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National Energy Administration
Ministry of Energy and Mining

Khartoum
Sudan

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FOREWORD

This Sudan National Energy Assessment report reflects over two years of intensive work since the establishment of the National Energy Administration (NEA) in 1980. The Assessment, of which this report is but one part, results from the efforts of NEA staff and a team of long and short term energy advisors, both Sudanese and non-Sudanese who have worked as part of the Sudan Energy Policy and Planning Project, supported by the Government of Sudan and funded by the United States Agency for International Development (USAID). This Project, which also included four major end-use sectoral committees, commenced in the Ministry of Energy and Mining in early 1981. The Project at various times has involved over forty NEA staff, with a wide variety of backgrounds, under direction of the Project Senior Counterpart, Sayed Ismail El-Gizouli, whose untiring efforts guaranteed much of the success of this Project. They were also aided by scores of experts and staff from many Sudanese institutions, agencies and companies.

Sudan faces a number of difficulties in meeting its energy requirements and solving its many energy problems during the next several years. It is hoped that this Assessment Report, with its technical annexes and special appendices, will help place Sudan's energy situation within a clear, definable context that will enable interested and responsible Sudanese and non-Sudanese to understand Sudan's current energy situation and, consequently, to affect positively its energy future.

We in the Ministry of Energy and Mining, look forward to the next stage of this Project, which will continue to be supported by the Government of Sudan and the USAID (as well as other interested parties), in analyzing and more clearly defining Sudan's energy options for development. We hope that this Assessment will be continually updated and that the information contained herein will be improved and put to ever-better uses.

KHARTOUM
September, 1982

Mohammed El-Amin Mukhtar
Undersecretary of Energy
and Mining

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Many people, not all of whom can be mentioned in this short space, have assisted the NEA and the Sudan Energy Policy and Planning Project during the past eighteen months. Several individuals, however, deserve particular mention due to their extensive involvement with the Project. H.E. Dr. Sharif El-Touhami, Minister of Energy and Mining, has been continually supportive of the efforts of the NEA and the Project Team. Without Dr. Sharif's unceasing interest, much of the progress of the Project would have been impossible. H.E. Sayed Yousif Suleiman, State Minister for Energy and Mining, has given the NEA valuable assistance during the course of the Project. Special thanks must also be extended to Dr. Omer El-Sheikh Omer, Director General of the General Petroleum Corporation(GPC), Dr. El-Fadl El-Jack, Deputy Director of the GPC and their staff as well as to Sayed Mohammed Nasr Abu Bakr, General Manager of the National Electricity Corporation(NEC) and his staff. Without their support, this report and the overall efforts of the Project would have been impossible. Sayed Kamal Badi, Director of the Forestry Administration, Ministry of Agriculture and Irrigation, Sayed Mohammed Hanafi Obeid, Head of the Inventory Section, Forestry Administration and all the Forestry Administration staff provided invaluable assistance in drawing up current forestry resource estimates. Sayed Omer El-Tay, Director General of the Statistics Department and numerous Department researchers, enumerators and staff rendered invaluable support to the Project through their work on household surveys, population and demographic analysis, and survey methodology.

Special thanks must also be extended to the members of the four NEA sectoral committees. We would like particularly to express our appreciation to the chairmen of the four committees for their untiring efforts: Eng. Mustafa Abdelrahim, Secretary of the Sudanese Industries Association; Eng. Abbas Hidayatallah, Special Advisor to the Minister of Agriculture and Irrigation; Dr. Yahia Hassan Hamid, Faculty of Engineering, University of Khartoum and the National Council for Research; Eng. Babiker Mohammed Babiker, Director of the Energy Research Institute (ERI); and Dr. Dafalla Bedawi, University of Khartoum. A list of all sectoral committee members and participants is appended to this report.

Thanks are also extended to Eng. El-Sir El-Khatim Mohammed Salih, Special Advisor to the Minister of Energy and Mining (formerly Deputy General Manager of the Public Electricity and Water Corporation), Sayed El-Hadi Ibrahim Hassan (White Nile Petroleum Company), Eng. Mubarak Omer Adam (GPC), Eng. Hashim Mu'tassim (NEC), Sayed Faisal Yahia (GPC), Sayed Hassan Mustafa (GPC), Eng. Abdelbagi Abdalla (GPC), Sayed El-Zein Hassan (Sugar Corporation), Dr. John Gindy (NEC), Sayed Mohammed El-Amin Ahmed (Forestry Administration), Sayed El-Amin Ahmed and Sayed Kamal Hassan Ali (Survey Department), Sayed Mohammed Said Ali (former Special Advisor to the Minister for Industry), many individuals from the private sector and numerous managers, engineers, accountants and workers from both the private and public sectors. During the course of this Assessment, all these people have given much of their time and energy to assist the NEA and Project staff draw up Sudan's first integrated national energy assessment.

GLOSSARY

1. PETROLEUM FUELS:
   In Sudan, people use terms for petroleum fuels that differ slightly from their usage in Western Europe or the U.S. The following provides brief definition, of each:

   a. butagas(or butagaz) - LPG (Liquified Petroleum Gas); i.e., refinery gas.
   b. benzene - Higher distillate, fraction from refining column. Port Sudan Refinery only produces regular benzene (i.e., gasoline) while all premium or "super" benzine is imported.
   c. kerosene - Kerosene refined in Port Sudan and used as a blend stock with residual oil from Port Sudan Refinery.
   d. kero-jet - higher fraction, distillate from refinery; Jet A-1. Both refined in Port Sudan and imported.
   e. gasoil - Middle distillate (called "diesel" in USA and Europe). Refined at Port Sudan and also imported.
   f. diesel - "Light fuel oil" in USA, and Western Europe. Is a mixture of gasoil (approximately 70%) and residual (furnace, see g. below, approximately 30%), which is used domestically by some power generators, Sudan Railways and the River Transport Corpoation. All produced at Port Sudan Refinery.
   g. furnace - Fuel oil, 1500"(a blend of long residue and kerosene), used extensively in industry and rails. All furnace produced at Port Sudan Refinery; none presently imported.
   h. residual - Both long and short residual fuel oil from refinery. Long residue, 4200", blended with kerosene to yield "short" residual, 3500" or "Bunkers" sold to Sudan Shipping Lines and other ships in Port Sudan as well as exported.

2. WEIGHTS AND MEASURES:
   a. feddan - approximately 0.42 hectares (ha) or 0.0042 km^2 or 1.04 acres.
   b. tonne(or ton) - always a metric ton (MT), i.e. 1,000 kg
   c. kantar(or qantar) - equals 143 kilograms (kg) of seed cotton or 50 kg cotton lint.
   d. rottle(or rutl) - 0.455 kg
   e. gallon - An "imperial gallon" (i.e. British measure), approximately 4.54 liters or 1.2 gallons U.S.
   f. tonne-kilometer (ton-km) - a transport measure: equals one tonne of weight carried one kilometer distance.
   g. passenger-kilometers (pass-km) - a transport measure: equals one passenger carried one kilometer.

3. CURRENCY/EXCHANGE RATES:
   a. LS - Sudanese Pound = 100 piasters (pt) or 1,000 milliemes (/mms)
   b. $ - Always refers to US dollars
   c. Currently (July 1, 1982) one pound Sudanese (LS) is equivalent to $1.11 at the "official" rate (prevailing at banks, hotels, etc.) while the "unofficial" (parallel, "free-market" but legal, through licensed exchange dealers) rate has varied over the previous three months from $1.000 = LS $1.130 to LS $1.420.

4. ENERGY CONVERSIONS

a. TOE - Tonnes of oil equivalent. A means of comparing the energy values of different energy sources (1 TOE = 41.8 x 10^9 Joules).

b.

Energy Source	TOE/MT
Benzine/Avgas	1.05
LPG	1.11
Kero/Jet	1.04
Gasoil	1.04
Diesel	1.02
Furnace Oil	0.96
Wood*	0.43
Charcoal*	0.72
Agri-Residues (households)	0.32
Agri-Residues (industry, i.e. bagasse)	0.20
Animal Wastes	0.25
Vegetable Oils	1.00
Electricity	86.12/Gwh

*For purposes of this assessment it is assumed that, under conditions prevailing in much of Sudan, one metric ton of dry fuelwood is equivalent to $3m^3$ of growing stock and that it requires 6 MT of wood to yield 1 MT of charcoal. Therefore, the growing stock equivalent of 1 MT of charcoal is $18m^3$.

CHAPTER I

INTRODUCTION

Since 1973 Sudan, like most developing countries, has faced a growing "energy crisis." The impact of the crisis varies by sector and type of energy. Most apparent to farmers are the shortages of essential petroleum fuels that affect their irrigation, their land preparation or the transport of their products to markets. Most apparent to many industrialists are seasonal shortages of power supplies to their industries. Housewives feel the effects of Sudan's energy crisis in the unavailability of kerosene to light their homes, the rapidly increasing prices of charcoal (a ten-fold increase in charcoal prices since 1976) or in the distance they must travel each day to collect firewood for cooking their families' food. In other words everyone is affected by growing energy problems, and these problems are very real. Project surveys show ever-larger numbers of farmers who are forced to leave the land because they are unable to irrigate their crops--gasoil is either too scarce or too expensive. Joint household surveys conducted by the NEA and the National Statistics Department show that growing numbers of families cannot obtain petroleum-derived lighting fuels nor can they afford increasingly expensive charcoal and are turning to vegetable oils to secure some household lighting. In densely populated rural and urban areas, the bulk of an increasing number of households' cooking fuels are obtained from animal wastes and crop residues. Industries, particularly in the public sector, are forced to close down their operations for months at a time due to often continuous interruptions of power. Crops may rot in the fields for lack of available transport due to shortages of petroleum fuels.

The causes of these problems are manifold. They stem in large part from Sudan's general economic problems. Bank of Sudan foreign exchange officials estimate that, until recent changes discussed later in this report, they spent as much as 80% of their time seeking finance (trying to open letters of credit) for petroleum imports. According to recent data, it appears that this year, for the first time, Sudan's total petroleum import bill may exceed total earnings from all Sudanese exports. Delays in expanding power generation capacity, largely due to lack of finance, have had dramatic effects on the performance of the industrial sector. Increasing demand for petroleum fuels for transport has meant a decrease in the availability of kerosene and its petroleum substitutes for Sudanese households. Rapid urbanization has increased the demand for charcoal for commercial restaurants and for household cooking while expansion of land under cultivation (particularly in the "mechanized rainfed" areas) has placed more land under cultivation and taken more land out of forestry. Lack of integrated land use planning and management have exacerbated this problem, forcing the productive forestry areas further and further from Sudan's major centers of charcoal demand. The rapid escalation of petroleum fuels prices has put further pressure on prices for charcoal and fuelwood (which must be transported long distances, mainly by road, to urban areas of high demand).

There has been a growing awareness that this crisis cannot properly be addressed without developing a clear, coherent picture of Sudan's energy situation. Thus, the Ministry of Energy and Mining (MEM) was established in 1977 for the explicit purpose of coordinating the various energy-related functions of the Government of the Sudan. During the course of the next five years, various autonomous agencies

such as the General Petroleum Corporation (which had evolved out of a department within the Ministry of Industry) and the National Electricity Corporation (which began as a private utility company and evolved into an autonomous public water and electricity corporation) were incorporated into the Ministry of Energy and Mining. The National Energy Administration (NEA) was established by Presidential Decree in 1980 with a mandate for monitoring energy activities in the nation, collecting energy resource and end-use data, and setting the agenda for national energy planning.

The senior staff of the NEA were drawn from various ministries and agencies including the GPC, NEC, the Ministries of Agriculture, Industry, and Commerce and Supply. USAID, at the request of H.E. Dr. Sharif El-Touhami (Minister of Energy and Mining), designed and agreed to fund a project to work within the Ministry, and more specifically within the NEA, to realize several objectives. These included:

- To assist the NEA and the Government of the Sudan in drawing up an extensive energy data base that would quantify the amounts of energy supplied and consumed in Sudan by detailing the origin and supply of energy to all primary consumers.
- To examine possible alternatives to current energy supplies.
- To use the above process to assist the NEA in its role as an information, monitoring and policy analysis arm of the MEM.
- To train Sudanese staff in energy data collection and analysis in all major supply and end-use sectors.

The USAID-supported Sudan Energy Policy and Planning Project came into being in January, 1981. The Project was designed to work closely with other MEM agencies as well as all Sudanese and foreign (e.g., official bilateral and multilateral) agencies engaged in energy monitoring and planning. Two long-term expatriate staff were assigned to the office of the Director General of the NEA to work closely with the NEA in its day-to-day tasks as well to work on the National Energy Assessment. A Sudanese Project Counterpart was assigned to act as the liaison between Project and NEA staff and to assist Project staff in carrying out the tasks of the Assessment.

Because "energy" is an input into nearly every economic activity, NEA and expatriate Project staff[1] worked (and continue to work) closely with a wide spectrum of individuals, agencies and ministries in Sudan. Within a month after the start-up of the Project, four "major" energy sector committees were established: Transport, Households, Industry and Agriculture. The Minister sought the active participation of individuals with a variety of interests and backgrounds for each of these committees. Thus, the Transport Committee was formed with members from the National Truck Owners Association, the Khartoum Union of Taxi Drivers, the General Petroleum Corporation, private oil distribution companies, and the University of Khartoum, to name but a few organizations involved. The Agricultural

[1]Henceforth, the terms "NEA staff" and Project staff" are used interchangeably, with the differentiation of local and expatriate.

Committee drew members of the Gezira Farmers Union, the Ministry of Irrigation, the Ministry of Agriculture, the Mechanized Farming Corporation, private farmers, members of various faculties from the University of Khartoum, and the Forestry Department, as well as other organizations. The Industrial Committee was composed of members from the private business community, various public industrial corporations, the Sudanese Industries Association, the National Electricity Corporation and so on. The Households Committee drew its members from the Desertification Control Encroachment and Rehabilitation Program, various research institutes associated with the University of Khartoum and various ministries, private individuals and staff from the Land Use Department, Department of Soil Conservation and numerous other agencies. The names of the individuals who participated on these committees are appended to this report.

As can be seen, the Minister and NEA sought to involve as many key individuals from concerned bodies as possible in an effort, on the one hand, to obtain sound, well-based information on energy supply and use in the country and, on the other hand, to involve these individuals and their agencies in discussions of major energy issues facing the Sudan. These committees met regularly for over a year and produced lengthy, well-researched reports on such specific issues as butagaz (LPG) distribution in the country, and energy requirements for irrigated agriculture along the Nile. Committee members brought a wealth of experience and information to their committees and assisted the NEA in laying the foundation for Sudan's first national energy assessment.

Project staff interacted extensively with individuals from other ministries and agencies. The most extensive association has taken place with the staff of the GPC and the NEC(until May, 1982, the Public Electricity and Water Corporation), as these are the government bodies most directly concerned in the energy sector. Extensive work with the private petroleum distribution companies has been an important factor in the NEA's ability to obtain detailed petroleum sector information, particularly concerning distribution at the micro-level. In their work on energy use in the industrial sector, NEA and Project staff have worked with the Ministry of Industry, over 70 private and public companies and corporations, the Ministry of Finance and Economic Planning, Statistics Department staff, and many others. Ministry of Transport staff and the staff of Sudan Railways Corporation and the River Transport Corporation, various private companies and owners, and many others have assisted in obtaining detailed transport sector data. NEA staff have worked closely with members of the University of Khartoum (particularly the Departments of Geography, and Sociology) and several of its research institutes, (Institute of Environmental Studies and Institute of Development Studies Research) as well as with many staff from the Statistics Department (Census Bureau, Manpower Department, etc.) in drawing up the methodology for and conducting household surveys and in preparing energy estimates. The NEA has worked closely with numerous members of the National Council for Research and the Faculty of Engineering, University of Khartoum, as well as with several members of the private business community, in drawing up estimates for renewable energy development potential in the country.

In addition, Project staff have exchanged much useful information with various embassies, bilateral and multilateral donor and assistance programs such the UNDP/IBRD Planning Assistance and Training Project(Ministry of Finance and Economic Planning), UNICEF, UNHCR, FAO, UNDP, the World Bank, Care-Sudan, USAID, Dutch Aid, Norwegian Church Aid, the World Bank, the IMF, British ODA, Sir Alexander Gibbs and Merz and McLellan (consultants to the NEC), and many other organizations involved in Sudan's energy development.

