16,679 mt). The former is equivalent to 12 days of crude oil requirements at full refinery capacity of 3660 mtpd. The latter will permit exports by larger tanker.

Pricing of Petroleum Products

4.26 The prices of petroleum products are fixed by the Government through the GPC. In the past, the Government has been reluctant to pass on to consumers the full delivered cost of these products; this is true whether costs are defined as the c.i.f. value of imports at the official exchange rate plus the financial costs of transport and distribution or whether economic costs are taken into account. Thus, the Government has tended to subsidize petroleum products to the extent that prices were held below the full delivered costs. According to a Bank report of February, 1982, subsidies ranged from 15% to 45% at the end of 1980. 1/ Following a 25% increase in the prices of petroleum products which took effect in March 1981, these subsidies were largely eliminated at the official exchange rate. However, since the Sudanese currency was overvalued, the application of economic costs (shadow pricing) would have led to the conclusion that petroleum products were still subsidized. Further price increases took effect in November 1981, averaging nearly 40% but a concomitant devaluation of the Sudanese pound meant that, even at the official exchange rate, all petroleum products were subsidised, with the exception of regular and premium gasolines. Following the November, 1982 devaluation, the situation worsened further and subsidies appeared across the board, with the possible exception of premium gasoline. The price increases announced in January, 1983, have improved the situation and underlined the Government's intention to minimize or eliminate the subsidies on at least some petroleum products.

4.27 In order to make an assessment of the adequacy of petroleum product prices in economic terms, the mission estimated the average economic cost of supply for 1982, using Khartoum (the major market) as a reference point. Although the market is served by a mix of imported and refined products, the relevant cost from an economic point of view is the marginal cost, which is represented by the c.i.f. value of imported products plus an appropriate allowance for the economic cost of unloading and handling at the port, marketing, distribution and transport to Khartoum. A complication arises in the case of diesel and fuel oil 1500, which are not imported but obtained by blending gasoil and kerosene, respectively, with residual. Since gasoil and kerosene are imported while residual is exported at the margin, the economic costs of diesel and fuel oil 1500 may be calculated as the weighted averages of the export price of residual and (respectively) the c.i.f. value of gasoil and kerosene. 2/ The results are in Table 4.10, which also shows the official pump prices for gasoline, gas oil and kerosene and the official ex-depot prices for diesel and fuel oil 1500.

4.28 For kerosene, diesel and fuel oil 1500, the pump or ex-depot prices are below even the c.i.f. import value of the products. While gasoil's pump price exceeds its c.i.f. import value, the margin is insufficient to cover the port, marketing, distribution and transport costs. Only in the case of regular and premium gasolines are the pump prices equal to or in excess of the economic costs of supply; in fact,

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1/ "Sudan: Investing for Economic Stabilisation and Structural Change".

2/ The weights used are: gasoil 70% and residual 30% for diesel; kerosene 6% and residual 94% for fuel oil 1500.

the margins are substantial, implying high rates of effective taxation (40% and 45% respectively) on the pump prices of those products.

4.29 As a minimum first step, petroleum prices should be adjusted to reflect their corresponding value in world markets (c.i.f. prices) plus the inland marketing, distribution and transport costs. For the Khartoum market (see Table 4.10), this implies increasing the official prices of fuel oil 1500 by 50%, diesel by 43%, and gasoil by 10%. As a second step, a further increase in fuel prices beyond their costs should be considered in line with the Government's policy to increase Government revenue, to conserve foreign exchange, to raise the level of domestic savings and in view of excess demand. Moreover, from an efficiency point of view, the relative retail prices, including taxes, of the various fuels should be brought in line with their relative costs. As Table 4.10 shows, at present there are large differences, positive and negative, between the costs and prices of the various types of fuel. In the case of kerosene, some departure from the above pricing principles may be warranted, kerosene consumption having special implications for the protection of forestry resources and for the lower income groups. Given the importance of appropriate fuel prices, the mission strongly recommends that the Government undertake a study of the subject within, say, the next six months. This study would not obviate the need to implement rapidly the first step price increases already identified; rather, it would be a prelude to the second step and should review present fuel costs, prices and taxes; it should propose a timetable for the next, say, two years, during which period gradual changes in taxes for the various fuel types would be undertaken to reflect the various Government objectives with regard to economic efficiency, Government revenue, balance of payments, and domestic savings.

Allocation Policy For Petroleum Products

4.30 Overall control of the allocation of petroleum products is exerted by the GPC as the official representative of the Government. As a first step, to estimate foreign exchange requirements, the Planning Department of the GPC prepares a consumption plan for the whole of Sudan at the beginning of each fiscal year. The plan shows the physical quantities of crude oil and imported products which will be required and is broken down into four quarters. The quarterly estimates of foreign exchange requirements are then forwarded to the Ministry of Finance. Following discussions between GPC and the Ministry of Finance, the latter makes a formal reply to GPC -- apparently usually accepting the GPC estimates with at most minor revisions -- and also instructs the Bank of Sudan to set aside, for each of the coming quarters, the appropriate amounts of foreign exchange.

Table 4.10

Economic Costs and Official Prices of Petroleum Products in Khartoum (LS/mt)

	c.i.f. import value 1/	other costs 2/	total cost	official prices 3/	% difference between prices and costs
Regular gasoline	489	71	560	924	+ 65
Premium gasoline	516	71	587	1078	+ 84
Gasoil	448	71	519	469	- 10
Kerosene	499	71	570	464	- 19
Diesel 4/	372	67	439	250	- 43
Fuel oil 1500 4/	213	67	280	140	- 50

Notes:

1/ Average for 1982, except for the export price of residual used to calculate the c.i.f. import value of diesel and fuel oil 1500, which is the f.o.b. price in October, 1982 (US$ 149.7/mt). All conversions have been made at the rate of US$1= LS1.3.

2/ A recent Bank study ("Sudan-Export Development Study") gives the following costs (LS/mt) for gasoline and gasoil: unloading and handling in Port Sudan, 4; marketing and distribution, 7; and transport from Port Sudan to Khartoum, 60. The table assumes that the same costs apply to kerosene and diesel but that marketing and distribution can be reduced to LS 3/mt for diesel and fuel oil 1500, which are sold ex-depot.

3/ The retail (pump) prices for regular gasoline, premium gasoline, gasoil and kerosene (corresponding to LS3.00, LS3.50, LS1.75 and LS1.65 per Ig respectively) and the wholesale (ex-depot) prices in the case of diesel and fuel oil 1500, as of January, 1983.

4/ A weighted average of the f.o.b. price of residual and the c.i.f. value of gasoil and kerosene respectively, as described in the text.

4.31 While this exercise in forward planning appears to work well in principle, in practice it is seriously undermined by the acute shortage of foreign exchange and the way it is allocated. Since the Bank of Sudan does not release foreign exchange on a regular and predictable basis, rational planning of the supply of petroleum products is effectively impossible and GPC is inevitably drawn into the day-to-day financing of petroleum imports. GPC submits a request for foreign exchange to the Bank of Sudan for each individual shipload, specifying the tanker's date of arrival and the value of the contents. The Bank of Sudan requests several commercial banks to share in each letter of credit and GPC officials may be faced with the task of contacting 10-15 separate banks. The system is time consuming and surrounded with uncertainty. GPC itself attempts to secure financing from individual suppliers but must clear the terms and conditions of each contract with the Bank of Sudan. A more rational foreign exchange allocation system must be devised for petroleum imports so that planning of the energy sector becomes possible.

4.32 As a second step in its allocation process, GPC prepares a monthly allocation plan for gasoil, kerosene, jet fuel and gasoline. For small and medium consumers, GPC starts by collecting information from the regional governors and from the consumers respectively. The information is incorporated, with appropriate adjustments, in the monthly plan which is then discussed by a Monthly Planning Committee. Large consumers are dealt with directly by the Committee, which functions under the chairmanship of the GPC and normally has representatives from each of the four marketing companies, the River Transport Corporation, the Sudan Railways Corporation, the Gezeira scheme, KSC, MFC, and the Southern Region.

4.33 The Monthly Planning Committee occupies a key place in the complex system of allocating petroleum products. It discusses in detail GPC's monthly plan and determines the monthly quotas for the different consuming sectors. In the allocation process, highest priority is given to gasoil supplies for NEC and the national water corporations, large agricultural users, the sugar factories, national defense and security and certain consumers deemed critical to the public interest (e.g. Khartoum airport, the Ministry of Health and public transport). Quotas for private gasoline usage are assigned directly to the regional governors and allocations to individual consumers are managed by them through their own rationing schemes. For example, in Khartoum province, rationing worked as follows at the end of November, 1982: taxis, 21 gallons per week; minibuses, 6 gallons per day; box cars, 4 gallons per day; small private cars, 2 gallons every 3 days; large private cars (2,000 cc. and above), 3 gallons every 3 days. Naturally, the rationing system requires careful implementation and policing. Nevertheless, a thriving black market in gasoline and gasoil exists.

4.34 A few consumers who earn foreign exchange or who are able to pay directly in foreign exchange, are allowed to import products through the oil marketing companies. 1/ Examples of such consumers are Chevron, Total, international airlines calling at Khartoum airport, some foreign general contractors and a few Sudanese factories in the sugar and textile industries.

1/ The imports themselves are handled by GPC through its normal channels, on behalf of the marketing companies.

Petroleum Products Consumption, Transport and Energy Conservation

4.35 The major scope for commercial energy conservation in Sudan lies within the transport sector. Industry accounts for only 17% of commercial energy consumption and 16% of the consumption of petroleum products (see Table 1.1). Given the major constraints on the supply of energy to the economy as a whole and to the industrial sector in particular, industry already has considerable incentive to use its limited energy supplies efficiently. The transport sector, on the other hand, offers considerable potential for the more effecient use of scarce supplies of commercial energy; it consumes 62% of all commercial energy and 65% of petroleum products (see Table 1.1).

(a) Inter-modal Allocation of Traffic

4.36 Perhaps the most significant trend in the transport sector has been the development of road haulage as the principal transport mode. It's share of total ton-km of freight hauled increased from 25% to 61% during the ten-year period 1971-80, as shown in Table 4.11; by 1982, the share had increased to about 70%. Around 75% of passenger traffic was handled by the roads in FY77 and the share has increased since. Rail and river freight traffic, on the other hand, have declined even in absolute terms. In parallel, passenger traffic on the railways fell from 1,100 to 900 million passenger-km between FY75 and FY82. These trends are disturbing if account is taken of the relative fuel efficiencies of the three traditional transport modes. It can be estimated that a 1% shift in freight traffic from road to rail in 1980, for example, would have saved 1,360 mt of fuel.

Table 4.11

Freight Haulage by Mode, 1971-80
(millions of ton-km)

Year	Railway	Road	River	Pipeline	Total
1971	2,683	920	90	-	3,693
1980	1,908	3,570	65	275	5,818

Source: Sudan: Investing for Economic Stabilization and Structural Change (IBRD, Feb. 16, 1982).

4.37 The reasons for the marked advance in the relative share of road transport, despite its higher cost in terms of fuel consumption per ton-km, are numerous and complex. Road transport has enjoyed a high priority in the public investment plans of the past decade and its expansion has been helped by a growing network of paved roads. It has proved to be more reliable and faster than rail and river transport and loss and damage to goods are less. There are also important institutional factors. Trucking is organized as a private competitive system whereas the railways are run by a parastatal body (SRC) and river transport has been largely monopolised by the River Transport Corporation (RTC), also a parastatal. This has given the road transport industry much greater flexibility in its pricing policy, whereas SRC and RTC are governed by comparatively rigid tariff policies.

4.38 Several measures are possible to improve the intermodal allocation of traffic. Railway and river freight rates need to be revised in relation to the marginal costs of supply. 1/ The price of gasoil should be raised at least to the level of its economic cost and there is in addition a case for a fuel tax to narrow the differential between the price of gasoil and gasoline (see para. 4.29). SRC and RTC should be reorganised to make the former more market-oriented and less monopolistic in outlook, while the latter could be faced with greater competition from private operators of river transport. Additional investment in the rail and river systems should also be considered.

(b) Road Passenger Transport

4.39 Table 4.12 shows the growth in the number of licensed vehicles over the period 1970-1980 by vehicle type. The total number of vehicles grew at an average annual rate of nearly 11% and by 1980 road transport accounted for 81% of total fuel use in the transport sector. From Table 4.12, it appears that, within the road transport sector, private passenger vehicles (cars and motorcycles) accounted for most (70%) of the growth since 1970 and all the growth in 1980; the number of licensed buses and boxes apparently fell in 1980, due to mechanical failure, the lack of spare parts and inadequate profit margins.

4.40 A study of traffic management in Khartoum, carried out by the NEA in 1981, recommended an increase in Khartoum's bus fleet of 1200 vehicles, to improve fuel efficiency directly and indirectly by reducing traffic congestion and allowing smoother traffic flow. The Government's decisions to import 150 buses from Spain and to carry out a one-year study of traffic management in Khartoum (due to be finished in Spring, 1983) are consistent with the NEA recommendation.

1/ Apparently consultants were engaged in 1982 to undertake the necessary cost analysis to provide a basis for modifying the railway rate structure.

Table 4.12

Number of Licensed Vehicles, 1970-1980

	Cars	Buses	Boxes 1/	M/cycles	Others 2/	Total
1970	25,387	2,003	5,716	2,030	14,348	49,484
1979	70,171	6,295	13,490	3,306	43,767	137,029
1980	84,958	2,956	8,883	4,131	37,765	138,695

Notes: 1/ "Boxes" are converted pick-ups which serve as passenger vehicles.

2/ Includes trucks and tractors.

Source: Transport Statistical Bulletin 1981/82 (Ministry of Finance and Economic Planning).

4.41 A further measure to improve the efficiency of energy use and to promote energy conservation would be to restrain the growth of passenger vehicles directly. An effective way to do this would be to apply rigorously the existing regulations concerning the licensing of imports and exemption from import duties. The physical ceiling on the import of motor cars which was recently imposed should also provide an effective restraint.

(ii) Natural Gas

4.42 Estimated reserves of natural gas discovered in the Red Sea are in the range 130-385 billion cu. ft. Two possible uses for the gas as a feedstock present themselves, namely in a urea fertilizer plant and -- perhaps more probably -- for power generation. Other uses would be as a fuel for cement production, sugar refining and cottonseed oil processing; consideration should also be given to constructing a natural gas pipeline parallel to the crude export pipeline (in place of the diluent pipeline) to heat the crude and to supply local markets. Some supply of natural gas to PSR would also permit savings on the current use of liquid hydrocarbons. The total supply of condensate (9-26 million barrels or about 50-150,000 mta over a twenty-year life) is assumed to be utilized by PSR.