The NEA has called upon Sudanese short-term consultants to examine such issues as laws and regulations governing the importation of energy-intensive consumer items, population projections to the year 2,000, forestry inventory estimates, and the effects of unplanned land use on debris accumulation resulting from water run-off into the Roseires Reservoir. Also, expatriate short-term consultants helped design a short-term reliability program for the National Electricity Corporation, worked with the GPC on petroleum distribution and allocation issues, and performed many Assessment tasks. Consultants' reports have already been published.

This Sudan National Energy Assessment Report, which pulls together much of the work of the first phase of the Project, is comprised of three major parts. The first is an Executive Summary intended to provide the reader with a succinct view of Sudan's energy picture and prospects for the future as well as of major issues and options facing Sudan. The second (this volume) is a General Report which analyzes the areas of supply and demand and major energy issues in more detail. Extensive examinations of each of the major energy use and supply sectors and of Sudan's current economic position, with careful attention to possible developments in the country's various economic sectors and sub-sectors economies, is intended to provide Sudanese leaders and policy makers with a framework of what energy futures for Sudan are possible and how they may be affected or achieved. Finally, the third part of the Assessment Report consists of the many appendices mentioned above. The first of these, "Base Year (1980) Supply Demand Balances", appears as Annex I to the main report. It is this technical annex which provides the general methodology and assumptions utilized in carrying out this assessment. The other supply-demand sectoral annexes (e.g., Transport, Households, Forestry/Woodfuels, etc.) provide the reader with specialized information on various topics examined during the course of this Project. Finally, several reports on industry, power and petroleum distribution, presented during the course of this Project are referenced as annexes.

It is the objective of the writers of this report to provide the reader with extensive data and initial analysis of that data, with clearly stated assumptions, in order to promote useful dialogue on critical energy issues facing Sudan. Energy and economic projections should not be viewed as "predictive." Rather they are planning tools intended to provide the reader with a framework by which to further analyze options available for altering the country's energy and economic growth paths.

CHAPTER II

ECONOMIC FRAMEWORK

Background

Sudan, heralded as "the future breadbasket of the Middle East," is blessed with many natural resources and great potential -- yet today Sudan has one of the lowest per capita incomes in the world; is dependent on the exports of one crop, cotton, for the bulk of its hard currency revenues; and is currently saddled with one of the largest per capita debts in the world (an estimated total debt above $7 billion). Prospects for servicing Sudan's external debt through increasing exports of primary agricultural commodities are not bright. Infrastructure is limited, fragile and overtaxed. The country continues to lose many of its most hardworking, skilled and aggressive workers to oil-rich neighboring countries offering improved job opportunities.

Sudan embarked upon an ambitious development program in the early 1970's. New schemes in the agricultural and industrial sectors were developed without corresponding improvement in the country's infrastructure. Railway performance decreased at a time of ever-greater transport demands. Road construction, while extensive, could not keep pace with the needs of decentralized development. Power sector development lagged behind the demands of such new pumping schemes as the Rahad, of the many new oil mills, of spinning and weaving plants designed to decrease Sudan's dependence on foreign processing of the country's raw materials, and other uses. Areas under cultivation expanded but production in existing schemes fell. By 1979 it had become clear that the country's economy was in great difficulty.

Petroleum import costs had reached over half the foreign exchange revenues earned from exports while accounting for over 30% of all imports. Power supplies to key industrial sectors had become increasingly unreliable, seriously undermining Sudan's industrial development strategy. Results from a number of large, expensive agro-industrial projects had been disappointing. External debt had increased to worrisome levels. At this point, the Government requested IMF assistance and began discussing consolidation of its external commercial bank debt.

Since 1979, the situation has deteriorated further. Despite recent relative price stability the oil import bill has more than doubled since 1979. Moreover, the next two agricultural seasons were disastrous for the country's export position. Cotton production fell in the 1980/81 harvest season to less than half the levels of the early 1970's. While the mechanized rainfed agriculture sector continued to perform relatively well, the public irrigated (and to a lesser extent, the private irrigated) sector was plagued with a host of problems, both structural and institutional. Since then, although production has turned around, world prices of almost all agricultural commodities (including cotton) have collapsed. External debt has continued to rise and, with record world interest rates, debt servicing payments have become a major foreign exchange drain. Estimated 1981 debt service payments and oil import costs together equal approximately 125% of the country's total export earnings. Even after deferring an interest payment and gaining substantial quantities of oil on concessional terms, the country is projected to be even worse off for 1982.

The Trade Balance

The Sudanese economy is now in an acute foreign exchange crisis, with a balance of trade deficit in 1981 of approximately $700 million. The principal exports are cotton, groundnuts, dura and livestock. The major imports are petroleum, sugar, machines and equipment, chemicals and spare parts.

Balance of Trade - 1980/81

Imports	Value in LS x 10^3	Exports	Value in LS x 10^3
Petroleum Products	161,811	Cotton	91,034
Sugar	91,819	Groundnuts	52,328
Metal Manufactures	57,224	Dura	48,817
Chemical Products	50,697	Livestock	25,075
Machinery Spare Parts	45,834	Sesame	24,717
Non-Electric Machinery	38,902	Gum Arabic	24,553
Auto Spare Parts	35,305	Other	64,764
Other	30,612		
TOTAL	512,204		331,288

Since 1973, Sudan has faced an almost continuous decline in its balance of payments position. Two key factors have played a role in this decline. First, agricultural productivity failed to reach targeted levels and in fact showed substantial declines for many crops. The output of long staple cotton fell from 3.8 Kantars per feddan in 1977/1978 to 2.1 kantars/feddan by 1979/80. The output of medium staple cotton fell from 3.9 to 2.8 kantars per feddan over the same period. Yields per feddan for dura and groundnuts declined by 20% between 1975/76 and 1979/80 (Table 1). While sesame yields remained roughly constant and those for wheat increased, both crops showed decreased total output (between 1975-1980) due to reduced areas planted. The decline of agricultural productivity has had a direct negative impact on export performance, with only modest export increases in cotton and gum arabic, stagnation in most other exports, and sharp reductions in groundnut exports due primarily to increased domestic oil production and consumption from groundnuts.

Second, the value of imports has continued to increase at an annual average growth rate of 6%, compared with less than 2% per year for exports (over the period 1976-1980). Petroleum and sugar together accounted for 70% of the $278 million increase in imports between 1975/76 and 1979/80. The bulk of the increase in the value of petroleum imports was due to price changes, while in the case of sugar there has also been a significant growth in the volume of imports, as shown below.

Imports of Key Commodities

1975-1980
(Millions of U.S. Dollars)

	1975/76	1976/77	1977/78	1978/79	1979/80
Total Imports	1061.6	985.6	1188.0	1137.9	1339.9
Petroleum	89.4	110.8	117.6	177.6	254.0
(Volume in MT)*	(1,103,999)	(1,077,586)	(1,060,332)	(1,012,662)	(921,449)
Sugar	91.0	58.6	43.7	28.0	122.7
(Volume in MT)	(143,693)	(141,637)	(197,750)	(155,608)	(301,234)

Preliminary data for 1981/82 suggest that certain important structural shifts are taking place in Sudan's agricultural sector. A substantial decline in sugar imports is expected as the Kenana Sugar Project moves to full production. 1981/82 output from Kenana is estimated at 165,000 MT, or 55% of 1979/80 sugar imports. Groundnut exports rebounded sharply in 1980/81, reaching 69,000 metric tons, compared with 6,000 MT and 10,000 MT in the two preceding years, and will rise even further (possibly 55% over 1981 exports) in 1982. Preliminary estimates for the dura crop in 1982 suggest that exports will reach one million metric tons though transport botttlenecks and falling international (primarily Saudi Arabian) prices could mean that only half of that amount actually will be exported this year. Sudan, with the assistance of major agencies (e.g., the World Bank) has embarked during this period upon its Export Action Program (EAP) aimed at increasing public and private investment in the agricultural, mainly public irrigated, sector. The whole system of pricing and supplying inputs to the sector was restructured and a host of new incentives for improved production were introduced during the 1979-1982 period.

Despite these positive signs in recent balance of trade developments, the overall balance remains unaffected, with the ratio of exports to imports diminishing between 1979/80 and 1980/81 (from about 0.46 to about 0.42). Under severe supply constraints, petroleum imports during the first half of 1982 are (at annual levels) about 20% below those for the previous twelve months (in both volume and value). At best, due to low world prices for cotton and groundnuts and declining prices for dura, the 1981/82 ratio of exports to imports will remain at 0.42 while the actual value of this imbalance will mean an increased balance of payments deficit. It appears likely that Sudan's total foreign exchange earnings for 1981-82 will decline from last year's levels, amounting to less than $600 million. Meanwhile, Sudan's oil import bill (excluding re-export of heavy fuel oil) will exceed $400 million, or over two-thirds the value of exports. Total external debt, currently in excess of $7 billion, will increase substantially.

The sections below briefly highlight important demographic and sectoral economic characteristics of the country.

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*Calendar years 1975, 1976, 1977, 1978, and 1979 respectively. Excludes changes in refinery stocks.

Demography

As shown in Table 1, Sudan's estimated total population in 1980 was 18.7 million, of which:

- 4.7 million (roughly 25%) was urban and the other 75% (14 million) rural;
- 1.6 million (8.6%) resided in Khartoum Province;
- 4.2 million (22.5%) are in the Southern Region; and
- 2.4 million (12.8%) and 2.6 million (13.9%) are in Kordofan and Darfur Regions respectively.

Figure 1 portrays the geographic distribution of Sudan's population in map form. Sudan's total population grew by an estimated 22.7% between 1973 and 1980, or an average of 2.96% per year.

- The country's total urban population grew at an estimated rate of 7.7% per year, a rate exceeding Khartoum Province's urban growth rate (6.8%) -- meaning urban centers outside the Three Towns were a major population magnet. Urban growth rates in Blue and White Nile Provinces, for example, were 10.4% and 9.0%, respectively. Urban growth rates in the South were particularly high (11.7% in East and West Equatoria, for example).

- Average annual population growth rates among regions and provinces were highly varied, ranging from 5.4% per year in Khartoum, 4.0% in Red Sea Province, 3.4% in Gezira, and 2.9% in Darfur to 1.7% in the Southern Region, 1.5% in Kordofan, and 1.0% in Northern Province.

Agriculture

Sudan's planners and many of its aid donors look to agriculture for improved economic performance, most especially in the export sector. The country's Export Action Program (EAP) sees rehabilitation of the major irrigated agricultural schemes as one of the keys to improved performance in this sector. The World Bank is presently directing much of its country-wide efforts toward rehabilitating the major irrigated schemes and views this as the key to improved export performance, particularly with respect to cotton exports. Meanwhile, many of the country's top leaders look to the mechanized rainfed agricultural sector (almost totally privatized) for the country's net agricultural and economic growth over the next two decades. Land under mechanized agricultural cultivation (planned and unplanned) has expanded by an average of some 350,000 feddans yearly since the early 1970's. Even so-called "traditional" agriculture (little or no mechanization) has responded well (mainly to pricing signals) over the past several years.

Most people concede that the modern irrigated agricultural sub-sector has been neglected over the past decade. Little of the large amounts of capital expended in the agricultural sector has gone to improve the old and new schemes (such as the Rahad). Several schemes stand out for particular attention from an energy efficiency point of view. These same schemes have been cited by others (most recently by the Minister of Finance himself) for poor economic performance and inefficient resource allocation. The Blue and White Nile Agricultural Corporations (originally private schemes that were brought under public control in the early 1970's) reported substantial economic losses (some LS 16 million and LS 8 million respectively during the 1981/82 agriculture season, according to the Ministry of Finance), while also receiving some of the highest per feddan petroleum allocations in the country.

TABLE 1

PROJECTED URBAN-RURAL POPULATION BY PROVINCE (IN THOUSAND)

YEAR	1973			1980			1985			1990			1995			2000		
PROVINCE	TOTAL	URBAN	RURAL	TOTAL	URBAN	RURAL	TOTAL	URBAN	RURAL	TOTAL	URBAN	RURAL	TOTAL	URBAN	RURAL	TOTAL	URBAN	RURAL
BLUE NILE	807	151	656	1,048	301	747	1,250	414	786	1,458	691	794	1,747	978	769	2,027	1,318	709
WHITE NILE	921	153	768	1,195	280	915	1,426	414	832	1,695	600	1,095	1,993	845	1,148	2,313	1,147	1,166
GEZIRA	1,941	219	1,722	2,520	333	2,187	3,006	436	2,570	3,572	575	2,997	4,201	748	3,453	4,873	955	3,918
NILE	563	135	428	606	182	424	646	225	421	691	276	415	740	334	406	791	400	391
NORTHERN	376	39	337	404	51	353	431	63	368	460	76	384	493	92	401	528	111	417
N. DARFUR	925	99	826	1,140	163	977	1,314	227	1,087	1,508	312	1,196	1,718	424	1,294	1,937	564	1,373
S. DARFUR	1,202	94	1,108	1,480	178	1,302	1,706	273	1,433	1,959	413	1,546	2,232	605	1,627	2,516	860	1,656
KASSALA	1,073	234	839	1,496	420	1,076	1,731	569	1,162	1,992	761	1,231	2,279	1,098	1,281	2,583	1,266	1,317
RED SEA	444	160	284	586	230	356	678	282	396	780	343	437	890	414	476	1,008	492	566
N. KORDOFAN	1,181	172	1,009	1,343	231	1,112	1,487	287	1,200	1,663	359	1,304	1,882	452	1,430	2,156	467	1,689
S. KORDOFAN	967	103	864	1,099	188	911	1,217	281	936	1,361	416	945	1,540	604	936	1,764	858	906
KHARTOUM	1,109	794	315	1,600	1,256	344	2,029	1,676	353	2,560	2,202	358	6,206	2,847	359	3,954	3,606	348
BAHR EL GHAZAL	778	79	679	870	165	705	971	270	701	1,089	423	666	1,223	612	611	1,374	855	519
LAKES	547	41	506	612	91	521	684	156	528	766	257	509	860	396	464	967	572	395
E. EQUATORIA	812	148	664	909	320	589	1,015	509	506	1,138	740	398	1,278	988	290	1,436	1,235	201
W. EQUATORIA	397	74	323	444	162	282	496	259	237	556	375	181	623	497	1,286	703	618	85
UPPER NILE	772	54	718	863	100	763	964	153	811	1,086	238	848	1,113	346	767	1,364	498	866
JONGLEI	415	14	401	465	14	451	519	14	505	580	14	568	653	14	639	734	14	720
TOTAL:	15,230	2,763	12,467	18,680	4,665	14,015	21,570	6,556	14,232	24,943	9,065	15,872	28,671	12,294	16,477	33,026	15,934	17,183

SOURCE: Mahmoud Khider, Dept. of Statistics.

The most dynamic agricultural subsectors are the mechanized and traditional rain-fed subsectors. It was primarily these two sectors which accounted for the impressive 55% increase in groundnut production and 22% increase in dura (sorghum) production during the 1981/82 season.

Industry

One of the most disheartening features of Sudan's economic performance over the past decade has been the disappointing performance of Sudan's industrial sector. Subsectoral generalizations are difficult to make in this sector, but generally the private sector (with several major exceptions) has proven more dynamic and responsive to economic signals than the public sector. Sudanese planners have pinned their hopes in the industrial sector on textiles and oilseeds. Both subsectors are plagued by a host of difficulties. These difficulties stem from the problems of supplies of raw materials, spare parts, energy and foreign exchange as well as management and high labor turnover.

During the course of this assessment over 75 industrial plants and factories were visited. One generalization became apparent: most industries located in Port Sudan (almost all private) were operating at significantly higher rates of capacity utilization than most industries located elsewhere. The reasons for this better performance include:

- Easier access to foreign exchange;
- Near-total reliance on self-generated electricity (therefore no dependence on unreliable public electricity supplies);
- Easier access to petroleum supplies (since the Port Sudan Refinery and the port are located nearby); and
- Easy access to imported raw materials; and spare parts.

The average operating efficiency in Port Sudan approaches 65% while industrial capacity utilization in the rest of the country averages less than 40%. This comparison is suggestive of what industrial performance potentially could be in a relatively less constrained supply situation. At the same time, operating rates of private sector plants -- regardless of geographical location -- typically were at least 10-20% higher than public sector plants in the same or related subsectors. This suggests that factors other than purely physical supply factors also are important to industrial sector performance.