4.43 Since the early 1970s, fertilizer imports have been mainly in the form of urea. Basic annual needs for the cotton and sugar plantations are in the order of 200,000 mt. If fertilizer requirements for other crops such as wheat, dura and vegetables are also added, there is an estimated demand of 400,000 mtpa. All of this would have to be imported. Although a naphtha based fertilizer plant (the Sudan-Ren plant) has been constructed in Khartoum and was supposed to start production in 1982, operations have yet to begin, due to the unavailability of naphtha caused by the shortages of foreign exchange. At full capacity the plant should require about 140 mt of naphtha per day.

4.44 It is usually not economical to use natural gas as a feedstock in a urea production plant with a capacity of less than 350,000 mtpa. However, in the case of the Sudan-Ren plant, conversion to natural gas might be considered. The plant could be expected to use 20 MMCF of natural gas per day. The capital expenditure incurred so far on the plant can be treated as a sunk cost. Conversion to natural gas could be done at a relatively low capital cost, say US$2-3 million. The major capital expenditure would be on a gas pipeline from Suakin to Khartoum, estimated to cost in the region of US$110 million. 1/ Alternatively, it would cost around US$150 million to construct a new gas-based urea plant with a capacity of 100,000 mtpa at Port Sudan or Suakin. 2/ Both these possibilities - conversion of the existing Sudan-Ren plant with a gas pipeline from Suakin to Khartoum and a new plant in Port Sudan or at Suakin should be studied.

4.45 The closest major market for natural gas for power generation would be in Port Sudan. The Gibb study has made a forecast of power demand in the Port Sudan area, looking at the industrial and non-industrial components separately, which account for 75% and 25% of the present demand respectively. The results are in Table 4.13.

Table 4.13

Port Sudan: Actual and Estimated Energy Requirements and Maximum Demand, FY81-FY95

	Actual	Forecast	
	FY82	FY90	FY95
Energy generation (GWh)	139	394	650
Growth rates (%)	-	12.3	10.5
Maximum demand (MW)	27	75	124
Growth rates (%)	-	12.0	10.6

1/ Assuming a pipeline diameter of 8" and an operating pressure of 100 psi.

2/ For comparison, a plant with a capacity of 350,000 mtpa would cost about US$300 million.

Existing generation plant in Port Sudan is in poor condition, but 30 MW of new diesel plant are expected by 1984 (see para. 4.47). At 75% plant factor, the new diesel plant produces about 200 GWh p.a. If natural gas is used in a steam turbine plant to supplement supply from the new diesel plant, requirements in FY90 would be about 5 MMCF of natural gas per day, increasing to about 11 MMCF per day in 1995. 1/ If natural gas were to meet the entire power demand in Port Sudan, thus saving on the use of oil, requirements would be about 10 MMCF per day in FY90 growing to 16 MMCF per day in 1995. Of course, if a gas pipeline were constructed to Khartoum to supply the fertilizer plant, much larger quantities of natural gas could be used for power generation in the BNG. However, taking 20 MMCF per day for fertilizer production and 10 MMCF per day for power generation would account for 220 billion cu. ft. of gas over a twenty-year period, in the lower end of the reserve range.

4.46 As noted in para. 2.05, one or two more wells are required to confirm the reserves of the Suakin structure and Total is trying to "farm out" its control area, which will require the "farm-in" partner to drill a delineation well. If Total is unsucessful, Sudan may consider participation, based on a more detailed appraisal of available data.

B. Power

Present Supply/Demand Situation

4.47 Public electricity operations are divided into eight regions, mostly served by isolated diesel systems. The only interconnected system is the BNG, with a mix of hydroelectric, steam, gas turbine and diesel generation. Generating capacity in 1982 and generation for FY 1981 by main plant type for the BNG are in Table 4.14, which also indicates the new capacity (210 MW) to be added to the BNG during FY84. The second most important system is in and around Port Sudan, which is the largest center of population outside Khartoum Province and the largest load center outside the BNG. Installed capacity in Port Sudan in 1982 was only 11 MW but a new power station is under construction and 30 MW in capacity should be added before the end of 1984. The major part of the demand in the area is met by private industrial generation. The remaining isolated systems have a combined installed capacity of 71 MW, of which 13 MW is hydroelectric and the balance consists of small diesel sets.

1/ Based upon a steam turbine plant producing 194 GWh in 1989-90 and 450 GWh in 1995 at 30% efficiency with 3% station losses. The gas contains 1300 BTU per cu. ft.

Table 4.14

	Capacity in 1982 (MW)	Generation in FY81 (GWh)	Additions to Capacity (MW)	Total Capacity by end-1984 (MW)
BNG				
Hydro	147	732	80	227
Steam	30	89	60	90
Gas Turbine	15	5	30	45
Diesel	37	15	40	77
Total BNG	229	841	210	439

Future Developments, Issues and Options

4.48 To a substantial extent, IDA's Power III project is expected to alleviate power shortages in the BNG from the beginning of FY84, as new capacity is commissioned. Similarly, power shortages in the Port Sudan area will be alleviated as the new diesels are commissioned. However, problems will persist in distribution, because networks are not being improved and expanded commensurately with the increased generating capacity, due to lack of funds. Only small improvements can be expected in the remaining systems, depending on the funds to be provided by donor countries.

4.49 Low-voltage distribution has played a secondary role in NEC's expansion program and comprehensive studies have not been made, except for Port Sudan and Khartoum. Loans have been obtained from Poland (US$24 million) and Romania (US$7.5 million) to cover a three year program for the Khartoum area, estimated to cost US$30-35 million. It appears that more attention will have to be given under the proposed Power IV project to coordinated distribution planning and possibly also to the financing of distribution expansion. Outside the Three Towns area, the condition of the distribution systems and the requirements for renovations, improvements and expansion should be investigated.

4.50 Although plans for the electrification of numerous villages have been included in NEC's 1980-86 development program, restricted funds will seriously delay execution. Renovation or replacement of existing plant, rather than expansion (except for Port Sudan) will be about the most that can be attained in the next five years in the existing systems; some four to five towns may be electrified. A new station is being built at Juba under IDA's Power II Project, but completion has been delayed due to technical and other difficulties and it is still not clear if it can be completed during 1984. A 1.6 MW plant addition in Wau, financed by Denmark, is expected in 1983. New capacity of 2X1.5 MW and 2X2.5 MW is expected to be available in Nyala by the end of 1984, with the benefit of French finance.

4.51 Studies for generation for centers outside the BNG have been carried out but they tend to be unrealistic; as in the case of the BNG, they are not up-to-date and they have not been completed in sufficient detail (see para. 2.16). A laudable effort was initiated by NEC (then PEWC) in March 1982, with the Electric Power Status Report; with some improvements, this effort should be repeated annually since it could define objectives concisely and analyze performance objectively in a process of self-evaluation. Studies for areas outside the BNG have also not been coordinated, due partly to the fact that financing has been contributed by a variety of donors and so far no single organization has attempted to collect, summarize and analyze all existing studies and to lay down future policy. NEA is responsible for the overall planning of the energy sector but NEC will be unable to execute its new task as power advisor to the regions unless it has responsibility for basic planning and design in the power sector, with NEA acting in a supervisory and advisory capacity with regard to the country's general energy framework, leaving the details to NEC.

4.52 Plans have to be drawn up for new capacity to be commissioned beyond 1985/86. All of this capacity will be oil based, as there are no hydroelectric projects that could be taken up which would yield benefits in the short term. The heightening of the Roseires dam would take up to eight years and the Merowe hydroelectric project on the Main Nile would take over twelve years to construct, including initial studies. A component of the Power IV project should be feasibility studies for the heightening of the Roseires dam and for the Merowe hydroelectric project.

4.53 Based on the demand forecast for power in the BNG area, about 300 MW of new capacity is likely to be needed during the period 1985-1990. Of this, 120 MW (2X60 MW) could be added at Khartoum North. One of the options to be considered in the petroleum sector is the topping plant at Kosti (para. 4.06), with a capacity of 4000 bpd which would provide about 100,000 mtpa of residual oil. As it would be difficult to inject this residual oil back into the pipeline, due to problems of viscosity, or to transport it by road or rail over large distances for power generation, an option that should be considered is the setting up of a generating station with a capacity of 100-120 MW in close proximity to the topping plant. The transmission lines between Kosti and Sennar would have to be strengthened, at an estimated cost of US$20 million. Specifically, two options need to be considered (assuming a topping plant at Kosti):

(a) Use the residual oil for power generation at Kosti and feed the power into the BNG by strengthening the transmission lines between Kosti and Sennar 1/; and

(b) Transport the residual oil to Khartoum North or to a new site at Khartoum for power generation.

4.54 In the Port Sudan area, the option of using gas for power generation could be available after the gas resources of the Suakin structure are proven. This may be particularly attractive if gas were simultaneously utilized for other purposes, for example fertilizer production. For the other isolated systems, the options are few and are limited to adding additional diesel sets of small to medium capacity.

Pricing of Electricity

4.55 In 1974, the Bank carried out a detailed study of electricity tariffs in the BNG and a tariff structure was formulated to reflect the long-run economic cost of supplying electricity to different consumer categories. A year later, a follow-up study was carried out by consultants, with a view towards implementing a new tariff structure based on marginal costs. Although a trial project was subsequently initiated, in which time-of-day meters were installed on a number of consumers' premises, and seasonal, time-of-day and maximum-demand tariffs were actually introduced as early as 1979, in practice they apply only to heavy industry and large agricultural pumping loads. A conventional flat rate continues to apply to domestic consumers and declining block rates to commercial, small industrial and small agricultural consumers. Even in the case of heavy industry and large agricultural loads, the maximum demand charge is based upon the consumer's estimated maximum demand and estimated installed capacity, not upon his metered maximum demand. Maximum demand meters have been installed in the BNG but the number is unknown. Energy charges, on the other hand, at least for the largest consumers, are metered by time of day ("peak" and "off-peak") and by season ("critical" months and "other" months).

4.56 From a financial point of view, NEC's average tariff has recently been inadequate to meet its operational, debt service, working capital and normal development requirements. The rate of return covenant under the Bank's Power III project -- which requires an 8% return on average revalued net assets -- was met in FY81 by was not met in FY82 and is not expected to be met in FY83. However, NEC is now implementing a major tariff increase in two steps. The first step was introduced on May 1, 1983. After the second step -- due to take effect on November 1, 1983 — the tariff level should be sufficient to enable NEC to meet its financial covenant in FY84.

1/ A suggestion has been made to burn crude directly in the power station but this has merit only if the power station must be commissioned ahead of the topping plant.

4.57 The mission has attempted to assess NEC's tariffs from the point of view of long-run marginal cost (see Annex 12). Although the data do not exist to carry out the exercise properly, the results suggest strongly that the increase in tariff level which NEC is now implementing was justified from an economic as well as a financial perspective. On the other hand, the new tariff structure may not provide consumers with appropriate signals about the differentials in system energy costs at different times of the day and in different months of the year. In so far as the BNG will increasingly require thermal generation on a year-round basis, these differentials may be less than suggested by NEC's new tariff structure. At the same time, the present maximum demand charge may need to be higher and seasonally differentiated; the charge should be based upon metered and not estimated maximum demand.

4.58 A further conclusion arising out of the mission's attempt to evaluate long-run marginal cost is that there is a need for a proper tariff study for the BNG to permit the eventual adjustment of tariffs to reflect more closely the long-run marginal costs of supply. USAID was considering financing such a study, which would cover the isolated systems as well as the BNG, but a decision seems to have been made to postpone the study. Alternative ways of financing the study should be sought.

C. Renewables

(i) Forestry

Projections of Total Fuelwood Consumption

4.59 The growing stock volume of the national forest resource was estimated to be of the order of 1,994 million m^3 in Chapter II. The annual allowable cut from this resource was estimated at 44.4 million m^3, i.e. a growth rate of approximately 2.2%. This level of annual allowable cut was insufficient to meet estimated consumption of 72.4 million m^3 of growing stock equivalent, inclusive of all fuelwood consumption for domestic, commercial and industrial purposes. The annual allowable cut was only 61% of estimated consumption, the balance representing overcutting of the resource. There is further loss of growing stock due to mechanized farming schemes, which is estimated at 3.4 milliom m^3. Total consumption plus losses add up to 75.8 million m^3, exceeding the annual allowable cut by 31.4 million m^3 and resulting in a loss of capital growing stock. Such a loss effectively reduces the total growing stock volume and the annual allowable cut in subsequent years (assuming a constant mean annual increment). Population growth and sectoral growth lead to increased demand for fuelwood in the form of firewood and charcoal, while agricultural expansion increases losses in growing stock. Thus, total removals increase while the annual allowable cut decreases. This progressive reduction in growing stock and annual allowable cut as a result of increasing consumption, has been determined for the total national forest resource. It is not possible to determine such a balance by Provinces since available data are not adequate.

4.60 Annex 11 shows projections of supply, losses and consumption balances at five-yearly intervals from 1980 to the year 2000, together with the percentage changes over the five year periods, assuming present trends continue. Thus, by the year 2000, the forest resource (and the annual allowable cut) will have been reduced by 69.6% of the 1980 base year figure, while consumption is expected to rise by 86%. The forest resource will become a wasting asset at an increased rate. The projections indicate that the total area of forest could be reduced from its present level of 112.5 million hectares to only 33.8 million hectares. The projections given are necessarily imprecise, since no distinction between wood-scarce and wood-rich provinces and regions has been made. Increasing fuelwood costs, due to scarcity and transport over long distances, will impose a limit on consumer demand in areas with scarce wood resources. Nevertheless, the figures indicate the serious depletion of the resource under present regimes of supply and consumption.

4.61 As knowledge of the resource is essential for rational planning, forestry inventory should have a very high priority. Such activity, supported by Canadian Government assistance, is about to be undertaken in the Blue Nile, Bahr-el-Ghazal and El-Buhrat Provinces. Further assistance will be necessary to cover the remaining forested areas and to assess the rate of deforestation over time. The allowable annual cut has been estimated at 2.2% of the growing stock volume. This seems to be a very low figure and more detailed studies are required to determine what steps should be taken to increase this percentage. Improved management practices, including protection of the resource, control of cutting within the annual allowable cut, improvement and extension of silvicultural practices depend upon adequate budgetary provisions.