Transport

There has been a dramatic change in transport in the Sudan. First, the intercity surfaced road network has increased from virtually zero in the mid-1960's to 334 kilometers in 1973 and 1750 km in 1982, with another 800 km under construction. One consequence has been a sizeable shift in freight transport from the Sudan Railway Corporation (whose ton-km have dipped roughly 50% since 1970) to trucks (whose ton-km over the same period have risen from close to zero to roughly equal to the SRC's). Second, there has been a very high rate of growth in private passenger vehicles, with vehicle registration increasing over 10% per year during the 1970's.

The road transport sector -- virtually entirely private -- has been one of the few dynamic growth sectors in the country. It is flexible, relatively reliable, and -- although generally much more expensive then the railroad -- increasingly the preferred mode of transport for all but a few (bulk) commodities.

CHAPTER III

BASE YEAR (1980) ENERGY SUPPLY AND DEMAND

Overview

In 1980, Sudan consumed the equivalent of slightly less that 7 million tons of oil equivalent (TOE). 85% of this was in the form of wood, charcoal, and other biomass; 14% was petroleum products; and 1% hydropower. Tables 2 and 3 present 1980 energy consumption, in TOE and original energy units respectively, by sector including electric power. Table 4 allocates electric power generation by consuming sector. From these tables, it can be seen that:

- Households consumed 93% of all biomass energy, primarily for cooking;
- The transport sector accounted for 58% of total petroleum product consumption, followed by 15% in industry, 10% in agriculture, and 8% in power generation;
- Hydropower accounted for 79% of total electricity generation; and
- Households and industry each represented one-third of total electricity sales, with 11% used by agricultural pumps.

1980 energy flows are presented in "reference energy system" format in Figure 2. Consumption of petroleum products increased by almost 50% between 1970 and 1980, as shown in Table 5, with a notable shift toward light products. Combined furnace and diesel (heavy products) consumption declined over this period, due primarily to the Sudan Railways' switch from steam to diesel locomotives, deterioration of PEWC thermal power stations, and falling cement output. Gasoil consumption almost doubled, reflecting the opening of the Khartoum-Port Sudan highway, growth of mechanized agriculture, growth of industrial and residential self-generation of electricity, and (unexpectedly) significant substitution of gasoil for kerosene for residential lighting. Benzene and avgas consumption more than doubled, reflecting primarily an increase in passenger cars and mileage traveled and secondarily an increase in air transport activity. The modest growth in kerojet consumption masks a major increase in jet fuel at the expense of kerosene.

Petroleum product consumption in 1970 largely reflected the real demand for these products, given prices at that time. In 1980 this is probably the case only for furnace oil and diesel. At present official prices, the effective demand for LPG, kerosene, benzene and gasoil is substantially greater than actual consumption. This supply constraint is particularly significant for gasoil, which in almost all uses is an economically productive fuel (Table 6). Gasoil also is the petroleum fuel with the greatest impact on rural welfare, due to its use for water pumping and for grinding in dura mills.

Similarly, 1980 electric power consumption represents a constrained demand, with conscious power curtailments ("load shedding") and unscheduled blackouts a regular occurrence. One measure of the PEWC's inability to meet power demands is the growth of self-generation of electricity (excluding the sugar industry, which has long generated power from bagasse) from virtually nothing in 1970 to over 110 MW of installed capacity (equivalent to over 40% of the PEWC's total installed capacity) by 1982. 80% of this self-generating capacity is in the industrial sector. Virtually all of this generation capacity, which will have to be used increasingly over the next 2-3 years, depends upon gasoil, representing further competition with other uses of this fuel.

TABLE 2

TOTAL ENERGY CONSUMPTION 1980[1]
000 TOE

Sector	Hydro-Power	Benzine/Avgas	LPG	Kerosene Jet Fuel	Gasoil	Diesel	Furnace Oil	Wood	Charcoal	Other Bio-Mass	Vegetable Oil	Total
Industry	--	--	0.8	0.9	43.5	6.4	100.1	95.9	--	94.5	--	342.1
Transport	--	207.0	--	46.6	296.2	--	21.0	--	--	--	--	570.6
Agriculture	--	--	--	--	94.5	Small	--	--	--	--	--	94.5
Commercial, Government Services	--	--	Small	--	9.2	--	--	111	98	--	--	218.2
Construction+ Oil exploration	--	--	--	Small	34.3	--	--	--	--	--	--	34.2
Households	--	--	4.7	17.5	32.1	--	--	3,366.9	1,763.3	402.6	8.5	5,596.2
PEWC Electricity Generation	63.5	--	--	--	21.2	14.4	42.5	--	--	--	--	141.6
Total	63.5	207.0	5.5	65.0	531.0	20.8	163.6	3,573.8	1,861.3	497.1	8.5	6,997.4

1 TOE (tons of oil equivalent) = 41.8×10^9 Joules

[1] Totals may not add due to rounding, excludes petroleum imports from Kenya, the quantities of which are at present undetermined.

TABLE 3

TOTAL ENERGY CONSUMPTION 1980 IN 000 TONS[3]

Sector	Hydro-Power	Benzine/Avgas	LPG	Kerosene Jet Fuel	Gasoil	Diesel	Furnace Oil	Wood	Charcoal	Other Bio-Mass[2]	Vegetable Oil
Industry	--	--	.75	.9	41.8	6.3	104.3	223	--	472.5	--
Transport[4]	--	197.1	--	44.6	284.8	--	21.9	--	--	--	--
Agriculture	--	--	--	--	90.9	Small	--	--	--	--	--
Commercial Govt' Service	--	--	Small	--	8.8	--	--	259	136	--	--
Construction and Oil Exploration	--	--	--	Small	33.0	--	--	--	--	--	--
Households	--	--	4.27	16.8	30.9	--	--	7,830	2,449	988-2039	5-12
PEWC Electricity Generation	737.8	--	--	--	20.4	14.1	44.3	--	--	--	--
TOTAL	737.8	197.1	5.02	62.3	510.6	20.4	170.5	8,312	2,585	1,460.5 2,511.5	5-12

1 Includes all transport.

2 Bagasse, groundnut shells, crop residues and animal wastes, due to large uncertainty, household consumption expressed as a range.

3 All tables exclude petroleum fuels imported from Kenya, which total approximately 5000 tons.

TABLE 4

PEWC ELECTRICITY SALES 1980

Region / Sector	Households	Government[1] +Commercial	Heavy Industry	Agriculture[2]	Services[3]	Total
Eastern	20.0	11.3	8.5	4.6	4.1	48.5
Northern	11.3	5.6	.4	1.8	3.5	22.6
Khartoum	190.3	35.8	114.5	15.3	19.1	375.0
Central	30.3	20.2	118.4	57.2	4.1	230.2
Southern	2.9	.2	--	--	1.4	4.5
Kordofan	4.0	1.5	--	--	.7	6.2
Darfur	2.7	1.1	.7	--	1.3	5.8
Total	261.5	75.7	242.5	78.9	34.2	692.8

1 Includes 21.6 Gwh of large customers from industrial tariff plus small industries

2 Includes 54.4 Gwh of large customers from industrial tariff; sugar included within industrial sector.

3 Street lighting, water pumping and utility use.

Source: PEWC and NEA estimates

Figure 2

(all units in 10^{11} joules)

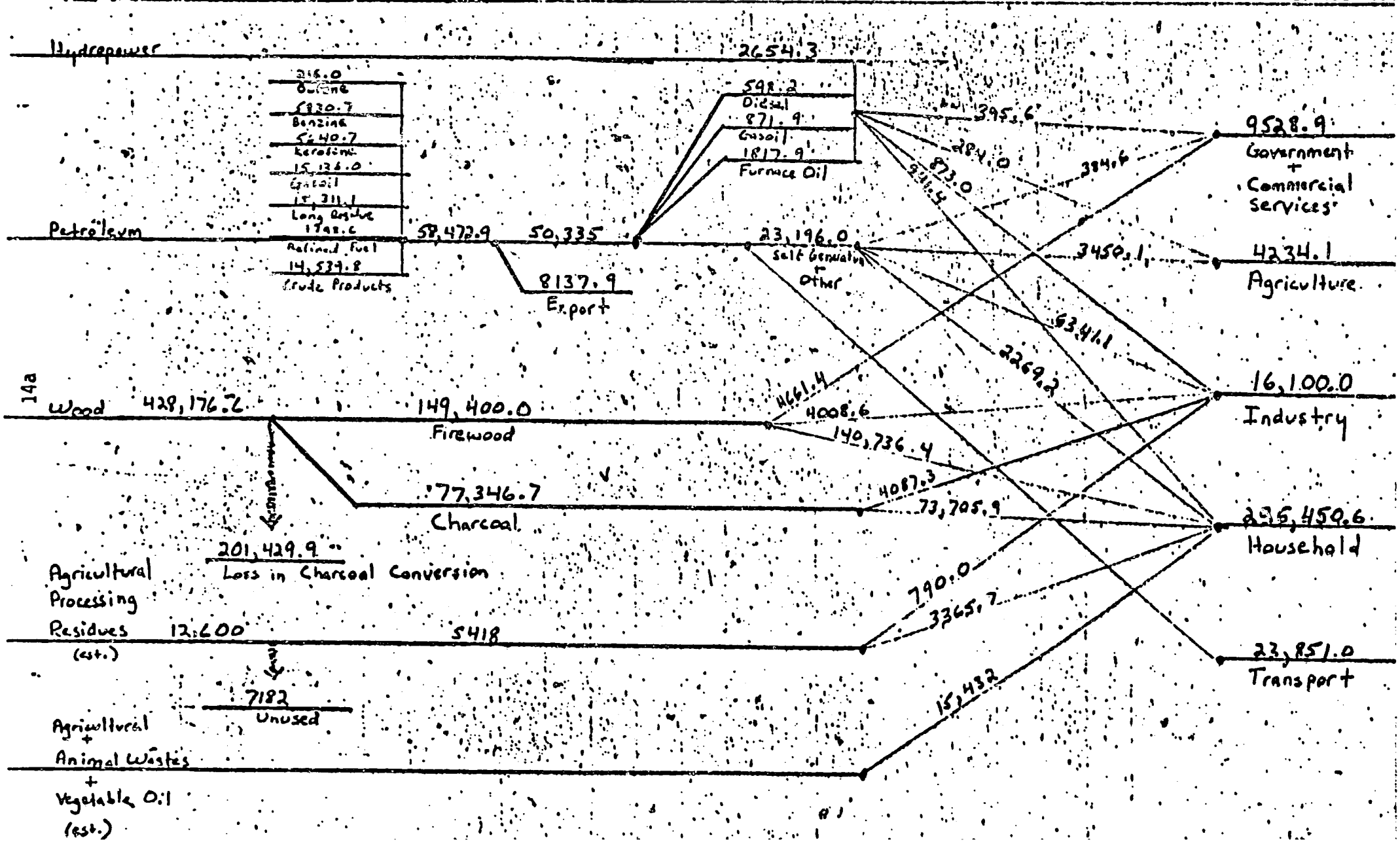

TABLE 5

PETROLEUM PRODUCTS CONSUMPTION, 1970 vs 1980
(TOE)

	1970	1980*	Percent Increase
LPG	-	5,550	-
Benzene and Avgas	100,823	206,955	105%
Kerosene and Jet	58,285	64,792	11%
Gasoil	282,213	531,024	88%
Diesel	27,927	20,815	-25%
Furnace Oil	199,392	163,647	-18%
TOTAL	668,640	992,783	48.5%

*Note: 1980 crude oil imports (and throughput through the refinery) were down over 15% from 1979 levels -- a downward trend which has continued into 1982. Total kerosene refined at Port Sudan and imported from abroad in 1980 was one-third the amount in 1979.

TABLE 6

GASOIL CONSUMPTION 1980

Sector/End Use		Tons
(1) Agriculture		90,900
Irrigation Pumping	29,300	
Agricultural Operations[2]	57,900	
Canal Maintenance	3,700	
(2) Transport[1]		284,800
Sudan Railways	26,600	
River Transport Corp.	2,300	
Lorries and Medium Trucks	176,200	
Heavy Trucks	35,200	
Buses	41,800	
Pipeline	2,700	
Diesel Autos	Small	
(3) Industry		41,800
Generators	24,400	
Boilers	small	
Bakeries	4,200	
Stationary Engines	1,900	
Sugar-Agricultural Operations[3]	11,300	
(4) Commercial, Gov't', Services		8,800
Water Pumping	8,000	
Generators	800	
(5) Construction & Oil Exploration		33,000
(6) Households		30,900
Generators[4]	4,500	
Lighting & Cooking	26,400	
(7) PEWC		20,400
TOTAL		510,600

1) Includes gasoil consumption of all goods or passenger moving vehicles including those owned by factories, schemes, government, etc.
2) Includes all operations from land preparation through harvesting and threshing.
3) Irrigation pumping uses electricity
4) Includes all cooperatives and other rural generation.

Source: NEA estimates

Regional energy consumption breakdowns with more detailed sectoral energy tables and analyses are presented in Annex I, "Base Year Energy Supply-Demand Balances." Such regional breakdowns (also summarized later in this report) show clearly that Southern and Western Sudan have much lower levels of per capita petroleum product and electricity consumption than do other areas, while consumption in the Khartoum area--due to much higher levels of household electric power consumption, passenger vehicle use, and industrial activity--far exceeds that in other areas. To illustrate the extent of variation, 1980 per capita electricity consumption was 234 KWh in Khartoum Province, 49 KWh for all of Sudan excepting the Southern Region, 2.7 KWh in Darfur, and only 1 KWh per capita for the Southern Region as a whole (with 22% of the country's total population). Another measure of this disparity in energy consumption is reflected in the fact that some 5% of the Khartoum residential households comprise nearly one-third of the peak residential load during six months of the year. Most of this is air conditioning load, which has been increasing at a rate of 15-20% per year since 1977. Much of this load is accounted for by the expatriate population.

Annex I describes energy consumption and supply for each sector in detail. The following sub-sections briefly summarize the most import factual points respecting each sector.

Energy Consumption

Households[1]

In 1980, the household sector consumed 80% of total primary energy in the Sudan (5.6 million TOE, of which 99% was biomass -- Table 7) and roughly one-third of all electricity (275 GWh). In the largest household energy consuming activity--cooking--wood and charcoal account for 60% and 32%, respectively, of total energy used. Efficiency of conversion and use of such fuels is very low (generally less than 15% of the heating value is effectively used). Other cooking fuels used are kerosene and gasoil (accounting for less than 20% of total household use of these fuels); in high-income urban households, LPG (98% of which is consumed in the Khartoum and Port Sudan areas); and crop residues and animal wastes. The second largest energy-consuming activity is lighting, with major fuels being gasoil (very widely used, particularly in rural areas), kerosene, electricity, wood, candles, and vegetable oil (Tables 7 and 8). Major points regarding household energy use include the following:

- It is estimated that, at current official prices, only 20% of the demand for kerosene is being satisfied. Substitutes--gasoil and, to a lesser extent, vegetable oil--are not as desirable as kerosene and may entail a higher opportunity cost to the country than would use of kerosene. Kerosene has become increasingly unavailable to Sudanese consumers since 1973. After rising for twenty years, domestic kerosene consumption has dropped from a peak of 66,000 MT in 1972 to a low of 16,000 MT in 1981 for several

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[1] Much of this information is based on detailed NEA surveys of over 1200 households in all areas of the country (Kordofan and Southern Regions - Eastern and West Equatoria, Kassala, Bahr El-Ghazal, White Nile, Blue Nile, Gezira and Nile Provinces). In addition, surveys conducted by other people were drawn upon.