4.62 The reservation of areas in the vicinity of townships for the supply of fuel to the urban areas in the future is of the greatest importance. The recent denudation of forest around towns, e.g. Khartoum, Juba and Wau, now necessitates long and costly haulage of fuels. The consumption of fuelwood and charcoal in Khartoum Province (including the Three Towns) in 1980 is estimated at 4.8 million m^3 of roundwood equivalent or about 1.6 million mt of fuelwood. Yields of 5 mt of dry fuelwood per hectare in well-managed energy plantations are not unrealistic. A feasibility study should be undertaken to establish the economic viability of energy plantations on a fairly large scale around urban areas, particularly Khartoum. Such plantations could provide fuelwood and charcoal to urban households, probably at a lower price than is being paid for these fuels. Additional benefits would be the preservation of the forest resource and elimination of long haulage of low value fuels with high value gasoil.

4.63 The traditional firewood stove is a simple open hearth of very low efficiency, probably less than 6%. Attention should be directed toward the design and introduction of <u>improved firewood cooking stoves,</u> particularly for use in urban areas, where wood is used for the preparation of bread and for long slow cooking. However, acceptance of firewood burning stoves to any significant extent, particularly by rural populations who are the greater users of fuelwood, is not considered likely in the foreseeable future.

4.64 Consumer testing for acceptability, followed by large scale production and dissemination of improved charcoal stoves with fuel efficiency double that of present market model, should be given immediate Government support. The involvement of authorities such as the Ministries of Health, Education and Information in the Northern Region, and the Ministry of Cooperatives and Rural Development and Community Development Officers in the Southern Region would be necessary.

4.65 The introduction of metal kilns into production centers needs to be studied. The introduction of a pilot masonry kiln into a plantation area capable of supplying the minimum requirement of 20 m^3 of wood per hectare is also desirable. The concept of maximum conversion of wood material into charcoal should be incorporated into all land clearance and in particular to rainfed and irrigated large scale mechanized agricultural schemes.

4.66 The requirement that 15% of the land area of agricultural schemes, both official and under private enterprise, should be retained under forest is presently virtually ignored. Forestry Administration guidelines with regard to the limits of agricultural activity on sloping ground, the retention of perimeter wind-breaks, the safeguarding of fragile lands and the retention of natural forest as internal shelterbelts (or the establishment of planted belts) are not generally followed. The return of abandoned agricultural land to the Forestry Administration for reforestation should be enforced.

4.67 A national scheme for the encouragement of community forestry and dissemination of advice, together with the establishment of a network of extension nurseries for the provision of seedlings to the local population is required. Objectives should lay emphasis on the establishment of community wood-lots and homestead plantings. In the Blue Nile Province there is an awareness of the need for local action and *Acacia tortilis* is protected by the local population. Similarly, in the Northern Provinces and in Kardofan and Darfur Provinces, there is an awareness of sand encroachment and deterioration of the environment intensified by rain failures. This has led to the formation of village committees for environmental protection. Extension activities should concentrate on encouragement of the local populations to establish such committees in order to overcome present reluctance towards self-help schemes, particularly in areas where population have traditionally looked to authority for assistance.

(ii) Solar

4.68 From the discussion in paras. 2.35 and 2.36, it appears that solar energy applications will not be instituted at an early date in Sudan, due to risks and low return. Additionally, market penetration would be a function of fuel cost and supply, solar system cost, capital availability and government actions (including tax deductions and subsidies). However, Sudan has a number of solar energy research projects at the Institute of Energy Research in collaboration with the University of Khartoum. Projects of this kind are worthy of support with a view to *their effective application in the longer term.*

(iii) Wind

4.69 While the potential for the use of windmills for pumping in the Sudan is large, rapid development will be subject to a number of constraints. Research in the country is still in its infancy and to design, manufacture, adequately site, erect and test windmills will require technical and financial assistance, both bilaterally and multilaterally. As the wind resource could make a significant contribution to the water pumping needs of irrigation, the setting up of demonstration projects should be pursued.

(iv) Molasses and Bagasse

Molasses

4.70 In view of the scale and location of the various sugar mills, priority for ethanol development from molasses should be given to Kenana, Sennar and Assalaya, which are situated relatively close to each other. In the case of the smaller mills, Guneid is best placed to continue supplying molasses to various industrial and livestock markets around Khartoum, while New Halfa, which is the closest mill to Port Sudan, would appear to be the most viable single source for future exports of molasses.

4.71 An ethanol project in the Kenana-Sennar-Assalaya area would transport ethanol to a point near Khartoum for blending with gasoline and subsequent distribution. The upper limit for blending (without major vehicle modification) is about 20% ethanol to 80% gasoline by volume. Sales of gasoline in 1981 in Khartoum province were 147,446 tonnes and the addition of other provinces likely to be served out of Khartoum would give a total 1981 market of about 166,700 tonnes. 1/ This would imply ethanol production of 30,000 mtpa or approximately 145,000 mtpa of molasses as input. It appears likely that Kenana, Sennar and Assalaya would be more than capable of providing this input by the late 1980s, although it would be prudent to defer any final commitment on a project of this scale until definite decisions have been reached on the rehabilitation program for the public sector and the financial future of KSC. At that time, a final decision on the optimal location for the ethanol project could also be taken.

4.72 Preliminary analysis by the mission (see Annex 13) suggests that the conversion of molasses to fuel ethanol will be economically attractive in Sudan. It is recommended that the implications for ethanol development should be borne in mind while decisions on the sugar industry rehabilitation are being taken. Once the future of the industry is clear, the Government should take a high level initiative to reopen dis-

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1/ Provinces served from Port Sudan (or in the extreme south, supplied by imports) would be less attractive markets due to higher transport costs.

cussions with KSC on the possible supply of molasses for ethanol production and a suitable agency should be chosen to develop fuel ethanol production of about 30,000 mtpa, probably at Kenana or conceivably at Sennar. If Kenana molasses can not be made available to the project, then a smaller project should be developed to use all the molasses from Sennar and Assalaya.

Bagasse

4.73 The estimates of surplus bagasse which could be available at the various sugar mills show that there is an important potential for reducing the sugar industry's dependence on external energy resources and for providing limited power exports to NEC's grid, even though the industry is unlikely to become a net energy exporter. Detailed study of the economics of this potential, as now envisaged under the Bank's Technical Assistance II Project, 1/ seems to be justified. However, any study should evaluate the cost of public power according to NEC's long-run marginal cost of supply to the sugar mills and the fuel cost of oil-fired generation should be based on the economic cost of importing and transporting to site the relevant petroleum products (e.g. gas oil). Exports of power from the sugar mills to NEC's grid should be valued according to NEC's long-run system cost savings, which means that the timing of the supplies must be identified (by season and by time of day) as well as the level (in terms of MW and GWh). The study should also examine the terms for the exchange of power and energy betweem NEC and the sugar factories and the appropriate institutional and financial arrangements.

4.74 The mission has made some illustrative calculations for the four government-owned mills in Annex 14, using the results on the economic cost of petroleum products and the long-run marginal cost of public power supply derived in Table 4.10 and Annex 12. These calculations suggest that the full utilization of bagasse for power production is economically justified at all four government-owned mills.

1/ "Energy Interface between NEC and the Sugar Industry" (Cr. 1153-SU), to be carried out by Merz and McLellan.

V. INSTITUTIONS IN THE ENERGY SECTOR

A. General

5.01 In the forestry subsector, the mission has perceived a need to strengthen the technical expertise of the Central Forestry Administration (CFA) by creating a body which would have the capacity to implement projects, especially the more ambitious energy plantation projects which the mission is proposing. For the other energy subsectors, including renewables, the mission has identifed the need for a team of technical experts to provide the basis for energy planning. The team would include expertise in finance, economics and engineering; it would be capable of examining pricing and all the available investment options, including the interrelationships between, for example, the gas, oil and power subsectors and it would make clear recommendations to enable the Government to take prompt decisions. Given the present shortage of such expertise in Sudan, the team would need to be consolidated and centralized and attached to the Ministry of Energy and Mining.

B. Ministry of Energy and Mining (MEM)

5.02 MEM has overall responsibility for policy formulation in the energy sector and it regulates the activities of institutions operating in the sector, including the public corporations, such as GPC and NEC. The Geological and Mineral Resources Department of the Ministry carries out geological studies, prospects for minerals and monitors exploration activities in the petroleum sector. It is divided into two divisions: the Mineral Resources Administration and the Petroleum Administration. The Mineral Resources Administration employs 144 geologists and carries out geological surveys for chrome, gypsum, mica and gold. The Petroleum Administration employs eight geologists and three geophysicists for monitoring petroleum exploration activites. The Petroleum Affairs Board is a high-level body responsible for all contract negotiations; it is presided over by the Ministry of Energy and has representatives from the Ministry of Finance and Planning. A National Energy Administration (NEA) was created in May, 1980 as the planning organ of MEM. NEA is receiving technical assistance from consultants (ISTI and EDI) financed by USAID. NEA has done a great deal of work, particularly in gathering data and in organizing a core of Sudanese officials to sustain future work in the energy sector. A chart showing the statutory functions and responsibilities of the different agencies in the energy sector is at Annex 15.

5.03 The main emphasis of the mission's recommendations for institutional improvement in the commercial energy sector has been given to MEM. World Bank technical assistance is already being directed at improving the performance of NEC and GPC and, furthermore, MEM accounts for many of the gaps which the mission has identified between actual performance and statutory responsibilities (see Annex 15).

5.04 There is no integrated system for controlling all ongoing activities and projects within MEM. Some information is provided by the executing agencies, but there is no nucleus within MEM to process the data for presentation to the Minister. In consequence, the Minister and the State Minister become involved in the day-to-day operational affairs of the different energy subsectors, leaving them little or no time for the policy, planning and supervisory functions.

5.05 The following areas need to be examined if MEM is to function more efficiently and exercise greater control over the energy sector:

(a) Institutionalize energy data collection. It is necessary to identify the key information needed for the Minister's decision-making and ensure the routine flow of that information to the Minister in a clearly understandable and digestible form. At present, this is not done. A great deal of information exists; not all of it is relevant to the Minister and he does not receive what is relevant unless he asks for it. It will be necessary to design forms and tables, and to train personnel to collect relevant information and to complete the forms and tables;

(b) Establish a mechanism for routinely coordinating the different groups within MEM and for coordinating the activities of MEM with other Ministries and with relevant bodies in the energy sector (e.g. NEC and the GPC);

(c) Design follow-up procedures for ministerial decisions. These do not now exist and follow-up is on an ad hoc basis when it takes place at all;

(d) Strengthen the Petroleum Administration of the Geology and Mineral Resources Directorate, so that it can monitor petroleum exploration and production sharing contracts more effectively, evolve a long-term strategy for development of the petroleum sector and compile and analyze all geological, geophysical and well-completion data provided by the contractors;

(e) Strengthen the secretariat of MEM with professionals from each of the energy subsectors; and

(f) Devise a system of allocation of foreign exchange which will secure the import of crude and petroleum products on a regular and predictable basis, so that once a budget figure is agreed upon for such imports, MEM and GPC will be able to plan imports in such a way that there is a continual flow of crude to the refinery and of products to the market.

C. Power Sector

5.06 Prior to May 1982, the power and water supply sectors were governed by the Public Electricity and Water Corporation Act of 1978 and

1980. This Act was repealed in May, 1982 and replaced by the National Electricity Corporation Act and the Khartoum Water Corporation Act. The new Acts provide for radical changes in the organization of the power and water supply sectors -- which have now been separated and regionalized -- although, in fact, these changes cannot be fully implemented for some time.

5.07 As it relates to the power sector, the May, 1982 legislation makes the National Electricity Corporation (NEC) responsible for:

(a) the construction and management of the power facilities of the national grids and the Khartoum distribution area;

(b) the generation and transmission of electricity on the national electricity grids, its supply in bulk to regional administrations and the fixing of bulk supply tariffs for this purpose;

(c) establishing technical standards for electricity installations and operations, to ensure uniformity throughout Sudan;

(d) providing consultancy and technical services to regional electricity organizations on a commercial basis; and

(e) providing training for its own staff and for the staff of the regional electricity organizations, which are to pay NEC for such training.

5.08 NEC estimates that the Regional Governments will be in a position to take over the management of almost all of the self-contained isolated electricity systems from July 1983. These include Darfour Area, Kordofan Area, Central Area, Northern Area, Southern Area (except Juba, where the power station construction is not yet complete) and Port Sudan. NEC will continue to manage areas connected to the BNG and the Eastern Grid until July 1, 1985 when the Regional Governments are scheduled to take over management responsibilities. NEC considers that this schedule will provide adequate time for it to install bulk supply meters and to determine and implement bulk supply tariffs.

5.09 With the help of its consultants, NEC has designed its top management structure, taking into consideration the regulations in Sudan which lay down specific salary scales for various categories of staff of public corporations. To enable it to attract higher caliber managers, it has designed a structure which includes four senior directors (or deputy general managers) and eleven managers.

5.10 NEC as an institution faces many problem areas, notably in planning, finance, operations and maintenance; indeed, perhaps the only area of strength is the project management office which has been created under IDA's Power III project. With one exception, the mission makes no specific proposals for technical assistance for institutional improvement to

NEC, in awareness of the numerous ongoing efforts financed, for example, by IDA, USAID and ODA. The one exception is in the area of power system losses, where the mission does recommend technical assistance to help NEC reduce its losses from the very high present level of 27% (para. 3.05)

D. Petroleum

(i) General Petroleum Corporation (GPC)

5.11 The General Petroleum Corporation (GPC), acting on behalf of the Government of Sudan, exercises control over the distribution, allocation and pricing of petroleum products. There are four marketing companies operating in the Sudan, but the market share of each is determined by the allocation of petroleum products to them by GPC. The competition between the four marketing companies is limited to their sales to large industrial and agricultural consumers, provided that GPC makes the products available.

5.12 With the agreement of the Bank of Sudan, GPC determines the quantity of crude oil and of petroleum products to be imported. GPC determines, with the refinery management, the product slate of the refinery, according to the country's requirements and the availability and quality of crude oil. Each month, GPC prepares an allocation plan for all petroleum products and quotas are delivered according to the priority of the consuming sectors. Pricing of petroleum products is also determined by GPC in consultation with the Government of Sudan. Finally, GPC owns and operates the pipeline from Port Sudan to Khartoum.

5.13 Another area of GPC activity is to assist the Government in monitoring the petroleum exploration contracts. It has a right to "buy-into" all the recent exploration contracts, with the exception of the Chevron contract. In recent years, it has also built up a core cadre of exploration personnel. In view of the current activities of GPC and its likely involvement as a partner in exploration contracts, the Government should consider the need to define and limit the contract award, management and monitoring activities of GPC which are the legitimate function of the Geology and Minerals Resource Directorate.