TABLE 7

HOUSEHOLD ENERGY CONSUMPTION 1980
TOE

Region \ Fuel	Wood	Charcoal	Crop[1] Residues	Animal[1] Wastes	LPG[2]	Kerosene	Gasoil	Vegetable Oil	Purchased Electricity	Total
Eastern	265,740	167,760	15,680	8,750	485	6,032	4,160	--	1,722.4	470,329.4
Northern	77,830	91,440	13,920	8,750	42	1,144	2,392	--	973.2	196,491.2
Khartoum	75,250	172,800	small	small	4,155	4,680	2,600	--	16,388.4	275,873.4
Central	647,150	425,520	67,200	87,200	35	3,224	8,736	8,500	2,609.4	1,250,174.4
Southern	1,223,780	261,360	14,080	187,250	--	--	1,352	--	249.8	1,688,071.8
Kordofan	505,250	316,800	small	small	--	1,560	4,784	--	344.5	828,738.5
Darfur	571,900	327,600	small	small	--	882	3,432	--	232.5	904,046.5
Undistributed (by region)	--	--	--	--	--	--	4,680	--	--	
Urban Subtotal	495,790	668,160	8,000	6,000	4,717	17,472	32,126	8,500	22,521.0	
Rural Subtotal	2,871,110	1,095,120	108,880	285,750						
GROSS TOTAL	3,366,900	1,763,280	110,880	291,750	4,717	17,472	32,126	8,500	22,521.0	5,618,146.0

1 Average of range appearing in Table III-3, Appendix.

2 Assumes 67% and 33% of industrial LPG is consumed in Khartoum and Port Sudan, respectively.

TABLE 8

HOUSEHOLD ENERGY CONSUMPTION 1980
(Units As Shown)

Region \ Fuel	Wood 000 Tons	Charcoal 000 Tons	Crop Residues 000 Tons	Animal Wastes 000 Tons	LPG Tons	Kerosene Tons	Gasoil[2] 000 Tons	Vegetable Oil Tons	Purchased Electricity Gwh
Eastern	618	233	40-58	26-44	437	5,800	4,000	--	20.0
Northern	181	127	14-73	11-59	38	1,100	2,300	--	11.3
Khartoum	175	240	Small	Small	3,743	4,500	2,500	--	190.3
Central	1,505	591	210	348	32	3,100	8,400	5,000-12,000	30.3
Southern[1]	2,846	363	18-70	321-1,177	--	--	1,300	--	2.9
Kordofan	1,175	440	Small	Small	--	1,500	4,600	--	4.0
Darfur	1,330	455	Small	Small	--	800	3,300	--	2.7
Undistributed	--	--	--	--	--	--	4,500	--	--
Subtotal Urban	1,153	928	12-38	10-38	4270	16,800	30,900	5,000-12,000	261.5
Subtotal Rural	6,677	1,521	270-373	696-1,590	--				
Total Sudan	7,830	2,449	282-411	706-1,628	4270	16,800	30,900	5,000-12,000	261.5

Generated Electricity = 2.4 Gwh Urban
10.9 Gwh Rural (Includes cooperatives)
13.3

Source: PEWC, GPC and NEA Surveys

1 Excluding petroleum products imported from Kenya.

2 Gasoil consumed in generators belonging to households and rural cooperatives.

TABLE 9

KEROSENE CONSUMPTION IN THE SUDAN

Year	Population (1)				Kerosene Consumption (2) (Imperial Gallons)		
	Urban (000)	Rural (000)	Total (000)	Percentage increase (%)	Total Consumption (000 I.G.)	Per Capital Consumption I.G./yr/cap	Percentage(%) Change P.C. Consumption
1972	2527	12,253	14,780		18.610	1.26	
1973	2763	12,467	15,230	2.96	14,285	0.94	-25.5
1974	2995	12,685	15,681	"	8,999	0.57	-39.4
1975	3244	12,896	16,145	"	10,021	0.62	+ 8.8
1976	3507	13,113	16,623	"	8,633	0.52	-16.1
1977	3764	13,346	17,115	"	8,886	0.52	0
1978	4053	13,567	17,621	"	6,672	0.38	-26.9
1979	4354	13,786	18,142	"	4,859	0.27	-28.9
1980	4665	14,015	18,600	"	4,977	0.27	0

(1) Breakdown urban (vs) rural, total population, and percentage increase derived from 1973 and 1980 demographic estimates made by Mahmaud Khider, Dept. of Statistics.

(2) Source: Dr. Abdel Rahim. "Towards a New Kerosene Consumption Policy", GPC, 1982.

reasons (Table 9): First, kerosene throughput at the Port Sudan Refinery has been decreased to allow for the refining of more benzine. Second, increasing amounts of kerosene are diverted every year for commercial jet fuel. Third, kerosene is used as a blend stock with heavy residual oil to give a throughput of lighter, (1500" residual "furnace oil"). Finally, kerosene distribution for domestic use has been taken over by the Government, through cooperatives which lack the facilities and experience of the private petroleum distribution companies. (Most kerosene made available for domestic consumption ends up on the black market where it fetches prices five to ten times that of official prices.) Moreover, NEA studies show that kerosene has not been available in certain rural areas for years. The most surprising effect has been widespread switching to use of gasoil for household lighting. NEA surveys show that at least 24,000 MT of gasoil are being diverted for household use (primarily for lighting, although, in the more wood-impoverished areas of Northern Sudan, it is also used for cooking). Ingenious Sudanese have discovered that adding a "blueing" agent (used for bleaching clothes) significantly reduces the smoke caused by burning gasoil in wick lamp or stove, and is reputed to improve the lighting effects of burning gasoil.

- Joint NEA and Statistics Department surveys indicate that household per capita consumption of charcoal has risen from an estimated 0.07 MT in 1962 to 0.13 MT with total household charcoal consumption increasing from some 690,000 MT in 1962 to over 2.4 million MT at present. (Tables 10, 11 and 12). This increase is due to population growth, urbanization and the decreasing availability of kerosene. Over 40% of all charcoal manufactured in Sudan is destined for urban consumers, who make up 25% of the population, and surveys of urban households show that 95% of all urban households use charcoal for at least a portion of their cooking needs.

- Consumption of crop residues and animal wastes as a cooking fuel is surprisingly large and apparently rapidly growing in some areas, particularly in the Central and Eastern Regions.

- Electricity consumption per residential customer is much higher around Khartoum than in other areas (1900 KWh/year vs., for instance, under 30 KWh/year in Darfur).

- LPG use currently is constrained not only by supply but also by limits on cylinders and distribution points. Proposals have been made to expand LPG distribution considerably, virtually entirely for domestic cooking (primarily displacing charcoal), have been approved by the GPC.

TABLE 10

TOTAL HOUSEHOLD FUELWOOD CONSUMPTION BY PROVINCES AND SECTORS: 1955/56

(in m^3 Growing Stock Wood Equivalent)

Province	(1955-56) Population (000)	Charcoal				Fuelwood				Total Fuelwood			
		Urban (000m3)	Rural (000m3)	Total (000m3)	Per Capita (m3)	Urban (000m3)	Rural (000m3)	Total (000m3)	Per Capita (m3)	Urban (000m3)	Rural (000m3)	Total (000m3)	Per Capita (m3)
Khartoum	505			783	1.55			290	0.57			1073	2.12
Gezira	854			2088	2.44			649	0.76			2737	3.2
Blue Nile	593			148	0.25			1141	1.92			1289	2.17
White Nile	623			965	1.55			455	0.73			1420	2.28
Kassala	784			1198	1.53			581	0.74			1779	2.27
Nile	491			182	0.37			295	0.6			477	0.97
S. Kordofan	1084			-	-			1273	1.17			1273	1.17
N. Kordofan	679			336	0.49			665	0.98			1001	1.47
S. Darfur	720			53	0.09			2157	3.0			2157	3.0
N. Darfur	608			279	1.78			1387	2.28			1440	2.37
Red Sea	157			68	0.18			118	0.75			397	2.53
Northern	380			-	-			151	0.4			219	0.58
E. Equatoria	589			-	-			748	1.27			748	1.27
W. Equatoria	315			-	-			621	1.97			621	1.97
Bahr El-Ghazal	991			-	-			1984	2.0			1984	2.0
Upper Nile	301			-	-			628	2.09			628	2.09
Jonglei	184			-	-			93	0.51			93	0.51
El-Buhyrat	405			-	-			604	1.49			604	1.49
TOTAL	10,263			6,100	0.59			13,840	1.35			19,940	1.94

Source: J.K. Jackson from 1955/56 National Census in "Report to the Government of Sudan on Forest Management," FAO, Rome, 1960.

TABLE 11

TOTAL HOUSEHOLD FUELWOOD CONSUMPTION BY PROVINCES AND SECTORS: 1962

(in m^3 Growing Stock Wood Equivalent)

Province	(1955-56) Population (000)	Charcoal				Fuelwood				Total Fuelwood			
		Urban (000m3)	Rural (000m3)	Total (000m3)	Per Capita (m3)	Urban (000m3)	Rural (000m3)	Total (000m3)	Per Capita (m3)	Urban (000m3)	Rural (000m3)	Total (000m3)	Per Capita (m3)
Region A:	2,3 19	2,176	3,978	6,154	2.65	378	3,335	3,713	1.6	2,554	7,313	9,867	4.25
Kassala Khartoum Northern													
Region B:	2,070	634	4,675	5,309	2.56	143	3,151	3,294	1.59	777	7,826	8,603	4.15
Blue Nile													
Region C:	3,091	612	18	630	.02	173	5,077	5,250	1.7	785	5,095	5,880	1.9
Kordofan Darfur													
Region D:	2,783	335	40	375	0.13	56	4,611	4,667	1.68	391	4,651	5,042	1.81
Upper Nile Equatoria Bahr El-Ghazal													
TOTAL	10,263	3,757	8,711	12,468	1.21	750	16,174	16,924	1.65	4,507	24,885	29,392	2.86

Source: T.S. Saini, "Present Wood Consumption and Future Requirements." FAO, Rome, 1962.

TABLE 12

TOTAL HOUSEHOLD FUELWOOD CONSUMPTION BY PROVINCES AND SECTORS: 1980

(in m^3 Growing Stock Wood Equivalent)

Province	(1980) Population (000)	Charcoal				Fuelwood				Total Fuelwood			
		Urban (000m3)	Rural (000m3)	Total (000m3)	Per Capita (m3)	Urban (000m3)	Rural (000m3)	Total (000m3)	Per Capita (m3)	Urban (000m3)	Rural (000m3)	Total (000m3)	Per Capita (m3)
Khartoum	1600	3636	684	4320	2.7	396	129	525	0.33	4032	813	4845	3.03
Gezira	2520	972	4374	5346	2.12	162	1320	1482	0.59	1134	5694	6828	2.71
Blue Nile	1048	864	1134	1998	1.91	258	1803	2061	1.97	1122	2937	4059	3.87
White Nile	1195	990	2304	3294	2.76	165	807	972	0.81	1155	3111	4266	3.57
Kassala	1496	1134	1890	3024	2.02	327	1278	1605	1.07	1461	3168	4629	3.09
Nile	606	468	918	1386	2.29	78	270	348	0.57	546	1188	1734	2.86
S. Kordofan	1099	1152	2484	3636	3.31	171	1656	1827	1.66	1323	4140	5463	4.97
N. Kordofan	1343	1260	3024	4684	3.19	183	1515	1698	1.26	1443	4539	5982	4.45
S. Dar Fur	1480	1098	3546	4644	3.14	162	2367	2529	1.71	1260	5913	7173	4.85
N. Dar Fur	1140	882	2664	3546	3.11	129	1332	1461	1.28	1011	3996	5007	4.39
Red Sea	586	540	630	1170	2.0	54	195	249	0.42	594	825	1419	2.42
Northern	404	126	774	900	2.23	18	177	195	0.48	144	951	1095	2.71
E. Equatoria	909	1368	552	1890	2.08	576	2142	2718	2.99	1944	2664	4608	5.07
W. Equatoria	444	846	252	1098	2.47	357	1026	1383	3.11	1203	1278	2481	5.59
Bahr El Ghazal	870	864	774	1638	1.88	240	1923	2163	2.49	1104	2697	3801	4.37
Upper Nile	863	270	828	1098	1.27	90	1110	1200	1.39	360	1938	2298	2.66
Jonglei	465	-	-	-	-	9	411	420	.09	9	411	420	0.9
El Buhyrat	612	234	576	810	1.32	84	570	654	1.07	318	1146	1464	2.39
TOTAL	18680	16704	27378	44082	2.36	3459	20031	23490	1.26	20163	47409	67572	3.62

Source: NEA and Department of Statistics Survey, 1981-82.

Agriculture

The agriculture sector consumed only 1% of primary energy in 1980 (94.5 thousand TOE), all of which was gasoil (Table 13). This total excludes sugar processing (included in the industrial sector and accounting for another 3% of primary energy, largely in the form of baggase) and transport of crops and labor (covered in the transport sector). In addition to primary energy, 78.9 Gwh of electricity, equivalent to 26,500 tons of gasoil, was consumed for irrigation pumping, primarily along the Blue Nile Grid.

Irrigation pumping accounted for about one-third of the sector's gasoil use (29,300 tons), while agricultural operations -- from land preparation through harvesting and threshing -- consumed almost two-thirds, or 57,900 tons. The large proportion of gasoil consumed in agricultural operations is due primarily to continued expansion in mechanized rainfed cultivation (Table 14). Canal maintenance accounted for around 3% of sectoral gasoil use.

For the major crops, fuel consumption for irrigation varies between the equivalent of 34 gallons per feddan for sugar at Sennar (high water requirement, high pumping head) to 2 gallons per feddan for dura at Kosti (low water requirement, low head). In general, irrigation fuel requirements per feddan are three to four times as great along the Blue Nile as along the White Nile, due to the much greater range in the pumping head along the Blue Nile. Fuel consumption for agricultural operations is less variable, ranging between one and three gallons per feddan for all crops except mechanically picked cotton, for which the picking alone requires four gallons per feddan.

Table 15 presents feddans under irrigated, mechanized rainfed and traditional cultivation in each region. The Central and Eastern regions account for 44% and 40%, respectively, of all irrigated or mechanized feddans (including the 120,000 feddans on which sugar is presently grown). Particularly notable is the large number of feddans devoted to traditional agriculture, to which no agricultural fuel consumption has been attributed although, especially in Kordofan, a number of traditional cultivators are now using tractors for land preparation.

In most cases estimated fuel consumption differs markedly from official fuel allocations to agricultural schemes. This discrepancy is due to (1) inclusion in official allocations of fuel for services and transporting crops and labor and (2) large differences in some cases between reported fuel allocations to schemes and reasonable values for fuel consumption per feddan, based on detailed analysis of location, crops, agricultural practices, and irrigation fuel consumption. The GPC and NEA currently are analyzing such discrepancies to determine whether decreases in some scheme's allocation are called for.

The agricultural sector accounted for 18% of total gasoil use in 1980. In view of gasoil shortages nationwide, it may be that sectoral gasoil consumption masks some unsatisfied demand. NEA interviews by scheme indicate that (1) for most government schemes, offical allocations are if anything high and that (2) most private farmers get the gasoil they need (albeit generally on the black market at much higher prices). There is evidence of seasonal gasoil shortages, which were particularly bad during the 1981-1982 season (when some crops could not be harvested on time due to lack of gasoil).

TABLE 13

AGRICULTURE ENERGY CONSUMPTION 1980[1]

Gasoil (Tons)

Regions	Irrigation[3]	Agricultural Operations	Canal[2] Maintenance	Total	Electricity (Gwh) Irrigation
Eastern	1,400	23,000	100	24,500	4.6
Northern	8,000	500	400	8,900	1.8
Khartoum	600	100	-	700	15.3
Central	14,200	29,400	3,200	46,800	57.2
Southern	300	3,300	-	3,600	-
Kordofan	2,200	1,500	-	3,700	-
Darfur	2,600	100	-	2,700	-
TOTAL	29,300	57,900	3,700	90,900	78.9

1 Sugar is included in industrial sector; gasoil used to transport crops and labor is included in transport sector.

2 Total consumption including transport estimated at 5,300 tons

3 Using the equations: gallons of gasoil = m^3 of water x head in meters x .355 x 10-3

Source: NEA estimates based on information from Ministry of Agriculture and Irrigation, Petroleum distributing companies and NEA surveys.

TABLE 14

TOTAL AREAS UNDER "PLANNED" MECHANIZED AGRICULTURE: 1970/71-1980/81

(000's Feddans)

	1970/71	1971/72	1972/73	1973/74	1974/75	1975/76	1976/77	1977/78	1978/79	1979/80	1980/81
Kassala	1,988	1,753	1,470	1,851	2,199	2,315	2,311	2,222	2,250	2,023	2,500
B. Nile	288	334	471	820	988	653	651	694	419	603	317
W. Nile	14	44	39	58	49	54	145	125	144	168	149
U. Nile	77	138	210	304	271	366	281	296	258	254	262
S. Kord.	19	80	99	144	192	206	414	229	240	207	227
	-	-	-	1	5	5	8	6	-	-	-
TOTAL PLANNED AREAS	2,381	2,349	2,289	3,178	3,704	3,599	3,810	3,572	3,314	3,255	3,455
APPROX. TOTAL UNPLANNED AREAS	714	752	788	1,112	1,482	1,620	1,905	2,322	2,486	2,930	3,510
TOTAL PLANNED AND UNPLANNED AREAS	3,095	3,101	3,067	4,290	5,186	5,219	5,715	5,894	5,636	6,244	6,965

Source: Mechanized Farming Corporation (June, 1982), NEA Agricultural Committee and NEA Staff.