(ii) Port Sudan Refinery (PSR)

5.14 PSR was contructed by Shell and BP and started operations in 1964. The initial investment of LS5 millions was provided entirely by Shell and BP but the Government had an option to purchase 50% of the shares. The option was exercised in 1976; BP transferred its shares to Shell in 1981, so that the refinery is now owned equally by the Government and Shell. The Board has four Sudanese Government representatives and four Shell representatives. The Board chairman is the State Minister of Energy. There is only one expatriate (the refinery superintendent) in management, compared with 25 in 1964, while all 216 operating personnel are Sudanese, except for two expatriates who are working on a temporary basis. However, the refinery faces competition for refinery engineers and technicians from other Arab countries, e.g. Saudi Arabia and Abu

Dhabi. Such competition is likely to create increasing problems in the future, even though the refinery reportedly pays the highest salaries in Sudan and provides generous fringe benefits.

5.15 The refinery is regarded as part of the private sector and is well run. Government control of policy is exercised through the Board but there is no interference with technical operations. Crude oil is purchased by GPC and supplied to the refinery, which merely refines the crude and then returns the products to GPC. In return, the refinery receives a fixed but renegotiable processing fee, 1/ to cover its operating costs (including depreciation) and a 15% return on capital. Fuel costs and refinery losses are not borne by PSR so that there is no incentive for PSR to minimize them. Instead, it operates to an agreed maximum of a 5% difference between the crude supply and product off-take. In view of the potentially high rate of return on energy-saving projects, consideration should be given to revising the contract between the Government and PSR to provide an incentive for reducing refinery losses further. 2/

(iii) White Nile Petroleum Corporation (WNPC)

5.16 WNPC is a newly formed corporation, with the Minister of Energy as chairman of the Board of Directors. In addition, the State Minister of Finance and representatives of Chevron, IFC and APICORP are on the Board. The Company will own the proposed pipeline from the Unity-Talih oil fields to the Red Sea terminal. Chevron, as the manager of the project, is preparing bid documents for the pipeline and will later supervise construction of the pipeline and terminal. The operation of the pipeline will be entrusted to a subsidiary of Chevron. One of the merits of ownership of the pipeline by WNPC is that the pipeline will serve as a common carrier for any oil discovered by other exploration contractors.

E. Forestry

5.17 All forest land is owned by the State and its administration is the responsibility of the CFA, consisting of the Northern and Southern regions, based in Khartoum and Juba respectively. Under the 1971 Peoples' Government Act, many of the powers relating to land use, forest conservation and utilization, the control of desertification, the control and direction of land apportionment, and resettlement have become the responsibility of the local administrations of the eighteen provinces. Consequently, many of the forest operations previously controlled by the CFA have become the responsibility of the provincial Forest Services.

1/ Set at LS1.28 per barrel on June 1, 1982 and LS1.90 per barrel on August 1, 1982 based upon an annual throughput of 850,000 mt of crude.

2/ The management of PSR has prepared six energy saving projects, which could lead to an annual saving of 2,400 mt of fuel at a cost of about LS641 thousand.

These powers include both budgetary control and the collection of revenue from the sale of forest produce. The powers left with the CFA are limited to: providing advice to the provincial Forest Services; responsibility for overall policy, control and evaluation of major development projects; staff administration, including staff postings and secondment; and forest inventory.

5.18 The Regions are presently staffed as follows:

Northern Region

University Graduates (Assistant Conservators and Higher Ranks)	64
Forest Technicians (Diploma)	178
Forest Overseers	320

Southern Region

University Graduates (Assistant Conservators and Higher Ranks)	13
Forest Technicians (Diploma)	30
Forest Technicians (non-Diploma)	58

The total number of permanent forest workers employed in the country is probably of the order of 6,000, most of them by the local authorities.

5.19 Since the preservation and proper utilization of the forestry resource is essential, a national coordinated program of forestry management and development is vital. Piecemeal development under local administration is unlikely to achieve the overall goals towards which the forestry sector should be moving. The CFA must be strengthened if it is to introduce legislation and execute policies for optimizing the use of the forestry resource. In particular, forestry will require increasing amounts of investment and must be regarded as an important Government activity requiring an appropriate financing structure. An important step would be the creation of a body within the CFA responsible for the planning, coordination, review and monitoring of projects, the most important of which would be the proposed energy plantations for meeting the needs of urban areas for firewood and charcoal.

5.20 As fuelwood contributes nearly 82% of the energy consumption of Sudan -- and this is not likely to change substantially in the near future -- there is a need to coordinate forestry activities wth national energy planning and policies. Suitable administrative procedures need to be established.

VI. INVESTMENT AND TECHNICAL ASSISTANCE IN THE ENERGY SECTOR

Investment Requirements

6.01 Commercial energy consumption in Sudan is relatively low at 58 kgoe per capita, due partly to a complete reliance on imports in the petroleum sector and serious underinvestment in the power sector. Investment in the power sector has varied between US$3 million and US$11 million annually and has averaged less than 5% of total development expenditure over the seven-year period FY76 to FY82. As a percentage of GDP, power investment has never exceeded 0.5% in the same period and has fallen as low as 0.1%.

6.02 Since 1975, over US$500 million have been spent for oil exploration, but this has been borne entirely by the international oil companies and to a large extent by Chevron. Current expenditure by Chevron is about US$200 million per year and represents the largest single investment in the energy sector. The only other investment in the petroleum sector has been in distribution facilities.

6.03 There has been minimal investment in the non-commercial energy sector. Funding for forestry activities has been inadequate in relation to the size of the forest resource and its rate of depletion. Very little investment has gone into improving the annual allowable cut as a percentage of the total resource and into the more efficient utilization of fuelwood for cooking as well as conversion to charcoal.

6.04 The mission has examined the likely future investment requirements for the energy sector up to FY91, in light of the demand forecasts prepared for Scenario A of Table 3.4. The conclusions are discussed below and the results (in 1983 prices) are summarized in Table 6.1.

6.05 In the petroleum sector, the major investments will be devoted to the development of the Unity-Talih oilfields and the proposed crude and diluent pipelines from the oilfields to the Red Sea, estimated to cost about US$1.7 billion. All the oilfield development cost will be met by Chevron, while the cost of the pipeline will be met by WNPC, in which the Government and Chevron are the major partners. The Government's required equity contribution to WNPC is estimated at some US$99 million. Another major investment by the Government in the petroleum sector would be for the topping plant at Kosti, estimated to cost about US$25 million. In addition, GPC has the right to "buy in" up to a share of 15% in the exploration contracts at its discretion. There is also the possibility of GPC participating in the Red Sea natural gas discovery on a "farm-in" basis. The investment by Government/GPC in these exploration contracts could amount to US$50 million. If the gas reserves of the Suakin field are confirmed after drilling another delineation well, plans could be drawn up for the utilization of gas for fertilizer and power production. Chevron estimated in 1976 that development of the gas field and a pipeline from the Suakin structure to Port Sudan would cost US$ 131 million for a production of 50 MMCFD. Investment at 1983 price levels might be US$300 million.

Table 6.1

Estimated Public Investment Requirements
for the Energy Sector to FY91
(US$ million at 1983 prices)

Petroleum and Natural Gas	
Crude oil export pipeline	99
Topping plant	25
Exploration	50
Gas development	300
Sub-total	474
Power	
(a) BNG	
-Power III	131
-Generation projects to be commissioned before 1991	300
-generation projects to be commissioned after 1991	150
-Transmission	180
-Distribution	145
(b) Isolated Systems	150
Sub-total	1056
Forestry	
New plantations, mainly near urban areas, and other forestry schemes	200
Total required investment for energy sector to 1991	1730

6.06 In the power sector, the remaining works under Power III are expected to cost US$131 million. Investment in new generation capacity for the BNG for projects to be commissioned before 1991 is likely to cost US$300 million (corresponding to 300 MW of thermal plant); a provision of US$150 million can be made for work on generation projects in the BNG (including hydroelectric projects) which must be started before 1991 although commissioning would occur after 1991. Investment in strengthening and expanding transmission and distribution facilities in the BNG is essential and would require some US$180 million and US$145 million respectively. In the isolated systems, an investment in the order of US$150 million is envisaged to meet projected demand.

6.07 It is difficult to project specific physical targets and associated investment needs in the forestry sector, but a conservative program should cover 500 thousand hectares under energy plantation programs. Most of this new plantation would be close to urban areas and over a ten-year period would meet a substantial share of the needs of urban households for fuelwood and charcoal. Investment costs per hectare for large-scale energy plantations are not available as there have been few really large projects. For smaller projects, covering a few thousand hectares, estimates have been as high as US$1,000 per hectare. Some studies in the U.S. indicate an investment figure of US$400 per hectare, with a projected harvested cost of US$25 per oven-dry ton of fuelwood. 1/ The major investment cost components have been identified as US$160 for seedlings and US$180 for site preparation. The seedling costs were based on tissue culture propagation and may be considerably less if conventional nurseries are adopted (with a possible reduction in fuelwood yield per hectare). These costs may be much lower in Sudan and a pre-feasibility study should be undertaken immediately to establish the major parameters. This could be followed by a more detailed feasibility study to determine the economic attractiveness of the schemes. Furthermore, there is an urgent need to improve on the annual allowable cut from the present 2.2% of total resource, by better forestry management practices. These programs may cost annually US$10 million.

6.08 The investments in gas development and forestry projects, totalling US$500 million, are tentative and would depend on the outcome of feasibility studies proposed separately. The estimated investment requirements for the energy sector as a whole (including gas development and forestry) in the eight-year period to FY91 total US$1,730 million in 1983 prices or approaching US$220 million per year. This corresponds to about 3.1% of GDP, which is not unreasonable compared with other developing countries.

6.09 Nevertheless, as explained in para. 3.13, these investments may not be realizable if constraints on foreign exchange and the Government's budget become so tight that even the high-priority energy sector cannot receive the resources it needs. It can be assumed that the main impact -- as far as public investment requirements are concerned in Table 6.1 -- would be felt through the power sector. Petroleum and natural gas can be treated as enclave projects and direct foreign-exchange earners or savers; forestry investment has a high local cost component. Within the power sector, generation projects for the BNG could be postponed after Power III; and investment in transmission, distribution and the isolated systems could be further neglected. If half the power investment outside Power III (US$462.5 million) could be deferred beyond 1991 -- based upon the much more pessimistic illustrative load growth described in para. 3.13 -- then total investment in the energy sector might be cut from US$1,730 million in Table 6.1 to, say, US$1,270 million (by about 27%) or about US$160 million a year (corresponding to about 2 1/4% of GDP). However, the very serious implications of such a cut for the Sudanese economy are not to be under-estimated: it would become even more difficult

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1/ Production of Woody Bifuels from Mesquite (Caeser Kleberg Wildlife Research Institute).

to achieve a satisfactory growth of GDP and exports and to resolve Sudan's immediate economic difficulties.

Technical Assistance

6.10 The discussion in Chapters II, IV and V identified a number of areas where technical assistance is required, including studies, demonstration projects and expatriate experts. Among these, the mission has identified the following as having the highest priority in the different subsectors.

A. Petroleum

(i) Utilization of Indigenous Crude

6.11 Sudan is expected to have at least 16,000 bpd of crude on a net basis (after the payment of annual costs) from 1986, when the pipeline is commissioned. Three options were identified in Chapter IV, which need further study.

(ii) Exploration Strategy, Management and Data Review

6.12 Sudan is in the process of awarding a number of new exploration contracts and is faced with certain "buy-in" and "farm-in" options. Furthermore, Chevron, Total, Phillips and Sun have large exploration commitments. Assistance needs to be given to the Geology and Mineral Resources Directorate of the Ministry of Energy and Mines in: (a) contract negotiations; (b) contract monitoring and management; (c) exercising options for "farm-in" and "buy-in"; (d) evolving a long-term strategy for the development of the petroleum sector; and (e) compiling and analyzing all geological, geophysical and well-completion data provided by the contractors.

(iii) Natural Gas

6.13 Gas has been discovered at Suakin 1 but the reserves of the structure need to be confirmed by additional drilling. Total is looking for a "farm-in" partner and the possibility of the Government taking up such an option needs to be studied. The study would require an assessment of gas reserves based on available data and the prospects for utilizing gas in the domestic market and would include the subject of gas pricing.

B. Power

(i) Hydroelectric

6.14 A number of studies have been carried out for the BNG, where potential hydroelectric sites have been identified, but no scenario is available from which an order of merit for the different schemes could be prepared based on a least-cost analysis. Further studies are therefore required, as indicated in paras. 2.24-2.25.

(ii) Thermal

6.15 The option of generating thermal power at Kosti, with a transmission line to the BNG, needs to be studied urgently as an alternative to additional thermal power at Khartoum. Furthermore, there is a need for technical assistance to help NEC implement a power system loss reduction study.

(iii) Distribution

6.16 The condition of the distribution systems within and outside the Three Towns and the requirements for their renovation, improvement and expansion need to be investigated.

(iv) Pricing

6.17 There is a need for a study of the structure of power tariffs in the BNG and in the isolated systems, taking into account the long-run marginal costs of supply.

C. Renewables

(i) Forestry

6.18 A continuing inventory of the forest resource is essential. Three provinces are being covered under Canadian Government assistance, but the study needs to be extended to all provinces under other bilateral and multilateral assistance schemes.

6.19 Technical assistance is required to identify the steps to be taken in implementing the proposals in paras. 5.19 and 6.07 to improve the productivity of the forest resource, revise forest policy and legislation and strengthen the administration of the forestry subsector.

6.20 Studies are required in the design and introduction of improved fuelwood and charcoal stoves and charcoal kilns.

6.21 If the forestry programs for augmenting urban fuelwood supplies suggested in para. 6.07 are to be successful, technical assistance will be required in carrying out a feasibility study and the setting up of demonstration and pilot projects.

(ii) Wind

6.22 As the potential for the use of windmills for irrigation pumping is large, technical assistance in identifying suitable designs for adoption in Sudan and siting them in the more promising areas will be required. Such assistance would supplement and coordinate the work being financed by Germany, Australia and the U.K.