TABLE 15

FEDDANS UNDER CULTIVATION 1980

(000' Feddans)

	Irrigated Gravity [1]	Irrigated Gasoil Pump	Irrigated Electric	Irrigated Flood	Mechanized Rainfed	Traditional	Total
Eastern	495.6	9	16.4	--	2,969.9	23	3,513.9
Northern	--	239	35	325	--	--	599
Khartoum	--	13	62	--	--	--	75
Central	1,413.5	230.7	168.1	--	2,052	1,601	5,465.3
Southern	--	25	--	--	500.3	1,552	2,077.3
Kordofan	--	16	--	--	237.9	3,365	3,618.9
Darfur	--	17	--	--	6	2,786	2,809
TOTAL	1,909.1	549.7	281.5	325	5,766.1	9,327	18,158.4

1 Includes Rahad scheme listed under Eastern region which also uses electric pumps and presently irrigates 225,000 feddans. Also includes some feddans in Gezira Scheme that are irrigated with gasoil powered pumps.

Industry

The industrial sector consumed 5% of primary energy in 1980, over half of which was in the form of biomass, primarily bagasse in the sugar industry, and wood (see Table 1). The sector accounted for 16% of national petroleum consumption, primarily furnace oil and to a lesser extent gasoil for self-generation of electricity. As Tables 16 and 17 show, the sector purchased 243 Gwh of electricity from the PEWC (35% of the PEWC's total sales) and generated another 314 Gwh--or almost 30% more than it purchased from the PEWC--itself, largely in the sugar factories (232 Gwh).

Tables 16 and 17 break down industrial energy consumption by sector and region, respectively, based on Ministry of Industry statistics and NEA surveys of 103 factories in all areas except the Southern Region. The following points stand out from the tables and underlying surveys:

- Industrial power generation, already large, could become much more significant. For instance, if all bagasse produced in 1980 were dried to 30% moisture content, it could displace the equivalent of 29,000 tons of furnace oil--more than 20% of the total amount consumed by the PEWC and industry combined in 1980.

- Conversely, if PEWC generation on the Blue Nile Grid and in Port Sudan had been sufficient (and sufficiently reliable) to displace industrial self-generation using petroleum fuels, 21,000 tons of gasoil--22% of that used in agriculture--would have been freed up.

NEA industrial plant surveys confirm that electric power cutoffs and "shortages" of petroleum products (often really public corporations' lack of money to buy such products) was a major contributing factor to the very low levels of capacity utilization of most Sudanese factories (see NEA Project Report: "An Examination of the Impact of Energy Supply Problems on Sudanese Industry," Nov., 1981). As shown in Table 18, average capacity utilization for major industrial sectors varied from 17% to 62% in 1981, with many individual plants falling below even this level. Since a plant's energy consumption declines relatively little as output declines (and hence energy consumption per unit increases rapidly), more reliable energy supply to industry -- to the extent it resulted in improved capacity utilization -- would improve energy as well as economic efficiency.

Transport

Transport in 1980 accounted for 8% of total primary energy use and 54% of total petroleum consumption in the Sudan. The sector accounted for 100% of benzine and 56% of gasoil consumption. As defined here, the transport sector includes significant fuel use--15-20% of total gasoil use in transportation--for transport by institutions in the agricultural sector. Also included is transport within the government sector, which owns 24% of all benzine-powered and 9% of all gasoil-power vehicles.

As shown in Table 19, road transport--trucks, buses, and passenger vehicles--accounted for 81% of total fuel use in transport in 1980. This relative importance is quite recent and reflects primarily expansion in the intercity surfaced road network (from virtually zero fifteen years ago to 334 kilometers in 1973 to 1750 km in 1982, with another 800 km under construction) and consequent shift in

TABLE 16

INDUSTRY ENERGY CONSUMPTION 1980(BY SUB-SECTOR)
(Units as Shown)

Sub-sector	Kerosene and LPG Tons	Gasoil Tons	Diesel Tons	Furnace Oil Tons	Wood Tons	Crop Residues Tons	Purchased Electricity Gwh	Generated Electricity Gwh
Textile	small	10,064	--	14,058	--	--	79.9	29.7
Cement	small	927	3,431	19,724	--	--	3.8	10.1
Sugar	small	11,300[2]	--	37,720	--	430,000[1]	58.8	232
Oil & Soap	small	5,309	132	19,479	29,600	42,500	30.8	12.7
Brick making	small	--	--	--	90,000	--	--	--
Bakeries	small	4,200	--	--	96,500	--	--	--
Miscellaneous	small	10,000	2,702	13,350	6,900	--	--	29.6
TOTAL	900 Kerosene 750 LPG	41,800	6,265	104,331	223,000	472,500	173.3	314.1

1 Assumes 3 tons bagasse = 1 ton furnace 0.7, 15% thermal efficiency; total bagasse production was 915,000 tons.

2 Total gasoil consumption including transport was 16,000 tons.

Source: NEA Surveys and Petroleum distributing Company sales data.

TABLE 17

INDUSTRY ENERGY CONSUMPTION 1980(BY REGION)

Fuel / Region	Kerosene and LPG Tons	Gasoil Tons	Diesel Tons	Furnace Oil Tons	Wood Tons	Crop Residues Tons	Purchased Electricity Gwh	Generated Electricity Gwh
Eastern	small	17,800	--	13,915	19,100	87,000	8.5	78.3
Northern	small	1,600	4,993	15,319	18,000	--	.4	11.7
Khartoum	small	8,500	872	24,473	68,200	--	114.5	16.7
Central	small	10,000	400	50,381	42,200	343,000	118.4	206
Southern	small	small	--	--	23,100	--	--	.1
Kordofan	small	1,300	--	243	35,300	23,000	--	1.5
Darfur	small	600	--	--	17,050	18,900	.7	.4
TOTAL	900 Kerosene 750 LPG	39,800	6,265	104,331	222,950*	471,900	242.5	314.4

1. Assumes 3 tons bagasse = 1 ton furnace oil, 15% thermal efficiency; total bagasse production was 915,000 tons.

2. Total gasoil consumption including transport was 16,000 tons.

Source: NEA surveys and Petroleum distributing company sales data.

* Data may not correlate precisely with Table 18, due to difficulties in assigning transported fuel to a particular region.

TABLE 18

CAPACITY UTILIZATION IN SELECTED INDUSTRIES 1980

Industry	Designed Capacity	Actual Production	Utilization %
Sugar	640,000 Tons	111,000 Tons	17%
Cement	300,000 Tons	173,000 Tons	58%
Textiles Spinning Only	16,800 Tons	5,565 Tons	33%
Other Textiles Public	53.8 million meters	11.1 million meters	21%
Private	236 million meters	87.3 million meters	37%
Flour	381,000 Tons	235,000 Tons	62%
Oil[1]	1.03 million Tons	.495 million Tons	48%

[1] Cotton Seed, groundnut, sesame

Sources: Ministry of Industry Statistics Department and Public Industrial Corporation's unpublished data; Ministry of Finance and National Economy Economic Survey 1980/81

TABLE 19

FUEL USE IN THE TRANSPORT SECTOR, 1980 ('000 TONNES)

	GASOIL	FURNACE OIL	KERO JET	BENZENE & AVGAS	TOTAL
Rail	26,600(1)	21,900			48,500
River	2,300(1)				2,300
Pipeline	2,700				2,700
Domestic Air	--	--	27,000	6,100	33,100
Int'l Air			17,600		17,600
Heavy Trucks	35,200				35,200
Medium Trucks	176,200				176,200
Khartoum Buses	10,300				10,300
Other Areas, Buses	31,500				31,500
Other Pass. Vehicles Khartoum				121,000	121,000
Other Passenger Vehicles Outside Khartoum				70,000	70,000
	284,800	21,900	44,600	197,100	548,400

(1) Fuel utilized is diesel oil, a mixture of gasoil and furnance oil.

Source: NEA Transport Committee, Farouk Shalaan, NEA (1), (2), (3)

freight from the Sudan Railway Corporation (whose ton-km dropped 40%, to 1908 million, from 1970/71 to 1979/80) to private sector heavy truck transport (which increased from close to zero to 1600 million ton-km over the same period). A second important cause is the growth in passenger vehicles: over the 10-year period 1969-1979, the average annual increase in vehicle registrations was 10% for private passenger cars, 11.7% for taxis, and 8.5% for taxis. As a consequence, benzine consumption rose 8.1% per year over this period and since then (1979-1981) has risen 11% per year--despite a system of allocation by coupons, long lines at service stations, and a remarkable 49% decrease in fuel per vehicle since 1972 (Table 20).

Table 21 illustrates the wide variation in fuel use efficiency among the various modes of freight transport, with the pipeline and rail transport being the most energy-efficient. The very high figure for river transport (which in many countries is quite energy efficient) presumably reflects the state of the River Transport Corporation, which has experienced a drop of 30% in freight moved over the past decade and has very low load factors, and may also reflect diversion to other uses.

Not reflected in the tables is the trend to replace steam locomotives (using furnace oil) with diesel engines using gasoil. SRC's diesel engines use 10 grams of gasoil per ton-km. The rate for furnace oil is 7-11 times that. Steam locomotives in 1980 accounted for about 10% of total ton-km. If in 1980 the switch to diesels had been complete, total railroad fuel use would have dropped 38%, although at a cost of a 13% rise in consumption of gasoil.

Other

Other Commercial, Government and Services establishments consumed 218.2 thousand TOE primary energy and 75.7 Gwh of electricity in 1980. The bulk of the primary energy used is in the form of wood and charcoal. Restaurants and tea houses account for 60% of charcoal consumption while beer houses, largely in the South and West, account for 80% of firewood used in this sector. Electricity (11% of PEWC sales) is accounted for by hotels, hospitals, government and private offices, urban retail establishments and a broad range of other users (Table 22).

Construction and oil exploration consumed an estimated 34.3 thousand TOE primary energy, or 33 thousand tons of gasoil. Electricity sales are included in the commercial sector. Data is based on government statistics and a survey of 26 major firms. Not included in this category are an estimated 22,000 tons of gasoil used for transport by oil exploration and construction companies.

TABLE 20

BENZINE AND GASOIL CONSUMPTION FOR THE ROAD TRANSPORTATION SECTOR
(FREIGHT AND PASSENGER SERVICES)

Year	Gasoil Consumption(1)		Benzine Consumption(1)		#of Licensed Motor Vehicles(2)				Gasoil Motor Vehicles(4)		Benzine Motor Vehicles(5)	
	Total (M.T.)	Road Transport. (MT)	Total (M.T.)	Road Transport. (MT)	Pass. Cars(3)	Buses	Lorries	Boxes and Vans	Total Number	Ave. Cons. (MT/yr/car	Total Number	Ave. Cons. (MT/yr/car)
1972	285,602	121,452	147,869	147,869	29,407	2782	15,813	4,955	34,362	3.53	18,595	7.95
1973	314,260	125,704	157,812	157,812	31,663	3084	20,088	6,556	38,219	3.29	23,172	6.81
1974	314,837	126,250	146,462	146,462	38,143	3137	22,908	6,700	44,843	2.82	26,045	5.62
1975	298,682	119,772	141,233	141,233	40,488	3274	30,462	9,385	49,843	2.4	33,736	4.19
1976	352,480	144,164	141,510	141,510	44,631	2952	29,465	10,699	55,330	2.61	32,417	4.37
1977	426,310	167,966	153,804	153,804	52,950	5771	31,100	11,766	64,716	2.6	36,871	4.17
1978	399,490	156,600	165,256	165,256	64,915	6013	33,559	N.A.	N.A.	N.A.	39,572	4.18
1979	433,962	172,714	163,638	163,638	66,817	4973	35,072	N.A.	N.A.	N.A.	40,045	4.09

(1) Source: GPC. Fraction of gasoil and benzine consumption for road transportation was derived from the Shell Company of the Sudan Ltd estimates for gasoil and benzine consumption for 3 sectors (road transportation, Ind. and Agr, River and railways).

(2) Source: Transport Statistical Bulletin (1977, 1978/79, and 1980/81), Transport and Communications Section, Ministry of National Planning.

(3) Traffic Police Dept. in Khartoum estimated that 27% of the passenger cars are not paying license fees and they are not included in the table together.

(4) Gasoil motor vehicles are assumed to form the bulk of the buses and lorries fleet.

(5) Benzine motor vehicles are assumed to form the bulk of the passenger cars, box cars and van fleet.

TABLE 21

FREIGHT TRANSPORT, 1980

	Tonne-Kms 10^6	%	Gasoil '000 tonnes	Furnace Oil '000 tonnes	Fuel Use Rate grams/ ton-Km
Rail	1908	25	26.6	21.9(1)	10
River	48	-	2.3	-	42
Pipeline	300	4	2.7	-	9
Heavy Trucks	1600	21	35.2	-	22
Small/Medium Trucks	3641	49	176.2	-	33-60(2)
Air	7	-	(3)		
	7504	99	243.0	21.9	

(1) A planned phase-out of furnace oil, steam-powered locomotives to diesel engines will lead to large oil savings. A total replacement of 1980 use levels corresponds to 29.7 thousand tonnes of gasoil equivalent, of which 24.1 thousand correspond to freight and 5.6 thousand tonnes correspond to passenger rail.

(2) The lower usage rate corresponds to primarily paved routes, the higher rate to dirt tracks.

(3) Fuel use by Sudan Airways is included entirely under passenger transport.

TABLE 22

GOVERNMENT, COMMERCIAL AND SERVICES ENERGY CONSUMPTION 1980

Fuel Sub-sector or end use	Gasoil Tons	Purchased Electricity Gwh	Generated Electricity Gwh	Wood Tons	Charcoal Tons
Petroleum Exploration[2]	10,000	--	u.k.	--	--
Round & Building Construction[2]	23,000	--	u.k.	--	--
Gov't & Comm'l Buildings	800[3]	75.7	2.4	--	--
Eating Places and Laundries	--	small	--	259,340	135,810
Water Pumping	8,000	17.0[1]	--	--	--
Street Lighting	--	8.8	--	--	--
Utility Use	--	8.4	--	--	--
TOTAL	41,800	109.9	2.4+	259,340	135,810

[1] Thought to be 67% of inter-departmental tariff throughout Sudan, as is the case in Khartoum.

[2] Estimated gasoil consumption including the portion counted in transport sector is 18,700 Tons for Exploration and 58,300 Tons for Construction.

[3] Fuel for generators.

Source: NEA Surveys and petroleum distribution company sales data.

u.k.: unknown

Energy Resources And Production/Conversion

Oil and Petroleum Products

Tables 23 and 24 show quite clearly both the trends in the Port Sudan Refinery (owned jointly by Shell Oil Co., Sudan and the Government of Sudan) throughput and the growing proportion of imported refined products in Sudan's total petroleum consumption. There have been two distinct periods in refinery operation: 1965-73, and 1974 to the present. During the first period, refinery throughput was raised from nearly 600,000 MT per year to 1.14 million MT in 1973. Very limited quantities of refined products were imported directly into Sudan during this period. This changed in 1974 when refinery throughput began a slow decline that has continued to the present. The proportion of refined product imports to total petroleum imports has risen from zero in 1972 to 28% in 1981. In 1981, imported gasoil constituted 46% of total gasoil and imported benzine accounted for 36% of total benzine sold in Sudan (Table 24). Total quantities of all petroleum imports rose a modest 1.1% during the 1972-1981 period; but that picture is misleading unless one examines the product mix of both refined imports and Port Sudan Refinery throughput. Again, Table 23 shows quite clearly that refinery throughput increasingly shifted toward refining middle and higher distillates(i.e., gasoil and benzine). Fuel oil (long residual) and kerosene throughput decreased proportionately to declining refinery intake and increased gasoil and benzine throughput. Both kerosene and long residue are the blend stock for furnace oil. "Diesel" (light fuel oil) is a blend of gasoil (30%) and 1500" furnace oil, used primarily by the railways, industry, and for river transport.

Refinery throughput has dropped over the past several years for three major reasons. First, the refinery is now twenty years old and its throughput capacity has decreased accordingly. Second, general port congestion, power outages,and other problems at times have disrupted scheduled tanker deliveries of crude oil. Third, and most important, Sudan has experienced increasing difficulties in financing crude oil imports as its balance of payments position has worsened. Table 23 shows that again, in 1979, refinery throughput declined at a time of rapidly escalating world crude prices. The nominal prices paid by Sudan nearly doubled between 1976, and 1980 and continued to rise (Table 25).

However, crude imports in 1981 were the lowest since the late 1960's, and imports of crude during the first half of 1982 were 20% lower than in 1981. Moreover, these imports in 1982 included a grant of 300,000 MT of crude from the Government of Saudi Arabia. During 1981, the time between GPC application to the Bank of Sudan for opening a letter of credit(LC) to the actual LC opening through a commercial bank averaged over 21 days and the time between LC application and actual delivery averaged over 37 days. On six different occasions(out of 19 letters of credit opened for crude) in 1981, it took over one month to open a letter of credit and in one case it took 50 days!

Opening LC's for refined imports takes even longer than for crude, averaging one month in 1981. Deliveries averaged a month and a half after GPC applications for opening letters of credit in 1981. In one case it took nearly three months (84 days) to open an LC and over three months from the GPC's application to actual delivery at Port Sudan. Yet, refined product imports continue to grow in

TABLE 23

PORT SUDAN REFINERY LIMITED

PORT SUDAN
CRUDE OIL AND REFINED PRODUCTS THROUGHPUT(1972-1980)

Year	Butane	Benzine	Kerosene	Gasoil	Long Residue	Ref. Fuel	Total Intake
1972	2,370	147,869	161,374	285,602	452,822	49,653	1,099,690
1973	2,773	157,812	166,379	305,673	452,558	54,156	1,139,351
1974	2,559	146,075	100,757	289,949	435,469	49,652	1,024,461
1975	2,927	141,233	159,946	286,682	458,659	54,552	1,103,999
1976	3,592	136,177	159,115	267,257	454,795	56,650	1,077,586
1977	3,656	138,683	155,194	256,060	459,177	47,582	1,060,352
1978	4,525	145,006	144,824	264,739	424,793	47,067	1,030,954
1979	3,962	138,081	119,811	243,753	381,004	36,838	923,449
1980	4,779	132,515	130,874	354,472	373,441	42,519	1,038,600

TABLE 24

COMPARISON OF PORT-SUDAN REFINERY THROUGHPUT MIX
(BENZINE, KEROSENE, GASOIL) TO IMPORTED REFINED PRODUCTS: 1972-1981

YEAR	BENZINE			KEROSENE			GASOIL			IMPORTED REFINED PRODUCTS AS % OF TOTAL PETROLEUM (CRUDE AND REFINED) PRODUCTS
	REFINED P. SUDAN M.T.	IMPORTED BENZINE M.T.	IMPORTED BENZINE AS % TOTAL BENZ. %	REFINED P. SUDAN M.T.	IMPORTED KEROSENE M.T.	IMPORTED KEROSENE AS % TOTAL KERS. %	REFINED P. SUDAN M.T.	IMPORTED PROD. M.T.	IMPORTED GASOIL AS % TOTAL GASOIL %	%
1972	147,869	0	0	161,374	0	0	285,602	0	0	0
1973	157,812	0	0	166,379	3,336	02%	305,673	8,587	03%	01%
1974	146,075	387	0	100,757	0	0	289,949	24,888	08%	02%
1975	141,233	0	0	159,946	0	0	286,682	12,000	04%	01%
1976	136,177	5,333	04%	159,115	3,388	02%	267,257	85,223	24%	08%
1977	138,683	15,121	10%	155,194	9,800	06%	256,060	170,250	40%	15%
1978	145,006	20,250	12%	144,824	19,000	12%	246,474	153,016	38%	14%
1979	136,081	27,557	17%	119,811	29,278	20%	243,753	190,209	44%	23%
1980	132,515	49,666	27%	136,874	11,231	08%	354,472	225,699	39%	23%
1981	129,315	72,554	36%	39,679	10,889	28%	294,663	249,156	46%	42%

SOURCE: GPC

TABLE 25

TOTAL VALUE (NOMINAL)* OF CRUDE AND REFINED PETROLEUM PRODUCT IMPORTS
(1972-1981)

Year	(A) Value of Total Crude Imports (000$)	(B) Value of Total Ref. Prod. Imports (000$)	(A+B) Total Value all Petrol Imports (000$)	(B/(A+B)) % Value of Ref Imports to Total Petrol Imports
1972	17,365	0	17,365	0%
1973	22,490	687	23,177	1%
1974	85,291	2,627	87,918	3%
1975	95,381	3,953	99,334	4%
1976	95,088	12,479	107,567	12%
1977	103,893	26,061	129,954	20%
1978	100,907	31,233	132,140	24%
1979	111,620	48,916	160,536	30%
1980	211,111	101,321	312,432	32%
1981	215,869	128,792	344,661	37%

* C & F, Port Sudan

Sources: Shell Oil Company, Port Sudan Refinery, Ltd, GPC.

both absolute terms and relative to crude imports. Several forces seem to be at work here. The GPC draws up an annual schedule(frequently updated) for deliveries of crude to the refinery. This schedule is based upon the GPC's assessment of projected needs throughout the year (and these needs vary, particularly with the agricultural seasons). Over the past two years, the GPC has applied to the Bank of Sudan for opening an LC an average of three weeks prior to their delivery schedule date, but, as shown in Table 26 deliveries very rarely occur within the three week margin set by the GPC. Moreover, the GPC has no idea at any given time whether the time between application for an LC and actual delivery will occur in more than or less time than the three week margin they have chosen. That is, they may receive a crude shipment within one week after application, or two months after application. Moreover, two pending LC's may open during the same week.

Clearly, then, one of the prime causes for varying and decreasing refinery throughput over the past several years lies with the GPC's inability to open LC's in a manner which would allow for regular, scheduled deliveries. Frequent refinery shutdowns and start-ups lead to decreased refinery (and pipeline) operating efficiency, less throughput and the need for more storage facilities. Frequent disruptions in refinery throughput also lead to the need for more refined product imports as a hedge against those disruptions. It seems apparent that until some method is found for securing sufficient foreign exchange for regular supplies of crude to the refinery, little improvement in refinery performance can be expected.

At present, a direct national economic evaluation of costs(in foreign exchange terms) of crude processed through the refinery versus costs of imported refined products in foreign exchange terms reveals that increasing crude imports would not lead to any net foreign exchange savings. This results from the fact that, at present, Sudan consumes less than half of its residual oil output(3500" residual) and must, in turn, re-export that fuel at a price of approximately $100 less per metric ton than it pays for crude. However, as the present study shows, within the next two years, Sudan will cease to export any residual and, at current refinery production levels, will in fact become a net importer of residual fuel.

Petroleum Products Pricing and Allocation

As world oil prices have risen since 1973, the government has pursued a policy of setting domestic petroleum product prices at a level just adequate to cover import costs (at official exchange rates) and domestic processing and distribution costs. With imports limited due to the country's increasingly severe foreign exchange constraints and with a generally overvalued pound at the official exchange rate, these price levels increasingly have been insufficient to "clear the market" (that is, to equate supply and demand). While no precise estimate is possible, the prevailing view in the energy sector is that petroleum product consumption increasingly has diverged from effective demand since 1973 and that, across the range of petroleum products, available supply currently satisfies little more than half of effective demand at official prices.

This imbalance of supply and demand has forced the government into the business of allocating petroleum products. Thus, since the early 1970's the government has taken an increasingly active role in the country's petroleum affairs. The government is involved in purchasing crude, allocating products, and even distribution, as in the case of kerosene mentioned earlier (in the households section). The General Petroleum Corporation (previously the Petroleum General

TABLE 26

SAMPLE SCHEDULE OF PERIODS BETWEEN GPC APPLICATIONS TO OPEN LETTERS OF CREDIT TO ACTUAL CRUDE DELIVERIES: 81/82

Date GPC Apply to Open LC	GPO Schedule for Arrival Port Sudan	Date LC Opened	Date Crude Arrived Port Sudan	Time From LC Appl. to LC Opening (Days)	Time from LC Appli. to Crude Delivery (Days)
May 12	June 4-8	June 15	July 8	34	57
June 11	June 22-26	July 15	Aug. 2	34	52
July 13	July 26-30	July 20	Aug. 9	7	27
July 22	Aug. 6-10	Aug. 18	Sept. 3	27	43
July 28	Sept. 1-5	Sept. 2	Sept. 28	36	62
Aug. 25	Sept. 17-21	Sept. 23	Oct. 21	29	57
Oct. 9	Oct. 29-30	Oct. 29	Nov. 23	20	45
Nov. 23[1]	Dec. 2	Dec. 1	Dec. 6	8	13
Jan. 11[1]	Jan. 18	Jan. 16	Jan. 24	5	13
Feb. 18[1]	Feb. 20	Feb. 20	Feb. 22	2	4

Source: GPC

[1] These three shipments were purchased from Egypt through official channels; hence time from application for opening LC to actual delivery at Port Sudan was shorter than usual.

Administration and earlier the Petroleum Department in the Ministry of Industry) has grown rapidly over the past decade. It is the agency primarily responsible for acquiring imports of both crude and refined products as well as working closely with the Bank of Sudan and the Ministry of Finance to obtain funds for those imports. The GPC is also the prime government agency which, in association with customers, other government agencies (national, regional and provincial), and the private distribution companies, determines the general allocation of petroleum fuels to all customers in Sudan. It uses various criteria, such as the end-user's contribution to the national economy or the importance of a consumer to national security or public welfare, for determining these allocations. However, one of the key factors that has hindered the GPC's maintenance of an effective, predictable allocation system is the serious constraint on petroleum imports due to lack of foreign exchange. Seasonal petroleum needs vary markedly due to the key role agriculture plays in the national economy. While consumption of petroleum goods in the agricultural sector is relatively small (8% in 1980), NEA surveys and interviews of many key people in the agriculture and transport sectors yield estimates that a significant fraction of all fuel consumed in the transport sector is used for in-field transport of goods, people and services (e.g., supplying water to field workers is very important in the mechanized agricultural sector, particularly in Kassala Province, where there is little ground water, hence, few wells) in the agriculture sector. Moreover, post-harvest transport of agricultural goods to processing points (e.g., cotton gins), markets and Port Sudan consumes a substantial proportion of the fuel allotted to the transport sector. Therefore, given the importance of directly or indirectly supplying petroleum fuels to the agricultural sector, it is understandable why the GPC faces so many difficulties in allocating petroleum under a supply-constrained situation. There is little available storage at the disposal of the GPC (this should be rectified by 1984 when the two large petroleum fuel storage complexes at Hala and Port Sudan are completed) to offset the vagaries of Sudan's current financial situation to allow for these seasonal petroleum requirement variations.

As is to be expected in any country relying heavily on price controls and allocation systems, a vigorous black market for petroleum products has developed. NEA and joint NEA-GPC surveys over the past year show thriving black markets for most petroleum goods in areas away from the Khartoum-Port Sudan road axis. These surveys suggest that levels of petroleum product use in outlying regions are significantly higher than these shown in a table of "official" consumption (Tables 27 and 28), which indicate an increasing concentration of consumption in the Eastern-Khartoum-Central area from 1970 to 1980. For example, a decline in petroleum products consumption for the Kordofan region is shown in these figures despite economic growth in this area. The implication is that a significant (and increasing) amount of petroleum products is reaching the outer regions through unofficial, unrecorded channels emanating from sources in the Central and Eastern regions. As has been mentioned earlier in this chapter, these sources are likely to include large agricultural schemes and other locations where allocations greatly exceed consumption.

Black market prices vary widely from place to place and in the same place from one point of time to another. Goods which command high black market price premiums are gasoil, benzine and kerosene. Butagaz (LPG), furnance and diesel do not appear to find their way into the black market, primarily because of the physical limitations inherent in handling them. It is safe to say that the further one gets away from the Khartoum-Port Sudan road, the higher the black market prices

TABLE 27

PETROLEUM PRODUCTS CONSUMPTION 1970
(TOE)

Region / Fuel	L.P.G.	Benzene and Avgas	Kerosene and Jet	Gasoil	Diesel	Furnace Oil	TOTAL
Eastern	--	11,876	8,133	47,590	7,394	12,010	87,003
Northern	--	4,767	8,029	37,440	4,610	27,830	82,676
Khartoum	--	52,145	23,321	73,600	11,301	100,637	261,004
Central	--	18,522	11,762	87,558	3,988	40,090	161,920
Southern	--	5,166	1,384	5,387	296	3,917	16,150
Kordofan	--	5,093	4,482	22,090	367	14,246	46,278
Darfur	--	3,255	2,174	8,549	--	662	14,640
TOTAL	--	100,824	58,285	282,214	27,956	199,392	669,671

Source: G.P.C.

TABLE 28

PETROLEUM PRODUCTS CONSUMPTION 1980
IN TOE

Region \ Fuel	LPG	Benzine[1] Avgas	Kerosene Jet A-1	Gasoil	Diesel	Furnace Oil	Total
Eastern	760	26,880	6,032	96,750	9,483	13,358	153,263
Northern	42	5,250	1,144	34,017	7,652	18,428	66,533
Khartoum	4,713	133,980	4,600	134,806	3,156	61,124	342,379
Central	34	25,515	3,224	130,979	524	48,534	208,810
Southern	--	3,255	--	16,120	--	--	19,375
Kordofan	--	4,200	1,560	23,088	--	1,179	30,027
Darfur	--	1,575	832	18,928	--	--	21,335
Remainder*	0	6,300[5]	47,320[2]	76,336[4]	0	21,024[3]	150,980
TOTAL	5,549	206,955	64,712	531,024	20,815	163,647	992,702

* not distributed by region because of difficulty in disaggregating totals

1 estimated by Farouk Shalaan
2 primary Jet Fuel
3 Sudan railways
4 Sudan Railways, river transport, pipeline, commercial, Govt & services, construction & oil exploration
5 Includes aviation gasoline, fuel for small generators.

Source: NEA estimates. Regional distribution estimates are judged to be less precise than those developed by Sector.

at any time. While prices do vary widely, they have shown sharp increases over the past three years. The largest black market is for gasoil, as this is the fuel most widely used and in highest demand in the country.

Electricity/Power

The Sudan's public electricity system consists of one major supply and distribution system, the Blue Nile Grid (BNG), a much smaller system (the Eastern grid), and a number of small, isolated systems serving several major and many small cities and towns. Hydropower provides 63% of the power generated by the Sudan's public systems. The Blue Nile Grid is the largest system in the country, with over 83% of total public generating capacity. The BNG presently has an actual maximum generating capacity of some 192 MW although in effect this capacity is reduced to less than 170 MW because of generating problems at Burri Power Station. The BGN is comprised of 120 MW hydro-generation at Roseires, 15 MW hydro-generation at Sennar, and the remaining capacity at thermal plants at Burri (steam and diesel, maximum 1982 output 18 MW), Kilo X outside Khartoum (gas turbine, 10.0 MW), and several small thermal units with varying output in Wad Medani (2.65 MW) and elsewhere (.392 MW). Kenana Sugar Corporation has supplied the BNG with a maximum of 13 MW during the summer months over the past two years. The BNG's hydro-electric generation capacity comprises just over 70% of total capacity. (Table 29.)

TABLE 29

BNG GENERATING PLANT ACTUAL CAPACITY (1982)

Location	Hydro Avail. Output (MW)	Thermal Avail. Output (MW)	Total Avail. Output (MW)
1. Roseires P/S	120.000	0.392	120.392
2. Sennar P/S	15.000	--	15.000
3. Burri P/S	--	17.980	17.980
4. Kiro X P/S	--	10.000	10.000
5. Wad Medawi	--	2.650	2.650
Total	135.000	31.022	166.022

Source: NEC Staff Report, March, 1982.

The Eastern Grid is comprised of 10 MW of hydro-generation at the Khashim El-Girba Dam and an additional 1.3 MW thermal generation in Kassala Town. Port Sudan has the next largest system, with generation capacity of some 7.5 MW (although the system rarely achieves maximum generation). A remaining 18.9 MW maximum generating capacity is spread throughout the country at isolated stations ranging from 6.9 MW in Atbara (Nile Province) to 0.2 MW in Malakal (Upper Nile Province).

Energy sales to customers on the BNG totaled 600 Gwh in 1980 or some 74% of a total of 812 Gwh generated that year. Residential consumers comprised 37%, industrial customers comprised 39%, large agricultural customers (large electricity-powered irrigation pumps) comprised 12%, and commercial and other customers comprised some 9% of total electricity sales in 1980. Some 87% of total electricity sales occurred in the Khartoum and Central regions, while the Southern, Kordofan and Darfur regions accounted for only 2% of electricity sales (Table 7).