General

6.23 There is a multiplicity of foreign donor activity which has taken place and is still taking place in the energy sector. There are numerous ongoing demonstration projects and studies which are uncoordinated and the number and scope of these projects/studies appears large in relation to the size of the energy sector and its absorptive capacity. For example, there are at least seven solar demonstration/ pilot projects; three wind energy projects; four forestry projects; and a number of technical consultancy/assistance agreements for the power sector. The total foreign donor assistance of this kind seems large in relation to the very low capital investment in the energy sector (para. 6.01); probably some of this assistance could have been used more effectively in providing essential spares and equipment. 1/ An appropriate permanent mechanism is needed to evaluate, monitor and coordinate, on a regular basis, all foreign donor activity (both project and technical assistance) in the energy sector. Some bilateral assistance to the Ministry of Energy and Mining for setting up a cell for this purpose should be considered.

6.24 The large investments which have been proposed in the petroleum and forestry subsectors represent completely new areas of activity. These activities will require cadres of adequately trained manpower and therefore appropriate programs must be planned and implemented.

1/ USAID has included in its program of assistance amounts for commodities and spares for the energy sector.

ANNEX 1

ENERGY BALANCE 1981
(10^3 mtoe)

	Primary Energy						Petroleum Products					
	Fuel-wood	Bio-mass 1/	Hydroelec-tricity	Crude Oil	Charcoal	Electri-city (NEC)	LPG	Gasoline	Kerosene Jet	Gasoil	Fuel Oil	Total
Gross Supply												
Production	7,765	526	188									8,479
Imports				812			1	74	13	246		1,146
Producers' Stock decrease (increase)				62								62
Total Available Supply	7,765	526	188	874			1	74	13	246		9,687
Conversion												
Petroleum Refining				(832)			5	133	41	295	358	0
Charcoal Production	(1,778)				1,778							0
Electricity Generation			(188)			248				(15)	(45)	0
Conversion Losses	(3,236)			(42)		(167)						(3,445)
Transmission/distribution Losses						(21)						(21)
Net Supply Available	2,751	526	0	0	1,778	60	6	207	54	526	313	6,221
Exports											(141)	(141)
Distributors' stock decrease (increase)								55	11	40	(38)	68
Net Domestic Consumption	2,751	526			1,778	60	6	262	65	566	134	6,148
Consuming Sectors												
Agriculture						7				98		105
Industry	75	100				22	1		1	53	106	358
Transport								262	47	337	28	674
Households	2,591	426			1,686	23	5		17	33		4,781
Public/Other	85				92	8				45		230

1/ The col. headed biomass represents biomass other than fuelwood and charcoal, notably bagasse, groundnut shells, crop residues and animal wastes.

2/ One ton of charcoal requires six tons of fuelwood.

3/ Fuel consumption and conversion losses in thermal electricity generation are based on actual results. The total conversion losses (167,000 mtoe) include also a hypothetical figure for hydroelectricity based on 34% efficiency.

Source: NEA and mission estimates.

ANNEX 2

SUDAN

FORESTRY RESOURCES

Province Group	Source	Total Area (Hectares)	Average Volume (m^3/Hectare)	Total Standing Growing Stock Volume (m^3)	Annual Allowable Cut (m^3)	Mean Increment (m^3/Hectare)
Eastern	Forest	2,748,065	2.55	7,007,855	234,602	0.09
	Other	700,000	4.76	3,332,000	222,133	0.32
	Total	3,448,065	3.00	10,339,855	456,735	0.13
Central	Forest	5,123,770	4.98	25,532,325	886,256	1.73
	Other	700,000	4.76	3,332,000	222,133	0.32
	Total	5,823,790	4.95	28,864,325	1,108,389	0.19
Khartoum	Forest	5,000	60.00	300,000	30,000	6.0
	Other	700,000	4.76	3,332,000	222,133	0.32
	Total	705,000	5.15	3,632,000	252,133	0.36
Kordofan	Forest	11,628,000	10.56	122,827,800	2,985,994	0.26
	Other	700,000	4.76	3,332,000	222,133	0.32
	Total	12,328,000	10.23	126,159,800	3,208,127	0.26
Darfur	Forest	17,693,300	26.97	477,199,800	9,587,083	0.54
	Other	700,000	4.76	3,332,000	222,133	0.32
	Total	18,393,300	26.13	480,531,800	9,809,216	0.53
Northern	Other	700,000	4.76	3,332,000	222,133	0.32
Northern Region Total		41,398,155	15.77	652,859,780	15,056,733	0.36
Buhayrat	Forest	6,525,400	15.03	98,069,800	2,911,378	0.45
Jonglei	Forest	11,863,900	3.76	44,643,700	2,007,915	0.18
Bahr-El-Ghazal	Forest	11,733,900	34.94	410,037,200	8,336,555	0.71
E. Equatoria	Forest	10,808,150	18.18	196,632,396	4,328,640	0.40
W. Equatoria	Forest	6,982,783	61.76	431,275,066	6,952,831	1.00
Upper Nile	Forest	23,171,600	6.94	160,842,700	4,673,027	0.20
Southern Region Total		71,095,683	18.87	1,341,500,862	29,300,346	0.41

ANNEX 3

SUDAN
SUGAR INDUSTRY PRODUCTION AND PERFORMANCE DATA
FY79 to FY82

	Cane Milled (10^3 mt)	Sugar (10^3mt)	Fuel Molasses (10^3 mt)	Bagasse (10^3 mt)	Furnace Oil (mt)	Gasoil (mt)	Gasoline (10^3 Ig)
Guneid							
FY79	416	36.5	13.3	203	3864	2143	49
FY-80	319	29.7	11.0	143	1829	2140	48
FY81	398	35.8	14.8	179	2000	2200	51
FY82	186	15.7	6.7	86	2694	n.a.	n.a.
New Halfa							
FY79	691	64.8	24.2	311	2852	2050	62
FY80	483	43.0	20.5	217	2933	2190	62
FY81	560	50.0	22.8	252	1079	2300	67
FY82	433	35.9	15.6	172	2439	n.a.	n.a.
Sennar							
FY79	233	18.2	9.0	105	4000	3000	120
FY80	386	39.0	18.3	174	4000	3000	120
FY81	400	32.0	19.6	180	4000	3000	120
FY82	314	22.3	11.8	141 1/	2696	n.a.	n.a.
Assalaya							
FY80	95	7.7	7.5	39	4500	3000	118
FY81	140	12.6	4.3	44	4000	3000	118
FY82	2/	2/	2/	2/	n.a.	n.a.	n.a.
Kenana							
FY80	330	19.7	26.7	122	15,751	7,058	233
FY81	1193	106.8	66.7	459	24,116	9,215	332
FY82	1742	165.4	97.9	644 1/	30,000 1/	14,000 1/	441 1/
Total							
FY79	1340	119.5	46.5	619	10,716	7193	231
FY80	1613	139.1	84.0	695	29,013	17,388	581
FY81	2691	237.2	128.2	1114	35,195	19,715	688
FY82	2675	239.3	132.0	1043 1/	37,829 1/	n.a.	n.a.

1/ Estimated

2/ No factory operation; cane milled at Kenana.

ANNEX 4

HOUSEHOLD FUELWOOD CONSUMPTION, 1980

Province	Urban/ Rural	m^3 roundwood equivalent per capita per annum
Khartoum	Urban	0.32
	Rural	0.38
Gezeira	Urban	0.49
	Rural	0.60
Blue Nile	Urban	0.86
	Rural	2.41
White Nile	Urban	0.59
	Rural	0.88
Kassala	Urban	0.78
	Rural	1.19
Red Sea	Urban	0.23
	Rural	0.55
Northern	Urban	0.35
	Rural	0.50
Nile	Urban	0.43
	Rural	0.64
N. Kordofan	Urban	0.79
	Rural	1.36
S. Kordofan	Urban	0.91
	Rural	1.82
N. Darfur	Urban	0.91
	Rural	1.82
U. Nile	Urban	0.9
	Rural	1.45
Junglei	Urban	0.64
	Rural	0.91
El-Buheyrat	Urban	0.92
	Rural	1.09
E. Equatoria	Urban	1.80
	Rural	3.64
W. Equatoria	Urban	2.20
	Rural	3.64
Bahr-El-Ghazal	Urban	1.45
	Rural	2.73
Average	Urban	0.85
	Rural	1.50

ANNEX 5

HOUSEHOLD CHARCOAL CONSUMPTION, 1980

Province	Urban/ Rural	m^3 roundwood equivalent per capita per annum	Source
Khartourm	Urban	2.9	M. Mukhtar
	Rural	2.0	M. Mukhtar
Gezeira	Urban	2.9	estimate
	Rural	2.0	NEA survey
Blue Nile	Urban	2.9	estimate
	Rural	1.5	NEA survey plus
White Nile	Urban	3.5	estimate
	Rural	2.5	estimate
Kassala	Urban	2.7	NEA survey minus
	Rural	1.8	NEA survey minus
Red Sea	Urban	2.3	estimate
	Rural	1.8	estimate
Northern	Urban	2.5	estimate
	Rural	2.2	estimate
Nile	Urban	2.6	NEA survey
	Rural	2.2	NEA survey minus
N. Kordofan	Urban	5.5	estimate
	Rural	2.7	estimate
S. Kordofan	Urban	6.1	NEA survey minus
	Rural	2.7	NEA survey plus
N. Darfur	Urban	5.5	estimate
	Rural	2.7	estimate
S. Darfur	Urban	6.1	estimate
	Rural	2.7	estimate
U. Nile	Urban	2.6	estimate
	Rural	1.1	estimate
Junglei	Urban	0.5	estimate
	Rural	0	estimate
El-Buheyrat	Urban	2.6	estimate
	Rural	1.1	estimate
E. Equatoria	Urban	4.3	NEA survey
	Rural	0.9	NEA survey
W. Equatoria	Urban	5.2	NEA survey
	Rural	0.9	NEA survey
Bahr-El-Ghazal	Urban	5.2	NEA survey minus
	Rural	1.1	estimate
Average	Urban	3.7	
	Rural	1.8	

Notes on Sources:

Per capita consumption based primarily on NEA surveys.

Estimates based on NEA surveys and surveys conducted by M. Mukhtar, (Khartoum 1980), A. Skeikh El Din (White Nile, 1980), T. Hammer (N.Kordofan, 1978).

"NEA Survey minus" or "plus" indicates that consumption is less than or greater than the survey result, an adjustment having been made where the survey location was judged to be atypical.

ANNEX 6

HOUSEHOLD FUELWOOD DEMAND BY PROVINCE, 1980-1995
($10^3 m^3$ roundwood growing stock equivalent)

Province	1980	1985	1990	1995
Khartoum	525	670	841	1047
Gezeira	1482	1756	2080	2438
Blue Nile	2061	2250	2508	2694
White Nile	972	976	1318	1509
Kassala	1605	1827	2058	2381
Nile	348	366	384	403
S. Kordofan	1827	1959	2095	2253
N. Kordofan	1698	1859	2057	2302
S. Darfur	2529	2856	3190	3512
N. Darfur	1461	1658	1873	2095
Red Sea	249	283	319	357
Northern	195	206	219	233
E. Equatoria	2718	2758	2781	2834
W. Equatoria	1383	1432	1484	1552
Bahr El Ghazal	2163	2305	2432	2555
Upper Nile	1200	1314	1444	1424
Junglei	420	469	526	590
El Buhyrat	654	719	791	870
Total	23490	25663	28400	31049
% increase by five-year period	-	9.3	10.7	9.3

ANNEX 7

PROJECTED DEMAND FOR CHARCOAL BY PROVINCE, 1980-1995
($10^3 m^3$ roundwood growing stock equivalent)

Province	1980	1985	1990	1995
Khartoum	4330	4566	7102	8974
Geziera	5346	6404	7662	9175
Blue Nile	1998	2380	2905	3990
White Nile	3294	3529	4838	5828
Kassala	3024	3628	4271	5270
Nile	1386	1511	1631	1762
S. Kordofan	3636	4241	5089	6212
N. Kordofan	4684	4819	5495	6347
S. Darfur	4644	5534	6694	8083
N. Darfur	3546	4183	4945	5826
Red Sea	1170	1361	1576	1809
Northern	900	967	1035	1112
E. Equatoria	1890	2644	3540	4509
W. Equatoria	1098	1560	2113	2698
Bahr El Ghazal	1639	2175	2932	3855
Upper Nile	1098	1290	1552	1743
Junglei	7	7	7	7
El Buhyrat	810	986	1228	1540
Total	44499	51785	64615	78740
% increase by five-year period	-	16.4	24.8	21.9

ANNEX 8

TOTAL HOUSEHOLD CONSUMPTION OF FUELWOOD AND CHARCOAL BY PROVINCE, 1980-1995

($10^3 m^3$ roundwood growing stock equivalent)

Province	1980	1985	1990	1995
Khartoum	4885	5236	7943	10021
Gezeira	6828	8160	9742	11613
Blue Nile	4059	4630	5413	6684
White Nile	4266	4505	6156	7337
Kassala	4629	5455	6329	7651
Nile	1734	1877	2015	2165
S. Kordofan	5463	6200	7184	8465
N. Kordofan	6382	6678	7552	8649
S. Darfur	7173	8390	9884	11595
N. Darfur	5007	5841	6818	7921
Red Sea	1419	1644	1895	2166
Northern	1095	1173	1254	1345
E. Equatoria	4608	5402	6321	7343
W. Equatoria	2481	2992	3597	4250
Bahr El Ghazal	3801	4480	5364	6410
Upper Nile	2298	2604	2996	3167
Junglei	427	476	533	597
El Buhyrat	1464	1705	2019	2410
Total	67989	77448	93015	109789

ENERGY BALANCE 1986 (Scenario A)
(10^3 mtoe)

	Primary Energy						Petroleum Products					
	Fuel-wood	Bio-mass 1/	Hydroelec-tricity	Crude Oil	Charcoal	Electri-city (NEC)	LPG	Gasoline	Kerosene Jet	Gasoil	Fuel Oil	Total
Gross Supply												
Production	9,046	823	283									10,152
Imports				1,250			2	102	15	262		1,631
Producers' Stock decrease (increase)												
Total Available Supply	9,046	823	283	1,250			2	102	15	262		11,783
Conversion												
Petroleum Refining				(1,187)			5	202	60	415	505	0
Charcoal Production	(2,137)				2,137							
Electricity Generation			(283)			405				(21)	(101)	0
Conversion Losses	(3,889)			(63)		(267)						(4,219)
Transmission/distribution Losses						(23)						(23)
Net Supply Available	3,020	823	0	0	2,137	115	7	304	75	656	404	7,541
Exports											(149)	(149)
Distributors' Stock Decrease (Increase)												
Net Domestic Consumption	3,020	823			2,137	115	7	304	75	656	255	7,392

ENERGY BALANCE 1991 (Scenario A)
(10^3 mtoe)

	Primary Energy						Petroleum Products					
	Fuel-wood	Bio-mass 1/	Hydroelec-tricity	Crude Oil	Charcoal	Electri-city (NEC)	LPG	Gasoline	Kerosene Jet	Gasoil	Fuel Oil	Total
Gross Supply												
Production	10,705	937	354									11,996
Imports				1,250			4	177	33	437	99	2,000
Producers' Stock decrease (increase)												
Total Available Supply	10,705	937	354	1,250			4	177	33	437	99	13,996
Conversion												
Petroleum Refining				(1,187)			5	202	60	415	505	0
Charcoal Production	(2,610)				2,610							0
Electricity Generation			(354)			650				(35)	(261)	0
Conversion Losses	(4,750)			(63)		(429)						(5,242)
Transmission/distribution Losses						(38)						(38)
Net Supply Available	3,345	937	0	0	2,610	183	9	379	93	817	343	8,716
Exports												
Distributors' stock decrease (increase)												
Net Domestic Consumption	3,345	937			2,610	183	9	379	93	817	343	8,716

ENERGY BALANCE 1996 (Scenario A)
(10^3 mtoe)

	Primary Energy						Petroleum Products					
	Fuel-wood	Bio-mass 1/	Hydroelec-tricity	Crude Oil	Charcoal	Electri-city (NEC)	LPG	Gasoline	Kerosene Jet	Gasoil	Fuel Oil	Total
Gross Supply												
Production	12,653	1,066	510									14,229
Imports				1,250			6	270	56	625	369	2,576
Producers' Stock decrease (increase)												
Total Available Supply	12,653	1,066	510	1,250			6	270	56	625	369	16,805
Conversion												
Petroleum Refining				(1,187)			5	202	60	415	505	0
Charcoal Production	(3,180)				3,180							0
Electricity Generation			(510)			1,015				(22)	(483)	0
Conversion Losses	(5,788)			(63)		(670)						(6,521)
Transmission/distribution Losses						(59)						(59)
Net Supply Available	3,685	1,066	0	0	3,180	286	11	472	116	1,018	391	10,225
Exports												
Distributors' stock decrease (increase)												
Net Domestic Consumption	3,685	1,066			3,180	286	11	472	116	1,018	391	10,225

ENERGY BALANCE 1986 (Scenario B)
(10^3 mtoe)

	Primary Energy						Petroleum Products					
	Fuel-wood	Bio-mass 1/	Hydroelec-tricity	Crude Oil	Charcoal	Electri-city (NEC)	LPG	Gasoline	Kerosene Jet	Gasoil	Fuel Oil	Total
Gross Supply												
Production	9,046	823	283									10,152
Imports				1,250			3	149	27	363		1,792
Producers' Stock decrease (increase)												
Total Available Supply	9,046	823	283	1,250			3	149	27	363		11,944
Conversion												
Petroleum Refining				(1,187)			5	202	60	415	505	0
Charcoal Production	(2,137)				2,137							0
Electricity Generation			(282)			405				(21)	(101)	0
Conversion Losses	(3,889)			(63)		(267)						(4,219)
Transmission/distribution Losses						(23)						(23)
Net Supply Available	3,020	823	0	0	2,137	115	8	351	87	757	404	7,702
Exports											(125)	(125)
Distributors' stock decrease (increase)												
Net Domestic Consumption	3,020	823			2,137	115	8	351	87	757	279	7,577

ENERGY BALANCE 1991 (Scenario B)
(10^3 mtoe)

	Primary Energy						Petroleum Products					
	Fuel-wood	Bio-mass 1/	Hydroelec-tricity	Crude Oil	Charcoal	Electri-city (NEC)	LPG	Gasoline	Kerosene Jet	Gasoil	Fuel Oil	Total
Gross Supply												
Production	10,705	937	354									11,996
Imports				1,250			6	268	56	633	146	2,359
Producers' Stock decrease (increase)												
Total Available Supply	10,705	937	354	1,250			6	268	56	633	146	14,355
Conversion												
Petroleum Refining				(1,187)			5	202	60	415	505	0
Charcoal Production	(2,610)				2,610							0
Electricity Generation			(354)			650				(35)	(261)	0
Conversion Losses	(4,750)			(63)		(429)						(5,242)
Transmission/distribution Losses						(38)						(38)
Net Supply Available	3,345	937	0	0	2,610	183	11	470	116	1,013	390	9,075
Exports												
Distributors' stock decrease (increase)												
Net Domestic Consumption	3,345	937			2,610	183	11	470	116	1,013	390	9,075

ENERGY BALANCE 1996 (Scenarion B)
(10^3 mtoe)

	Primary Energy						Petroleum Products					
	Fuel-wood	Bio-mass 1/	Hydroelec-tricity	Crude Oil	Charcoal	Electri-city (NEC)	LPG	Gasoline	Kerosene Jet	Gasoil	Fuel Oil	Total
Gross Supply												
Production	12,653	1,066	510									14,229
Imports				1,250			9	427	96	963	449	3,194
Producers' Stock decrease (increase)												
Total Available Supply	12,653	1,066	510	1,250			9	427	96	963	449	17,423
Conversion												
Petroleum Refining				(1,187)			5	202	60	415	505	0
Charcoal Production	(3,180)				3,180							0
Electricity Generation			(510)			1,015				(22)	(483)	0
Conversion Losses	(5,788)			(63)		(670)						(6,521)
Transmission/distribution Losses						(59)						(59)
Net Supply Available	3,685	1,066	0	0	3,180	286	14	629	156	1,356	471	10,843
Exports												
Distributors' stock decrease (increase)												
Net Domestic Consumption	3,685	1,066			3,180	286	14	629	156	1,356	471	10,843

ANNEX 11

SUDAN

FUELWOOD AND CHARCOAL: PROJECTIONS OF SUPPLY, LOSSES AND CONSUMPTION BALANCE, 1980-2000
AND PERCENTAGE CHANGE ON BASE YEAR, 1980
($10^3 m^3$ growing stock equivalent)

Year	Growing Stock Volume	Annual Allowable Cut	Firewood: Household	Firewood: Commercial	Firewood: Industrial	Charcoal: Household	Charcoal: Commercial	Poles Timber	Losses	Total Losses and Consumption	Balances
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
1980	1,994,361	44,357	23,490	778	669	44,499	2,445	510	3,370	75,761	-31,404
1985	1,810,278	40,263	25,663	851	806	51,785	2,673	585	3,479	85,842	-45,579
% Change	-9.2	-9.2	+9.3	+9.4	+20.5	+16.4	+9.3	+14.7	+3.2	+13.3	+45.1
1990	1,539,212	34,234	28,400	1,016	995	64,615	3,191	682	3,740	102,639	-68,405
% Change	-22.8	-22.8	+20.9	+30.6	+48.7	+45.2	+30.5	+33.7	+11.0	+35.5	+117.8
1995	1,145,450	25,476	31,049	1,236	1,211	78,740	3,882	784	4,107	121,009	-95,533
% Change	-42.6	-42.6	+32.2	+58.9	+81.0	+76.9	+58.8	+53.7	+21.9	+59.7	+204.2
2000	606,991	13,500	34,110	1,503	1,459	93,665	4,723	903	4,550	140,913	-127,413
% Change	-69.6	-69.6	+45.2	+93.2	+118.0	+110.5	+93.2	+77.1	+35.0	+86.0	+305.7

SUDAN

ELECTRICITY TARIFFS

1. NEC has made a reasonable effort to update its official schedule of electricity tariffs in accordance with marginal cost. A recent exercise was completed in November, 1982 and the results were submitted to the Ministry of Energy. However, the exercise reflected costs only one year ahead, the uncertainties in the basic assumptions were considerable, distribution costs were selected from individual investment items rather than the full development program, and economic costs were not taken into account. NEC did adjust the capital costs to take into account the November, 1982 devaluation but operational costs, including fuel costs, were not amended.

2. In view of the shortcomings in NEC's calculations and the fact that the BNG system and its underlying cost structure have changed considerably since the Bank's 1974 study, 1/ the mission attempted to re-estimate the structure of long-run marginal costs in the BNG, as seen from December, 1982. Such an attempt should, of course, proceed from an analysis of the long-run marginal cost of meeting demand with the least-cost development program. Unfortunately, a development program of this kind has not yet been identified for the BNG (see Chapter II); neither does a medium-term program exist in any agreed form. The mission therefore made use of the fragmentary information which is available -- notably NEC's immediate program of ongoing works and the study recently drafted by the consultants for the proposed Power IV Project (Sir Alexander Gibb and Partners) --in order to piece together something approaching a medium-term program of capital works. The result covers a five-year period from FY83 to FY87. Generation investment includes, principally: rehabilitation of existing sets and the installation of new diesel sets (4X10 MW) at Burri power station; additional gas turbines (2X15 MW) at Kilo X power station; the installation of three new units (40 MW each) at Roseires hydroelectric station and the heightening of the dam; and a new power station at Khartoum North, with initially 2X30 MW oil-fired steam units, followed later by 2X60 MW units. Transmission investment includes, principally: a 110 kV ring around Khartoum; a load dispatch center; and a second line from Roseires. Distribution investment was built up from NEC's simple master plan and short-term budget; since the data was not separable, it includes 33 kV and 11 kV as well as LV works proper. The results are in Table 12.1. All calculations use a discount rate of 12.5% and a standard conversion factor of 0.8 for local expenditures. Transmission and distribution losses (4% and 16% of generation respectively) have been included.

1/ See R. Turvey and D. Anderson, "Electricity Economics", Johns Hopkins University Press, 1977.

Table 12.1

Capacity Costs for the BNG
(LS per kW per year)

Item	Supply Level: Bulk (HV)	Supply Level: Distribution (LV)
Generation capital	262.0	299.4
Generation O&M	23.6	27.0
Sub-total generation	285.6	326.4
Transmission capital	106.3	121.5
Transmission O&M	12.3	14.1
Sub-total transmission	118.6	135.6
Distribution capital	-	60.2
Distribution O&M	-	11.7
Sub-total distribution	-	71.9
Grand total	404.2	533.9

Note: Distribution costs in the table include 33 kV and 11 kV works, which could not be separated from LV works.

3. The above figures are tentative and preliminary; they are not accurate representations of long-term marginal cost because they are short-term or at best medium-term in nature and even, in some cases, to a degree committed. All the cost figures should be revised when demand projections and the future investment program are firmer. The numbers, the analysis and the conclusions which follow are intended to indicate general results and rough orders of magnitude.

4. The timing of additions to generating capacity in the BNG appears to be determined mainly by the system's energy requirements during the dry season. More precisely, the months of March, April and May are the most critical from the energy standpoint; water availability is limited and irrigation requirements, which govern water releases at the Roseires dam, are at a minimum. Furthermore, energy demand is approaching its monthly maximum, which is reached in June. The system's power capability, on the other hand, is at a minimum during the summer; in the period June through September, the power output from Roseires is reduced substantially during the early part of the flood season, when the minimum reservoir level and the high downstream water level combine to reduce the head available for power generation. Consequently, with properly scheduled maintenance, the energy constraint normally can be expected to lead

the power constraint. The detailed computer simulations of the BNG system, carried out for the Power IV feasibility study, largely confirm that the critical period for capacity will arise during the months of March through May for the years 1984-5 to 1989-90. 1/ Generation capacity costs should, therefore, be attributed to this period. Transmission capacity costs should be attributed to June, when system demand reaches its maximum level, and distribution capacity costs to the time of peak demand on the local distribution system, which will vary across localities; it is assumed to occur in June in the Three Towns, to which the analysis below is related.

5. The seasonal component of NEC's published tariffs distinguishes between six "critical" months (March through August) and six "other" months (September through February). Given the existing data limitations, the distinction is acceptable in the light of para. 4, although some attention might be given to starting and finishing the critical season one month earlier.

6. Within each season, there are daily variations in demand but it was not possible to obtain from NEC any reliable daily load duration or load dispatch curves. The Bank's 1974 study identified two daily peak periods: 0700-1400 hrs and 1800-2100 hrs. At that time, the evening peak exceeded somewhat the daytime peak. Such data as could be made available to the mission suggested that the gap between the daytime and evening peaks might now be quite short and the daytime peak appears to exceed the evening peak in the hottest months (June through August), presumably due to the air conditioning load. No distinction seemed to be warranted in the 1974 study between Friday (the day of rest) and other days and no other information was available to the mission to review that position. NEC's published tariff defines "peak" hours as 0700-1400 hrs and 1800-2200 hrs, seven days a week. The mission has no basis for questioning the definition; however, a new analysis is required of the Friday load duration curve relative to other days and a careful review should be undertaken of the rationale for reducing or eliminating the afternoon "off-peak" hours (1400-1800 hrs).

7. To relate this information on the daily load pattern to the marginal cost of energy, it is necessary to calculate the mean expected value of energy costs during peak hours and off-peak hours in the

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1/ The results of the printouts are not always consistent with the hypothesis and in a few cases show the energy and power constraints coinciding in April, when Roseires power is at or near its maximum. The power limit at those times appears to stem from energy limitations and planned maintenance.

"critical" and other months, i.e. during four load-dispatch periods. The energy cost per kWh in any one period would be a weighted average of the incremental fuel costs of the various generating sets operating during that period, where the weights are the proportion of the hours in that period for which each type of plant will be running, but at less than capacity.

8. Such an exercise clearly could not be undertaken by the mission but the mission did conduct a rough and ready approximation to it for the period 1982-87. The results -which are essentially guesses- are interesting. Significant thermal generation will be required during peak and off-peak hours in the "critical" months but good use can be made of the relatively efficient steam units which are scheduled for Khartoum North and the new diesel units at Burri. During the remaining months, the need for thermal generation is much less (although it grows steadily over the period) and a proportionately greater use of the gas turbines at Kilo X is necessary; the fuel cost of the gas turbines is significantly higher per kWh than other plants. The net result is that peak energy costs and off-peak energy costs seem to be slightly lower in the critical months. However, the calculations underlying the results are very sensitive to small changes in the generation requirements at peak and off-peak in the non-critical months. For purposes of simplicity and since the data does not clearly indicate a different conclusion, the best judgement of the mission is that, for the present exercise, only two tariff periods are necessary to designate incremental energy costs: one energy cost per kWh can be taken for the peak hours in the critical and other months and the second (lower) energy cost can be taken for the off-peak hours in the other months, as shown in Table 12.2. All calculations use a discount factor of 12.5% and transmission and distribution losses are included

Table 12.2

Energy Costs for the BNG
(LS per kWh)

Item	Supply Level: Bulk (HV)	Supply Level: Distribution Level
Peak energy	0.0892	0.0996
Off-peak energy	0.0842	0.0940

(4% and 16% of generation respectively). Energy costs are based upon the average imported cost of petroleum products in 1982, with local transport from Port Sudan to Khartoum, as shown in Table 4.10.