The NEC and Sir Alexander Gibbs/Merz and McLellan (consultants to the NEC, for Power III and IV Projects) estimate that total demand has grown an average 9% per year since 1970. All agree that there is considerable surpressed demand as evidenced by frequent imposed power cuts ("load shedding"). Load was shed on the BNG 130 times an average of 18.1 MW shed each time) in 1980 and 203 times (an average of 17.9 MW shed) in 1981. There were 29 "blackouts" in 1980 and 20 in 1981. All told, the NEC estimates that some 35 Gwh worth $1.9 million (only in electricity sales) were lost in 1980 and 1981. This has led to a rapid increase in industrial and non-industrial self-generating capacity. The costs to the economy due to power disruptions over the past two years are very substantial and warrant further study. NEA studies reveal that approximately 49 MW of installed self-generation capacity exists along the BNG (excluding the sugar industry) with industrial capacity at over 38.0 MW and non-industrial capacity totalling over 11.0 MW. Despite three major Power Development Programs (Power I, II and III) since the mid 1960's, generation capacity has lagged behind demand growth. Several factors have mitigated against the NEC's ability to match demand with generation capacity: the high cost of large-scale infrastructure programs (particularly hydo-power development), deferral of several large-scale thermal generating units which PEWC engineers and their consultants initially recommended in 1962 to be built prior to the commissioning of the first turbine at Roseires in 1970 and substantial delays in several large Power II thermal stations (e.g., 15 MW diesel in Port Sudan and 5 MW in Juba) which are still under construction as the NEC prepares its program for Power IV.

The time and costs required to implement large-scale hydro-power projects, as well as the Blue and Main Niles' wide seasonal stream flow variations, make hydropower development less attractive than thermal power alternatives. Post-Roseires expansion in generating capacity has been oriented almost exclusively toward thermal power stations. As discussed in a later section, this has important implications for future petroleum products demand.

Self-Generation

Private self-generation capacity (excluding the sugar industries) has grown an estimated 250% since 1978 (at an annual rate over 70%) to approximately 110 MW (real capacity), or nearly half of the NEC's real generation capacity of 230 MW. In 1979, the PEWC (now the NEC) eased restrictions on the licensing of private generators while the Ministries of Finance and Commerce eased generator import license restrictions. Consequently, private industrial self-generation grew

some 60% in the 1979-81 period while residential and commercial self-generation increased ten-fold during the same period.

The provinces which have witnessed the greatest growth in industrial self-generation are Khartoum (31.0 MW), Red Sea (26.56 MW) and Gezira (3.35 MW). Nearly all private industries in Port Sudan generate their own electricity. The Nile Province now has some 14.2 MW industrial self-generation capacity, with the addition of the new 10 MW power plant at the Maspio Cement Factory in Atbara.

NEA surveys show an estimated 10.4 MW of non-industrial private self-generation in Khartoum alone (Table 31). The bulk of this capacity is found in foreign (expatriate) residences, some Sudanese residences, foreign embassies and companies, hotels, large offices (mainly banks), and small commercial establishments. This private, non-industrial self-generation has grown from virtually zero in 1978. Very few of these self-generating units are licensed with the NEC. An additional 13.5 MW of non-industrial self-generating capacity has been installed throughout the rest of Sudan by rural and urban councils, small cooperatives and to a lesser extent private sources for personal use.

The sugar industry--Kenana, El-Guneid, Assalaya, Sennar and New Halfa--has an estimated "real" generating capacity of some 68.12 MW. Bagasse supplies an estimated 62% of the fuel (TOE) used for such self-generation (Table 30).

TABLE 30

SUGAR INDUSTRY SELF-GENERATION

Factory	Rated Capacity (M.W.)	Estimated "Actual" Capacity (M.W.)
Sennar	13.0	9.36
Assalaya	13.0	9.36
El-Guneid	6.8	4.7
New Halfa	6.8	4.7
Kenana	40.0	40.0
	79.6	68.12

TABLE 31

SELF-GENERATION CAPACITY

REGION	SECTOR	ESTIMATED "ACTUAL" CAPACITY (MW)
EASTERN[1]		
	Sugar	4.70
	Private Industry	21.15
	Public Industry	5.40
CENTRAL		
	Sugar	63.42
	Private Industry	3.50
	Public Industry	4.10
KHARTOUM		
	Private Industry	28.00
	Public Industry	3.14
	Residential, Commercial, Diplomatic, etc.	10.40
KORDOFAN		
	Public Industry	2.40
DARFUR		
	Public Industry	2.00
NORTHERN		
	Public Industry	14.20
SOUTHERN		
	Public Industry	2.00
SUDAN SUB-TOTAL	Rural/Urban Councils, Coops, etc.[1]	13.50
SUDAN TOTAL SELF-GENERATION		177.91

1 Because of lack of data, it is not presently possible to disaggregate total urban and rural council, cooperatives and other private self-generation in Sudan. Moreover, it has not been possible under the present project to estimate private residential self-generation in Port Sudan, although it may be as high as several megawatts installed capacity.

Forestry/Fuelwood

Estimates of forestry resources made in the 1950's and early 1960's by forestry experts (i.e., Hasek, Harrison and Jackson) and more recent estimates (based largely on Jackson's work) made by Mohammed El-Amin Mukhtar, Under-secretary of Energy and Mining and former head of the Forestry Administration's Utilization Section, remain the basis for discussion. However, little actual surveying of Sudan's forestry resources has been done over the past twenty years, and this has been an area of great uncertainty. Jackson estimated Sudan's total forested area as ranging from 455,000 km^2 to 585,000 km^2 (455,000 km^2 is roughly 20% of Sudan's total area). Recent studies (1982) commissioned by the NEA and conducted by the Forestry Administration using early 1970's Landsat photo-imagery yielded much higher estimates of both forested area and volume of wood than studies.

Previous studies estimated a total wood volume of approximately 1.3 billion cubic meters, or an average of some 28.6 m^3 per hectare of forested land, with actual yields ranging from over 150^3 per hectare in the high mountain forests of the South to a fraction of cubic meter in the desert areas of Northern Sudan. Preliminary results of project-funded Forestry Administration ground surveys conducted in the three central provinces of Kassala, Blue Nile and White Nile in April and May, 1982 are alarming. For example, average volume in even the more heavily forested areas of Southern Blue Nile is one-third of previous estimates (less than 9 m^3 per hectare). Preliminary data from these surveys are summarized in Tables 32 and 33. This data yields an estimate of total forest volume in Sudan of nearly 2 billion m^3, or almost 700 million m^3 more than Jackson's last estimate in 1960 (which he felt was correct within a 50% margin of error).

The Landsat and ground surveys reveal clearly that forest distribution within the twelve northern provinces of Sudan is heavily skewed, with the provinces of Southern Darfur and Southern Kordofan containing more forested area than all the other ten Northern provinces combined. Data from the 1982 ground surveys, regardless of the margin of error, reveal that the total forest volume in the three northern provinces of Kassala, Blue Nile and White Nile has dropped far below previous Forestry Department estimates and that the level of allowable cut permitting sustained-yield harvesting in these three provinces is less than one-tenth present off-take. When this data is compared to recent NEA household surveys, Forestry Administration utilization statistics (e.g., for building materials, legal charcoal production, and so on) and estimates of annual losses due to fire and over-grazing (Table 34), one is lead to the clear conclusion that this loss and consumption, if allowed to continue at present rates, will leave Central Sudan nearly devoid of forest lands within a decade.

Rising charcoal consumption has shifted the area of charcoal production south by an average of 15-20 kilometers per annum, with the rate increasing in the last five years (Figure 3). The bulk of all charcoal consumed in Khartoum in 1960 came from the northern Blue Nile Province and the area around Gedaref in Kassala Province. Today, the major centers of commercial charcoal production are around Damazin (and south) in the Blue Nile Province and in the southern reaches of Kassala Province; some charcoal reaching Khartoum comes from over 400 km away. Extension of all-weather roads has made many areas in these provinces accessible by truck for the first time. This is particularly true in the Kassala, Blue Nile and White Nile Provinces. Moreover, many areas previously under forests have been put under mechanized cultivation. An average of 350,000 feddans, or some 8,750 square kilometers, of dryland forest are being cut each year for mechanized

TABLE 32

FORESTRY RESOURCES IN SUDAN
BY PROVINCE AND REGION

REGION	PROVINCE	TOTAL AREA (HECTARES)	AVERAGE VOLUME (m^3/HECTARE)	TOTAL VOLUME (m^3)	ANNUAL ALLOWABLE CUT(m^3)
EASTERN[1]		2,748,065	2.55	7,007,855	234,602
	Red Sea	-	-	-	-
	Kassala	2,748,065	2.55	7,007,855	234,602
CENTRAL[1]		5,123,790	4.98	25,532,325	886,256
	B. Nile	4,957,440	4.90	24,313,794	831,198
	W. Nile	157,450	3.93	618,051	21,602
	Gezira	8,900	67.47	600,480	33,456
KHARTOUM[1]		5,000	60.00	300,000	30,000
KORDOFAN[1]		11,628,000	10.56	122,827,800	2,985,994
	S. Kordofan	11,628,000	10.56	122,827,800	2,985,994
	N. Kordofan	-	-	-	-
DARFUR[1]		17,693,300	26.97	477,199,800	9,587,083
	S. Darfur	17,693,300	26.97	477,199,800	9,587,083
	N. Darfur	-	-	-	-
NORTHERN[1]		-	-	-	-
	Northern	-	-	-	-
	Nile	-	-	-	-
Total Northern Region Scrub and Semi-Desert[1]		4,200,000	4.76	19,992,000	1,332,800
NORTHERN SUDAN SUB-TOTAL[1]		41,398,155	15.77	652,859,780	15,056,735
SOUTHERN		71,095,683	18.87	1,341,500,862	29,300,346
	Buhayrat	6,525,400	15.03	98,069,800	2,911,378
	Jonglei	11,863,900	3.76	44,643,700	2,097,915
	B. El-Ghazal	11,733,900	34.94	410,037,200	8,336,555
	E. Equatoria	10,818,150	18.18	196,632,396	4,328,640
	W. Equatoria	6,982,733	61.76	431,275,066	6,952,831
	Upper Nile	23,171,600	6.94	160,842,700	4,673,027
TOTAL SUDAN		112,493,838	17.73	1,994,360,642	44,357,081

1 Forestry Administration sources and Moh. El-Amin Mukhtar estimate the total area of desert and semi-desert scrub and brush wooded area at approximately 4,200,000 hectares, with a total growing stock of 19,992,000 m^3, an average growing stock volume per hectare of 4.76 m^3, and an annual allowable cut of approximately 1,332,800 m^3. These resources are scattered and are found primarily in Northern Kordofan and Darfur, Northern, Nile, Khartoum and Red Sea Provinces. Because of the inability to assign these resources to particular provinces, all estimates are included in both Northern Sudan sub-totals and in the estimate of Sudan's total forestry resources.

Source: NEA and Forestry Administration.

TABLE 33

HOUSEHOLD WOODFUELS BALANCE
BY PROVINCE AND REGION[1]
(in '000 m^3 Growing Stock Equivalent)

REGION	PROVINCE	HOUSEHOLD CONSUMPTION	ANNUAL ALLOWABLE CUT	REGIONAL BALANCE
EASTERN		6,048	457	- 5,591
	Red Sea	1,419	-	
	Kassala	4,629	235	
CENTRAL		15,153	1,108	-14,045
	Blue Nile	4,059	831	
	White Nile	4,266	22	
	Gezira	6,828	33	
KHARTOUM		4,845	222	- 4,623
KORDOFAN		11,445	3,208	- 8,237
	S. Kordofan	5,463	2,986	
	N. Kordofan	5,982	-	
DARFUR		12,180	9,809	- 2,371
	S. Darfur	7,173	9,587	
	N. Darfur	5,007	-	
NORTHERN		2,829	222	- 2,607
	Northern	1,095	-	
	Nile	1,734	-	
NORTHERN SUDAN SUB-TOTAL		52,500	15,026	-37,474
SOUTHERN		15,072	29,301	+14,229
	El-Buhayrat	1,464	2,911	
	Jonglei	420	2,098	
	B. El-Ghazal	3,801	8,337	
	E. Equatoria	4,608	4,329	
	W. Equatoria	2,481	6,953	
	Upper Nile	2,298	4,673	
TOTAL SUDAN		67,572	44,327	-23,245

[1]Note: Estimates of total growing stock of desert and semi-desert scrub and bush for Northern Sudan yield a total volume estimate of 1,332,800m^3. For illustrative purposes and due to the impossibility, at present, of scientifically distributing this growing stock among the various provinces, one sixth of the total(i.e., 222,000m^3) is assigned to each northern region's total volume estimate. This figure would be higher in some regions(e.g., Kordofan and Darfur) and lower in other regions (e.g., Northern and Eastern).

Source: NEA, Forestry Administration and Statistics Dept.

TABLE 34

FORESTRY/WOOD CONSUMPTION AND LOSS: 1980

CONSUMPTION/LOSS	WEIGHT '000 MT		GROWING STOCK VOLUME EQUIVALENT '000 m^3	
Firewood:(1) Total	8,312		24,937	
(Households)		7,830		23,490
(Commercial, Services, etc.)		259		778
(Industry)		223		669
Charcoal:(1) Total	2,585		46,527	
(Households)		2,449		44,082
(Commercial, Services, etc.)		136		2,445
Fire Losses(2)	250		750	
Over-Grazing(2)	290		870	
Mechanized Agri-Expansion(3)	363		1,090	
Traditional Shifting Cultivation(2)	220		660	
Other Causes(Bldg. Poles, Lumber, etc.)(2)	170		510	
Total Growing Stock Loss and Consumption(m^3)			75,344	

(1) NEA, Statistics Dept. Surveys
(2) NEA and Forestry Administration estimates.
(3) Land under mechanized cultivation increased by approximately 721,000 feddans(302,820 ha) in 1980/81. Assuming an estimated 4 m^3 growing stock hectare yields a growing stock loss of 1,211,280 m^3 or 403,760 MT for that year. Finally, assuming that 10% of the wood thus cleared for mechanized agriculture was used for charcoal and firewood(discussions with Forestry officials reveal that this is a very high estimate as most trees cleared for mechanized agriculture are merely burned in place) this yields an estimated loss due to mechanized agriculture of some 363,384 MT or approximately 1,090,152 m^3 in 1980.

Sources: Mechanized Farming Corp., NEA, Forestry Administration.

agriculture. This implies a loss of some 588,000 cubic meters of growing stock each year (assuming a conservative estimate of 1.68 m^3/feddan). Very little, not more than one tenth, of this cleared wood is converted to charcoal or used for domestic fuelwood. Afforestation of land later abandoned under this type of agriculture is meager. The Forestry Administration estimates that not more than 68,000 feddans (28,560 ha) of land under mechanized rainfed agriculture have been afforested since 1960. Natural regeneration of forests on land with rainfall below the 300mm rainfall isohyte (Figure 4) is extremely slow and can be halted completely if erosion or grazing are not controlled. Of more concern is the expansion of mechanized rainfed agriculture and medium to large-scale charcoal production into the Upper Nile, and Southern Kordofan and Darfur Provinces. In these areas, two factors are at work which would make clear cutting of forests in the manner (uncontrolled) or the scale (extensive) of Kassala and Blue Nile ecologically and eventually economically disastrous for the nation. First, the soil is extremely sandy (unlike Kassala or Blue Nile, for instance, where clay soils prevail); once forests are cut and the soil deep plowed, the delicate surface and sub-surface soil balance is destroyed, thereby leading to rapid wind erosion unless great care is taken to leave planned wind breaks in select areas around farms and schemes. Second, these areas are extremely important grazing grounds for large numbers of cattle during the dry season, and many indigenous tree species provide much of the cattle's fodder during these times. Foresters estimate that if land clearing methods which have prevailed in Kassala and Blue Nile are applied to Southern Kordofan or the Upper Nile, they fully expect extensive desertification to proceed more rapidly there than in any other part of Sudan.

Clear-cutting for agriculture and over-cutting for charcoal, fuelwood and other purposes has further lowered the yields of woodlands in present charcoal producing areas. An ever increasing proportion of inferior wood species are being used in charcoal manufacturing thereby requiring more wood to be cut to yield the same amount of charcoal. Charcoal yield estimates in the late 1950's and early 1960's showed a yield of one metric ton of charcoal for every 17.1 cubic meters of stacked wood burned. Today, experts agree that it takes at least 18 cubic meters of wood to yield one metric ton of charcoal. Considering the rapid expansion of charcoal production, this difference is very significant in the central forested areas of the country.