9. The preceding estimates of capacity and energy costs for the BNG, assuming that capacity costs are all allocated to the six "critical" months, are summarised in Table 12.3 but conversion of those costs into

Table 12.3

Estimated Marginal Costs of Supply

	Capacity Cost (LS/kW/month)	Energy Cost (LS/kWh)	
		Peak	Off-peak
1. "Critical" Months			
LV Level	66.738	0.0996	0.0892
HV Level	57.262	0.0892	0.0842
2. "Other" Months			
LV Level	0	0.0996	0.0940
HV Level	0	0.0892	0.0842

Note: Capacity costs assume diversity factors of 0.75 and 0.85 at the LV and HV levels respectively.

a tariff based strictly on marginal costs requires additional assumptions. Table 12.4 sets out specimen results for the cases where seasonal metering is and is not permitted. 1/ In both cases, it is assumed that maximum demand metering would not be applied to LV consumers, so that all capacity costs are converted into kWh (proportional) charges for LV consumers, taking a load factor of 60%.

1/ In the latter case, capacity costs are spread over 12 months instead of 6.

Table 12.4

Possible Tariffs Based on Marginal Costs

	Capacity Charge (LS/kW/month)	Energy Charge (LS/kWh) Peak	Off-Peak
A. Seasonal Tariff			
1. "Critical" Months			
LV Supply	None	0.2520	0.2464
HV Supply	57.262	0.0892	0.0842
2. "Other" Months			
LV Supply	None	0.0996	0.0940
HV Supply	None	0.0892	0.0842
B. Non-Seasonal Tariff			
LV Supply	None	0.1758	0.1702
HV Supply	28.631	0.0892	0.0842

10. The results of the preceeding analysis may be compared with the new tariff which NEC is implementing in two steps. The first step was introduced on May 1, 1983; the second step is due to take effect on November 1, 1983. Table 12.4 suggests that the differences in system energy costs at different times of the day and in different months of the year may not be as great as implied by the differences in energy rates which appear in NEC's tariff for HV supply. It appears that, for the rest of the 1980s, the BNG system will increasingly require thermal generation on a year-round basis. At the same time, NEC should consider a seasonal maximum demand charge at a much higher level than the present maximum demand charge, which is not seasonally varied, and furthermore the charge should be based on metered and not estimated maximum demand. The HV tariff may, in other words, give incorrect signals. 1/ The point does not apply in quite the same way to the LV tariff; in that case, capacity costs must be provided for in the energy (kWh) rate, which does lead to a significant seasonal differential. The time-of-day differentials in NEC's LV tariff, however, could be excessive. Finally, NEC

1/ The power factor penalty clause must also be vigorously applied.

should again carefully consider the possibility of applying to LV consumers the principles of the seasonal tariffs which exist on paper.

11. Evidently, there is an urgent need for a careful analysis of the long-run marginal costs in the BNG and for the formulation of a new tariff which will reflect those costs more faithfully. USAID was considering financing such a study, which would cover the isolated systems as well as the BNG, but a decision seems to have been made to postpone the study indefinitely. Alternative ways of financing the study should be sought, so that it can proceed as soon as possible, and consideration should be given to including provision in the possible Power IV loan for the expected capital costs of metering an adequate seasonal and time-of-day tariff.

SUDAN

PRODUCTION OF ETHANOL FROM MOLASSES

1. Minimization of transport costs would favor the siting of an ethanol project at Kenana, which could supply most of the molasses required. Kenana could also offer good load-bearing conditions for the distillery. On the other hand, Kenana's heavy requirements for irrigation water pumping and its energy-intensive mill design imply that no surplus energy from bagasse is likely to be available for a distillery and energy requirements will have to be met from fuel oil. This is probably true of any possible location although, depending on the decisions taken on the rehabilitation program, there is a slight possibility that Sennar might be able to make surplus steam available to a distillery during the cane season. Initial calculations suggest that, in such a case, the trade-off between fuel oil savings and additional transport costs for molasses might be a relatively close one. Further considerations would then need to be taken into account, notably the value of foregone power supplies to the grid and the relative shares of molasses actually to be supplied by each factory. 1/

2. Tate and Lyle Technical Services (TLTS) will propose two alternative project designs, one with 'slops incineration' and one without. The former would eliminate distillery effluent and reduce fuel oil consumption but project complexity would be greater and capital costs would be increased by 80%. In the mission's view, effluent disposal into irrigation channels need pose no problem and the fuel savings are insufficient to offset the higher capital cost. It is therefore strongly recommended that the cheaper and simpler project design be preferred.

3. TLTS estimate the long-run export value of Sudanese molasses (f.o.b. Port Sudan) at about US$65 per mt in 1982 prices. The opportunity cost of molasses at factory gate, under such circumstances, must be close to or below zero. In all recent years, most molasses output has been dumped, creating a pollution problem, although the proportion exported has risen since contracts were signed which placed some of the onus for mill-to-port transport on the purchaser. The production and export of molasses are shown in the Table below.

1/ KSC is considering other processing possibilities for some of its molasses, such as liquid sugars.

	Molasses production	Exports
	--------('000 mt)--------	
1978-79	46.5	7.4
1979-80	84.0	11.5
1980-81	128.2	36.6
1981-82	132.0	58.4

Additional sales for domestic use are below 10,000 mtpa. It is understood that much of the success in raising exports has resulted from greater use of road transport. The transport costs, however, eliminate any financial return to the sugar industry (other than in years of abnormally high world molasses prices) beyond the benefit of disposal itself. Economic transport costs may be higher than financial costs in view of prevailing gasoil prices. If the efficiency of the railway system were to improve radically, it might be possible to reduce unit transport costs significantly, but such an improvement cannot be depended upon and backhaul capacity is likely to continue to be limited.

4. The TLTS draft report estimates financial rates of return for several alternative scenarios. Perhaps the most useful base for economic analysis is the case using the November 1982 exchange rate, a world gasoline price of US $385 per mt and no slops incineration, which leads to an estimated rate of return of 24%. The energy assessment mission tested the modification of some of the TLTS assumptions. An adjustment of the fuel oil price from a financial to an economic basis would still give a return of 20.8%. Reducing the assumed cost for the handling and transport of imported gasoline from LS 94 per mt to a more conservative LS 64 per mt would further reduce the return to 17.8%. In addition to the adjustments made above, the project would remain viable even with a fall of 15% in the gasoline price.

SUDAN

ECONOMIC ANALYSIS OF POWER PRODUCTION USING BAGASSE

Introduction

1. The following paragraphs review and analyze the future potential for energy self-sufficiency at each of the five sugar mills; tentative calculations are made concerning the amount of electricity generation which might take place, including export to the national grid. Data for the public sector are based upon the study by Tate and Lyle Technical Services (TLTS) and the findings of the Bank's mission which preappraised the sugar rehabilitation project in January, 1983; projections for KSC are mission estimates. Finally, some illustrative calculations are made on the economics of power generation from bagasse at the four government-owned mills. KSC could not be included in the economic analysis, as the mission did not have even rough data on the capital costs of bagasse-fired and oil-fired alternatives at the KSC mill.

Potential for Power Generation

2. It is assumed that: (a) the four mills in the public sector are rehabilitated, which will make it possible to achieve steady and well-managed operations at full production, thus ensuring that the mills are in balance for their primary energy requirements; (b) the ratio of fibre to cane will be reduced from 18% to 17% after rehabilitation; (c) power supplies from the NEC grid will be reliable; and (d) mill-white rather than refined sugar will be produced. Since, under these circumstances, bagasse availability should be more than sufficient to meet the needs for steam and power of each factory, the calculations determine the surplus bagasse, over and above the needs of the factories, which could be available for electricity generation to meet irrigation requirementS, or for export to the NEC grid.

3. At Guneid, the irrigation demand for electricity is 9.9 GWh during crop and 10.5 GWh out of crop, i.e. a total of 20.4 GWh. 1/ The current supply is from the NEC grid, which is unreliable and a cause of low cane production. Based upon full production, a bagasse surplus would exist, equivalent to 14.5 GWh. In order to burn all the surplus bagasse, an additional condensing turbo-alternator (4 MW) would be required, at a cost of US$3.8 million. Imports from NEC would still be required, amounting to 5.9 GWh. Alternatively, power could be generated from 3.3

1/ The in-crop season is from November to April and the out-of-crop season lasts from May to October.

MW of diesels at a capital cost of US$2.6 million or purchases from NEC could be continued to satisfy all needs.

4. Since the irrigation water at New Halfa flows by gravity, there is no irrigation demand for electric power and all power generation would be available for export. The potential bagasse surplus at full cane production is equivalent to 20.4 GWh, The power equipment needed fully to utilise the bagasse is similar to that at Guneid and the capital costs of the alternatives are therefore estimated to be US$3.8 million and US$2.6 million for steam and diesel generation respectively.

5. Sennar is well endowed with steam and power plant but there is no facility for producing condensing turbo-alternator power for the irrigation load, which is estimated at 22.7 GWh (9.8 GWh during crop and 12.9 GWh out of crop). The irrigation pumps are 56 km from the factory and power to them is supplied by NEC. At full production, the bagasse surplus is equivalent to 25.7 GWh, making Sennar able to supply power to NEC's grid during the crop season and potentially a net exporter of power overall. The cost of a bagasse-fired condensing turbo-alternator (6.5 MW) would be US$4.2 million (including transmission), compared with US$4.3 million to provide diesel generation (5.5 MW).

6. The Assalaya factory is similar to that at Sennar but the high irrigation pumping head leads to a much higher electricity requirement of 42.0 GWh (25.3 GWh during crop and 16.7 GWh out of crop). Supply is currently unreliable and met by NEC. Low cane production has also been caused by insufficient agricultural equipment. In effect, Assalaya has operated for only two trial crops and rehabilitation will be costly. If full cane production can be attained, the bagasse surplus would be equivalent to 24.0 GWh. Power supply could be secured with a condensing turbo-alternator of 6.5 MW at a cost of US$4.9 million; as with Sennar, no additional boiler would be required. However, given the high irrigation demands, it would still be necessary to purchase electricity from NEC's grid, mostly during the out-of-crop season. A diesel generator (9.9 MW) would cost US$7.1 million.

7. The Kenana factory generates most of its power needs from bagasse, supplemented by fuel oil, purchases from NEC's grid and diesel generation (see Table 14.1). Estimated irrigation demand at full production is 112.9 GWh (71.0 GWh in crop and 41.9 GWh out of crop). During crop, the availability of bagasse is likely to be more than sufficient to supply all power demands; there should also be the condensing capacity to supply up to 9.4 MW for export. However, excess bagasse availability is likely to permit the usage of only a small part of this capacity and fuel oil would be required to take full advantage of the spare power capability. Out of crop, all power would be generated from fuel oil, requiring about 30,000 mt to meet the needs of irrigation,

the factory and the township. 1/ Some 4 MW of capacity would be available for export, but fuel oil consumption would correspondingly increase. The power availability for export out of crop could be increased with the installation of extra condensing turbine capacity to utilise more fully the boiler capacity which is available out of crop. For example, a back-pressure turbo-alternator might be operated with the steam being condensed in the evaporator, which could be supplied with raw water.

The Economics of Power Generation

8. The annual power requirements at Guneid, Sennar and Assalaya are 20.4 GWh, 22.7 GWh and 42.0 GWh respectively. These annual requirements are shown for the six in-crop months of November-April and the six out-of-crop months of May-October in cols. (3) and (5) of Table 14.2. The average loads per month (in MW), during the in-crop and out-of-crop seasons, are shown in cols. (2) and (4) of Table 14.2 and are based on these energy requirements. The peak loads (in MW) are shown in col. (1).

9. Guneid, Sennar and Assalaya are all connected to the BNG. From the point of view of the BNG, the year can be divided into six months (March-August) which are critical, and the rest of the year (September-February) (see Annex 12). Hence, there are two "critical" months in the in-crop season and four "critical" months in the out-of-crop season. For power supply from the BNG, the marginal capacity cost is estimated at $44/kW/month during these "critical" months. Energy costs for supply from the BNG are US$0.065/kWh and US$0.069/kWh for off-peak and peak hours respectively. 2/

10. Three alternatives are considered. The first is to install diesel generators and achieve power self-sufficiency at Guneid, Sennar and Assalaya. This involves purchasing diesel plant and operating for twelve months a year using gasoil. The second is to install additional steam generating plant, using bagasse as a fuel. All available bagasse is burned during the crop season. Any excess power is exported; any power deficit is imported. The third alternative is to take all power supplies from the BNG. Given the inadequate data on peak demands at Guneid, Sennar and Assalaya, two cases are considered for alternative three. Case A bases the annual costs on the average load, in MW per month. Case B incorporates the actual peak loads of the schemes (taken from the TLTS study) and assumes that these peaks fall in the "critical" months.

1/ Irrigation requirements of 41.9 GWh plus other requirements of 13.9 GWh, making a total of 55.8 GWh at a conversion rate of 0.53 kg/kWh.

2/ These capacity and energy costs are from Annex 12, converting at the rate of LS1.3 = US$1.

11. The annual costs incurred in setting up and operating diesel generators and steam-based generating equipment are given in col. (2) of Table 14.3. The capital cost of col. (1) is annuitized using a 12.5% discount factor, a 20-year life for steam-based generators and a 30-year life for diesel generators. The non-fuel operating costs are in col. (3) and include annual maintenance, repairs and labor costs. Fuel costs for diesel generators are shown in col. (4), based on a gasoil utilization of 0.25 kg/kWh and a price of US$374/mt. 1/ Bagasse is assumed to be available at zero cost in the quantities described in paras 3-6. Power exports and power imports are valued at the long-run marginal cost (LRMC) of the BNG, accounting for MW and kWh separately. The values of these exports or imports are in cols. (5) and (6) of Table 14.3. Col. (7) of Attachment 3 shows the total annual costs of the bagasse and diesel alternatives. These totals are transcribed to cols. (7) and (8) of Table 14.2, where they can be compared with the annual costs of the third alternative, which assumes all power is imported from the BNG, in col. (8) (case A) and col. (9) (case B).

12. According to Table 14.2, generation using bagasse appears to be the least-cost alternative at all three mills. Diesel generation appears to be the highest-cost alternative, even though power is valued at LRMC rather than considering the lower tariff currently charged by NEC.

13. At New Halfa, which is connected to the Eastern grid, all surplus bagasse can be used to generate power for export, amounting to 20.4 GWh. Since the power equipment required to do this is the same as at Guneid, annual capital and non-fuel operating costs would be US$703,171 (see Attachment 3) or US$0.0345/kWh. Energy costs at peak and off-peak on the Eastern grid would almost certainly be higher. The Eastern grid faces two future options: connection to the BNG or the installation of new thermal plant. The latter is the most likely for the foreseeable future. In either case, the marginal cost of energy is likely to be represented by thermal energy at a level equal to or greater than the marginal energy cost of the BNG (US$0.065 and US$0.069 at off-peak and peak respectively).

1/ From Chapter 4, the c.i.f. value of gasoil in Port Sudan is US$345/mt (LS 448/mt). The cost of unloading and handling in Port Sudan is US$3/mt (LS 4/mt). Marketing, distribution and transportation to Khartoum are estimated at US$52/mt (LS 67/mt). In the case of the sugar factories, bulk supplies would be used and the distance to Port Sudan is shorter so that the cost of marketing, distribution and transportation would be less, say one-half the figure for retail delivery in Khartoum or US$26/mt. A representative price for gasoil of US$374/mt delivered to the sugar factories is therefore taken. The assumed fuel consumption of 0.25 kg/kWh may be conservative. Part-load operation in practice could increase the figure to 0.30 kg/kWh. Also, gas turbines using gasoil are technically feasible but capital and operating costs would be higher.

Table 14.1

Kenana Sugar Company
Electricity Generation and Consumption, 1981-82

	Generation					Consumption				
	Condensing Sets	Back Pressure Sets	Diesel	Total	Import	Export	Factory	Irrigation	Train	Total
1981 Sept.	3853	-	17	3870	2819	1877	873	4379	856	6108
Oct.	2555	-	70	2626	4472		951	5049	1098	7098
Nov.	5307	1909	9	7225	2085		2583	5941	786	9310
Dec.	3630	7110	2	10742	1557		5095	6027	680	11802
1982 Jan.	2272	9798	2	12072	1656		6318	6552	858	13728
Feb.	1631	10720	3	12354	1637		6957	6314	720	13991
Mar.	2537	12227	3	14767	2084		7960	7823	1068	16851
Apr.	5369	10637	5	16011	510	114	7132	8094	1181	16407
May	7043	6499	102	13644	82		4812	7794	1120	13726
June	10185	-	-	10185	167		1263	9390	1202	11855
July	9917	-	-	9917	2516	147	1466	9746	1074	12286
Aug.	8705	-	-	8705	219	173	1508	6288	955	8751
12 month total (Sept.-Aug.)	63,004	58,900	213	122119	19804	2311	46918	83397	11598	141,913
6 month total (Nov.-April)	20,746	52,399	24	73172	9529	114	36045	89338	5293	82,089

Note: Due to discrepancies in the original data, total generation plus imports minus exports does not equal consumption for September and December, 1981 and for January and June, 1982. In consequence, the 12 month and 6 month totals also do not add across.

Table 14.2

	Nov.-April			May-Oct.		Annual Costs (US$)			
	Peak load (MW)	Average load 1/ (MW/mo.)	Energy Reqts. for 6 mos. (MWh)	Average load 2/ (MW/mo.)	Energy Reqts. for 6 mos. (MWh)	Steam gen. (bagasse and furnace oil) 3/	Diesel generation 4/	Grid Supply Case A 5/	Grid Supply Case B 6/
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Guneid	3.0	2.2	9.9	2.5	10.5	1,428,546	2,374,295	1,990,851	2,143,996
Sennar	4.9	2.1	9.8	3.1	12.9	1,588,248	2,838,091	2,246,782	2,804,553
ssalaya	7.6	5.5	25.3	4.0	16.7	3,886,118	5,101,201	3,995,000	4,813,400

1/ Based on 190 days.
2/ Based on 175 days.
3/ Assuming a 20-year life for steam generating equipment.
4/ Assuming a 30-year life for diesel generators.
5/ Using the peak energy charge for 11 hours a day and the off-peak energy charge for 13-hours a day (see Chapter 4).
6/ In addition to 5/, assuming the peak load of col. (1) occurs during the "critical" months of March to August.

Table 14.3

(All Figures in US$)

	Net Capital Cost	Annuitized Capital Cost	Annual non-fuel Operating Costs	Annual Fuel Costs	Exports to (-) or Imports from (+) BNG In Crop	Out of Crop	Total Annual Costs
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Steam based generators (Using bagasse and furnace oil)							
Guneid	3,821,000	527,743	175,428	0	-501,033	1,226,408	1,428,546
Sennar	4,153,100	573,612	185,391	0	-893,233	1,722,478	1,588,248
Assalaya	4,853,300	670,321	191,197	0	570,883	2,453,717	3,886,518
Diesel generators (using gasoil)							
Guneid	2,643,800	340,462	140,112	1,893,721	0	0	2,374,295
Sennar	4,262,800	548,953	173,482	2,115,656	0	0	2,838,091
Assalaya	7,108,100	915,363	258,838	3,927,000	0	0	5,101,201

ENERGY SECTOR FUNCTIONS AND RESPONSIBILITIES BY AGENCY

ANNEX 15

1. STATUTORY FUNCTIONS

Energy Sector Functions	MEM	NEC	GPC	GMRD	NEA	OIL CO's	NCR	OTHERS
National EGY Policy	FA				PR			
Regional EGY Policy	FA				PR			
Sub-sectoral Strategy for Conservation	FA	PR	PR		P		P	P
Allocation of Funds for Import of Hydro-carbon	PR		PR		M			FA
Sub-sectoral Budget and Planning	FA	PR	PR					
Allocation of EGY to Sectors	FA	P	P		PR			
Refining	M		P		M	E		
Transportation and Distribution Hydro-carbon	M		E		M	E		E
International and Domestic Marketing	M		E		M	E		
Power Generation and Transmission	M	E			M			E
Power Distribution	M	E			M			E
Monitoring Performance	M	P	P	M				
Giving Concession	FA			PR				
Exploration and Production	M		E	M		E		
Renewable Energy	M				M		E	E
Controlling Performance	E	P	P	M		E		
Inter-sectoral Coordination	E	P	P		P			
Energy Research	M						E	

2. ACTUAL PERFORMANCE 1/

Energy Sector Functions	MEM	NEC	GPC	GMRD	NEA	OIL CO's	NCR	OTHERS
National EGY Policy								
Regional EGY Policy								
Sub-sectoral Strategy for Conservation								
Allocation of Funds for Import of Hydro-carbon							E/FA	
Sub-sectoral Budget and Planning		PR	PR				FA	
Allocation of EGY to Sectors		E	E					
Refining			P		M	E		
Transportation and Distribution Hydro-carbon			E		M	E		
International and Domestic Marketing			E			E		
Power Generation and Transmission		E			M		E	
Power Distribution		E			M			
Monitoring Performance				M				
Giving Concession	FA			PR				
Exploration and Production			M	M	M	E		
Renewable Energy					M		E	
Controlling Performance					M		E	
Inter-sectoral Coordination								
Energy Research	M						E	

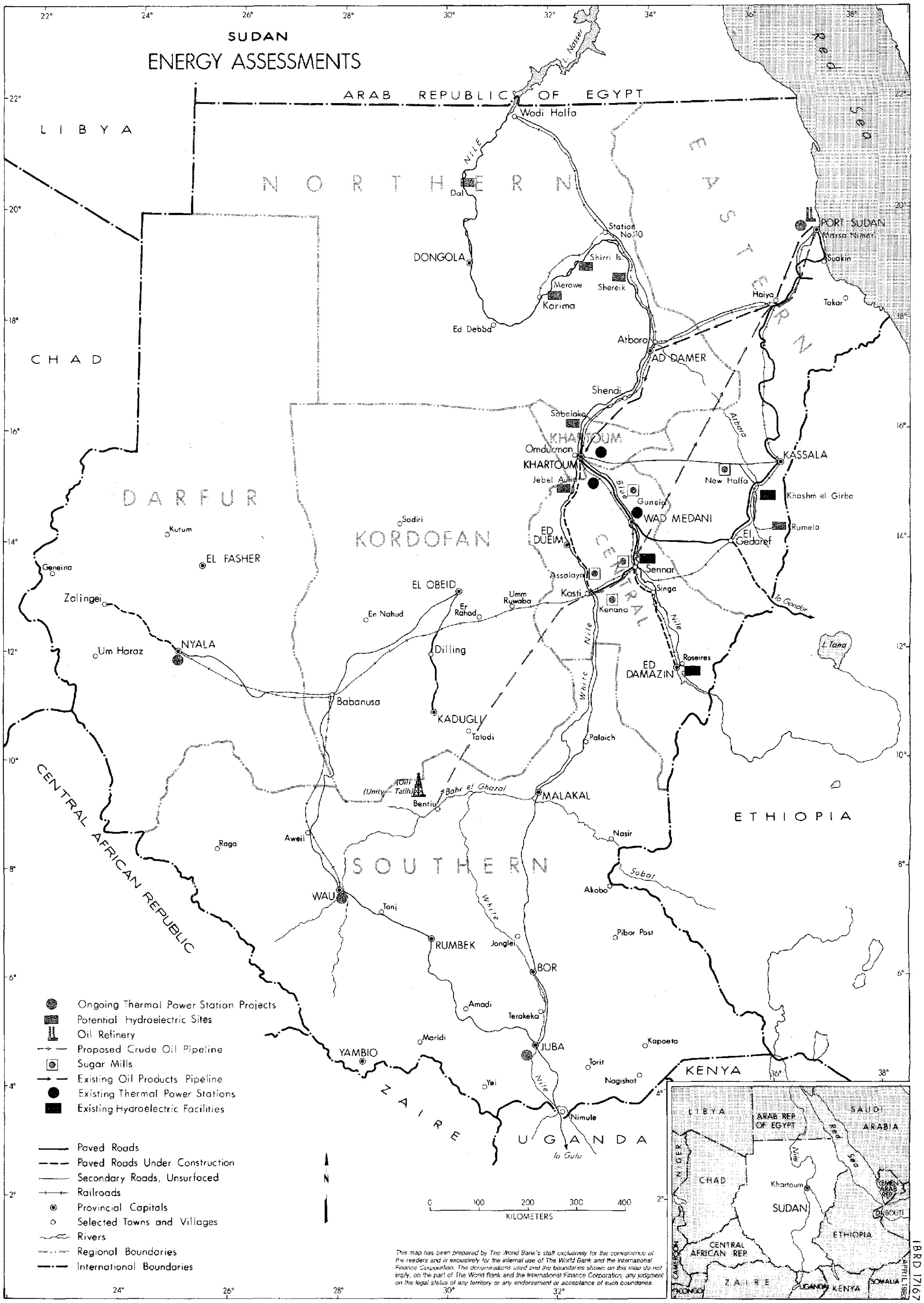
3. PERFORMANCE GAP

Energy Sector Functions	MEM	NEC	GPC	GMRD	NEA	OIL CO's	NCR	OTHERS
National EGY Policy	X				X			
Regional EGY Policy	X				X			
Sub-sectoral Strategy for Conservation	X	X	X		X		X	X
Allocation of Funds for Import of Hydro-carbon	X		X		X			Y
Sub-sectoral Budget and Planning	X	O	O					Y
Allocation of EGY to Sectors	X	Y	Y		X			
Refining	X		O		O	O		
Transportation and Distribution Hydro-carbon	X		O		O	O		Y
International and Domestic Marketing	X		O		O	O		
Power Generation and Transmission	X	O			O			O
Power Distribution	X	O			O			X
Monitoring Performance	X	X	X	O				
Giving Concession	O			O				
Exploration and Production	X		X	O		O		
Renewable Energy	X				O		O	X
Controlling Performance	X	X	X	O		O		
Inter-sectoral Coordination	X	X	X		X			
Energy Research	O						O	

E = Executes
PR = Proposes Reccomendation
P = Participates to provide input
FA = Final Approval
M = Monitors

1/ Information presented on this chart does not include personal and individual performance. It represents the the performance of the organization as an institution in a systematic and routine manner.

O = Functioning according to statute
Y = Functioning more than statute
X = Not functioning according to statute


SUDAN
ENERGY ASSESSMENTS
ARAB REPUBLIC OF EGYPT
LIBYA
CHAD
NORTHERN
EASTERN
DARFUR
KORDOFAN
KHARTOUM
CENTRAL
SOUTHERN
CENTRAL AFRICAN REPUBLIC
ZAIRE
UGANDA
KENYA
ETHIOPIA
Red Sea
L. Nasser
L. Tana
Nile
Blue Nile
White Nile
Atbara
Bahr el Ghazal
Sobat
Wadi Halfa
Dal
DONGOLA
Station No. 10
Shirri Is.
Merowe
Shereik
Karima
Ed Debba
PORT SUDAN
Marsa Nimeri
Suakin
Haiya
Tokar
Atbara
AD DAMER
Shendi
Sabaloka
Omdurman
KHARTOUM
Jebel Aulia
New Halfa
KASSALA
Khashm el Girba
Guneid
WAD MEDANI
Rumela
El Gedaref
ED DUEIM
Sennar
Assalaya
Kosti
Singa
Kenana
to Gondar
Kutum
EL FASHER
Geneina
Zalingei
NYALA
Um Haraz
Sodiri
EL OBEID
En Nahud
Umm Ruwaba
Er Rahad
Dilling
Babanusa
KADUGLI
Talodi
ED DAMAZIN
Roseires
Paloich
(Unity) (Unity Talih)
Bentiu
MALAKAL
Nasir
Aweil
Raga
WAU
Tonj
RUMBEK
Jonglei
Akobo
Pibor Post
BOR
Amadi
Terakeka
Maridi
YAMBIO
JUBA
Kapoeta
Torit
Nagishot
Yei
Nimule
to Gulu
Ongoing Thermal Power Station Projects
Potential Hydroelectric Sites
Oil Refinery
Proposed Crude Oil Pipeline
Sugar Mills
Existing Oil Products Pipeline
Existing Thermal Power Stations
Existing Hydroelectric Facilities
Paved Roads
Paved Roads Under Construction
Secondary Roads, Unsurfaced
Railroads
Provincial Capitals
Selected Towns and Villages
Rivers
Regional Boundaries
International Boundaries
0 100 200 300 400
KILOMETERS
N
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LIBYA
ARAB REP. OF EGYPT
SAUDI ARABIA
NIGER
CHAD
Khartoum
SUDAN
YEMEN ARAB REP.
DJIBOUTI
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CENTRAL AFRICAN REP.
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KENYA
SOMALIA
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