Non-Forest Biomass

Due to its large agricultural sector, the Sudan has a significant agroprocessing and field crop residue base (estimated by the NEA at 250 GJ/year), particularly in the Gezira, Blue Nile, and other main agricultural regions. The main residue currently used is bagasse. 1980/1981 bagasse production was estimated at 1.1 million tonnes and should reach more than 2 million tonnes annually when the Kenana factory is operating at rated capacity (1983/1984). Most bagasse is used in the boilers of these sugar factories with small amounts used for building materials. 1980/1981 molasses production is estimated at 105 thousand tonnes (Table 35) and should reach 215 thousand tonnes annually when Kenana is running at rated capacity. Much of this molasses currently is wasted, since transportation costs exceed the international prices for the molasses. Proposals to produce ethanol from this molasses have not proceeded beyond the pre-feasibility study state. Other agroprocessing residues which could be used include cotton gin trash and groundnut shells. These and other residues are generated in large quantities at industrial sites which in many cases also could use the energy

TABLE 35

ANNUAL SUGAR, BAGASSE AND MOLASSES PRODUCTION IN SUDAN: 1978/79 - 1980/81

('000 MT)

PROCESS	El-Guneid			New Halfa			Sennar			Assalaya			Kenana			TOTAL		
	78/79	79/80	80/81	78/79	79/80	80/81	78/79	79/80	80/81	78/79	79/80	80/81	78/79	79/80	80/81	78/79	79/80	80/81
Sugar Production	36.54	29.69	35.85	64.85	43.05	50.00	18.19	39.00	32.00	-	7.67	12.60	-	24.40	91.80	119.6	143.8	222.3
Bagasse Production	203.4	143.4	179.3	311.1	217.4	252.0	104.8	173.8	180.0	-	42.7	63.0	-	122.0	459.0	619.3	699.3	1133.0
Molasses Production	13.30	11.00	14.80	24.22	20.55	22.80	9.06	18.36	19.60	-	3.50	6.28	-	11.09	41.73	46.58	64.50	105.2
DESIGN CAPACITY FOR SUGAR PRODUCTION	60			90			110			110			330			700		

Source: Sugar Corporation, Kenana Sugar Corp.

produced. Field crop residues such as cotton stalks are generated in far greater quantity but must be collected from a wide area and transported to users' locations at a time--harvest season-where competing labor and transport demands are at their peak. Other biomass includes animal manure (estimated at 275 million tonnes/year) and water hyacinth (estimated at 9 million tonnes/year).

In its surveys, the NEA found rapidly growing use of animal dung and crop residues as cooking fuel, which raises concern over the impacts of diversion of such materials from use on the land as fertilizer/soil amendments. It also appears that brickmakers are having increasing difficulty in these areas procuring dung, which is an important ingredient in brickmaking and adobe production throughout Central and Northern Sudan.

Decentralized Hydropower

Small-scale hydropower units potentially could make major contributions to local energy needs in a few areas of the Sudan, especially in the Southern Region primarily along the White Nile from Malakal to the border with Uganda. A study of Southern Region hydropower potential being carried out by Bonafica SpA, consulting engineers from Italy, should result in identification of specific sites by the end of 1982. A decentralized hydropower team visited a number of sites (Upper Atbara-Setit, Sunnar, Sabulok, etc.). They determined (as have others previously) that hydropower potential in most other areas of the Sudan (outside the South) is limited by wide seasonal stream flow variations (with little or no flow at least 2 months per year and reduced output due to flood condition at other times), design and operation of all dams primarily to meet irrigation rather than power needs, high siltation rates in some areas, and high evaporative and absorptive losses from impoundments. Nevertheless, a few opportunities in the North -- such as diverting a portion of the flow of the Nile at Sabaloka Gorge--await more detailed investigation. An obstacle to adoption of decentralized hydropower in the South or North is the lack of trained maintenance people.*

Wind

The Sudan has substantial potential for utilization of wind energy. The Northern Region around Dongola has an excellent wind regime, with annual wind power density in excess of 400 watts per square meter (Wm^2). The Khartoum, Gezira, and Port Sudan areas also have very favorable wind regimes, with annual wind power density of 280-380 w/m^2 (Tables 36 and Figure 5). Areas of high wind energy potential match very well with areas of potential utilization, particularly for irrigation and borehole pumping. Seasonal variation in wind density and pumping needs also match reasonably well. Previous projects (e.g. several hundred multi-blade water pumping windmills installed in the Gezira region in the 1950's), although terminated (primarily because of maintenance and spare parts problems and competition from then-inexpensive gasoil pumps), proved the potential of windpumps in major irrigated areas. This project experience demonstrates the need to assure that future efforts to introduce wind-powered waterpumps address problems of assured availability of spare parts, local responsibility for routine maintenance, and a maintenance training and service network.

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* For further information, see the "Decentralized Hydro-Power Assessment" Appendix.

TABLE 36

List of Meteorological Stations

and

Corresponding Mean Annual Wind Speed and Mean Annual Wind Power Density

(height above ground = 15.2 meters)

Station	Mean Annual Wind Speed* (m/s)	Recording Period	Mean Annual Wind Power Density (W/m^2)			
			Case 0[1]	Case I[2]	Case II[2]	Case III[2]
Abu Hamed	4.67	1976-1980	65.8	103.5	141.6	328.8
Abu Naama	2.83	1964-1980	14.6	29.6	40.4	94.0
Atbara	2.62	1961-1980	11.6	23.6	32.3	75.0
Dongola	4.58	1967-1980	62.1	133.5	182.6	424.1
Ed Damazin	2.6	1963-1980	11.4	23.7	32.4	75.3
El Fasher	2.21	1961-1980	7.0	22.6	30.9	71.8
En Nahud	2.32	1963-1980	8.1	41.1	56.2	130.4
El Obeid	3.35	1961-1980	24.3	63.1	86.2	200.3
Gedaref	2.68	1966-1980	12.4	35.1	48.0	111.8
Geneina	2.97	1961-1980	16.9	59.7	81.6	189.6
Ghazala-Gawazat	3.04	1966-1980	18.2	26.0	35.6	82.6
Halfa El Gadida	3.5	1970-1980	27.7	49.7	68.0	57.9
Juba	1.24	1961-1980	1.2	7.2	9.8	22.9
Kadugli	2.55	1973-1980	10.7	34.1	46.6	108.3
Karima	4.3	1961-1980	51.4	96.9	132.9	307.8
Kassala	1.8	1961-1980	3.8	6.6	11.8	27.3
Khartoum	4.12	1961-1980	45.2	98.7	134.9	313.4
Kosti	2.37	1961-1980	8.6	34.6	47.3	109.9
Malakal	2.62	1961-1980	11.6	46.4	63.4	147.4
Port Sudan	3.76	1961-1980	34.4	88.6	21.2	281.4
Wad Medani	3.52	1961-1980	28.2	67.6	92.4	214.7
Wadi Halfa	4.22	1961-1964 1976-1980	48.6	100.9	138.0	320.5
Wau	1.65	1961-1980	2.9	11.0	15.1	35.0

*Mean annual wind speed was averaged over the recording period

[1]Wind power density at 15.2 meters above ground level was derived as follows:

$P=\frac{1}{2}\rho v^3$

with P=wind power density at 15.2 meters (W/m^2)

ρ=air volumetric mass=1.293 kg/m^3

v=mean annual wind speed at 15.2 meters above ground level

[2]Wind power density was derived from the wind speed frequency distribution for each station assuming:

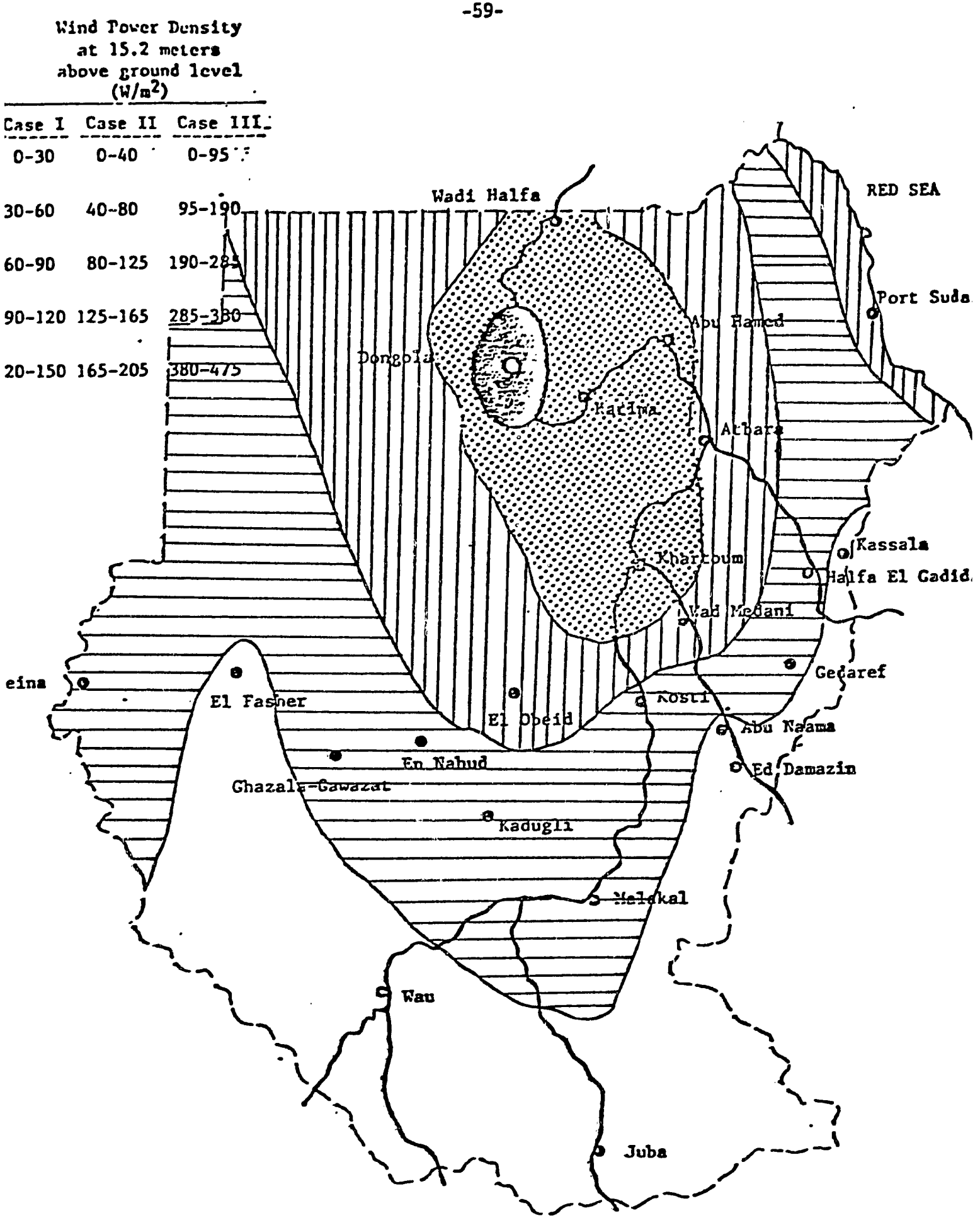

FIGURE 5 Wind Power Density Map for Sudan (W/m^2) at 15.2 meters above ground level

Solar

Even with a relatively high fraction of diffuse radiation lost due to cloudiness and sand storms, Sudan enjoys considerable solar energy resource potential, with annual total solar radiation ranging between 6.9 and 10.1 $GJ/m^2/year$ (Table 37 and Figure 6). The annual total solar radiation is low in the Southern Region and increases as one moves north. It reaches very high values in the Northern, Darfur and Khartoum Regions and in Gezira Provinces. Although a number of potential applications--water pumping, solar water heating, power for rural health centers, power for remote telecommunications stations, low-temperature industrial process heat, etc.--exist, activity in the Sudan has been limited to a few pilot--test projects. The high capital cost of solar energy systems, lack of long-term operating experience for most such systems, in many cases complex maintenance requirements and disappointing performance of pilot units tested to date in the Sudan (e.g. the photovoltaic water pumping systems installed at Burri in 1980/81 and the solar thermal water pumping systems installed at Soba in 1980/81 as part of a joint UNDP/World Bank project; none of which are currently operating) pose major obstacles to implementation.

Regional Energy Balances

The large land area of the Sudan, coupled with the great climatogical, ethnic, and religious diversity within its borders, produce wide ranges of economic activity and, consequently, sharply different energy use patterns within its different regions. Poor inter-regional communications and difficulties in transportation further exacerbate these differences and also complicate efforts to quantify energy consumption in individual regions. Thus, the regional energy balances depicted in Tables 38 to 46 must be regarded as rough breakdowns of the distribution and use of different fuels.

Tables 38 through 46 are balances prepared specifically for the Eastern, Northern Khartoum, Central, Southern, Kordofan, and Darfur regions, utilizing the same basic format as the national balances. Regional breakdowns of the data for the various energy use sectors were derived from the geographical location of the principal users, in the cases of the agricultural and industrial sectors, and from household surveys. Demographic data and information on fuel availability complemented these sources. Regional breakdowns for road transportation were made on the basis of regional sales of benzine and gasoil at retail stations, as reported by the petroleum distribution companies and the GPC.

A few exceptions to a complete regional allocation of energy consumption were necessary. For several transportation modes that link two or more regions together, it was considered impractical to allocate fuel consumption among the regions. Thus, fuel use by Sudan's railway, river boats, pipeline and airplanes was omitted from the regional allocation and is presented separately in Table 45. Also included in Table 45 is the fuel use by construction firms who are principally involved in building roads that link two or more regions. A final category of fuel consumption that has not been broken down by region is that of stand-by electric generators. In this instance the allocation by region was not completed because of lack of data.

Despite the difficulties and uncertainties of regional data collection, the diversity in patterns of energy consumption and the significant variation in the regional importance of individual fuels is clearly indicated. Table 47 (found

TABLE 37

Monthly Mean Daily and Annual Total Solar Radiation (MJ/m²/day, GJ/m²/year)

(Averaged over recording period)

Mean Monthly Total (Direct and Diffuse) Solar Radiation (MJ/m²/day)

on	Recording Period	Jan.	Feb	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual Total Solar Radiation (GJ/m²/year)
ama	1963-1990	23.6	26.1	27.6	28.3	27.6	25.9	24.1	24.6	25.4	24.3	23.8	22.6	9.23
	1973-1980	22.2	23.6	25.7	26.6	25.8	25.2	25.6	28.6	27.3	24.3	21.4	19.4	8.98
ma	1974-1980	23.5	26.1	27.7	28.3	27.6	26.2	23.7	23.8	25.0	23.6	22.8	22.3	9.16
la	1973-1980	23.1	26.2	29.6	31.3	31.7	31.6	30.0	29.0	27.7	26.3	23.9	21.8	10.1
ther	1957-1980	23.6	26.3	28.6	29.3	28.8	27.5	25.9	26.1	26.6	26.0	24.7	23.2	9.61
wak	1971-1980	23.9	26.9	29.4	30.3	29.2	31.2	25.6	25.8	26.5	25.3	24.0	22.4	9.76
la Gavaret	1964-1980	23.8	25.9	27.1	27.2	26.0	25.0	23.7	23.6	24.7	24.8	24.6	23.5	9.12
ba	1974-1980	22.5	24.8	28.1	29.3	28.4	26.4	26.0	26.8	26.7	24.9	23.3	22.1	9.39
	1957-1980	22.3	22.5	22.2	21.8	23.7	22.1	20.6	22.3	24.4	23.4	22.4	22.1	8.21
ll	1973-1980	24.9	26.4	27.4	27.9	26.4	23.9	21.6	21.2	21.4	23.2	25.0	24.3	8.96
al	1960-1980	23.2	24.7	25.7	25.6	23.3	20.9	20.7	22.4	22.0	22.2	23.3	22.8	8.42
Sudan	1957-1980	17.3	21.7	26.1	28.9	29.2	27.4	26.3	26.0	25.8	23.7	19.1	16.5	8.76
at	1957-1980	23.3	26.2	27.1	29.6	28.3	26.9	26.3	26.1	26.3	24.7	23.7	22.4	9.45
	1973-1980	12.6	15.8	19.6	24.9	25.3	22.4	20.0	19.5	20.1	19.0	14.7	12.2	6.88
dani	1957-1980	24.1	26.6	28.4	29.2	28.3	27.3	25.5	25.7	26.8	25.8	24.4	23.3	9.59
er	1971-1980	25.1	27.5	29.5	29.5	28.9	27.2	24.0	23.1	25.0	26.3	26.3	24.9	9.65

ource: Unpublished Data From Meteorological Department, Khartoum, Sudan.

Figure 6

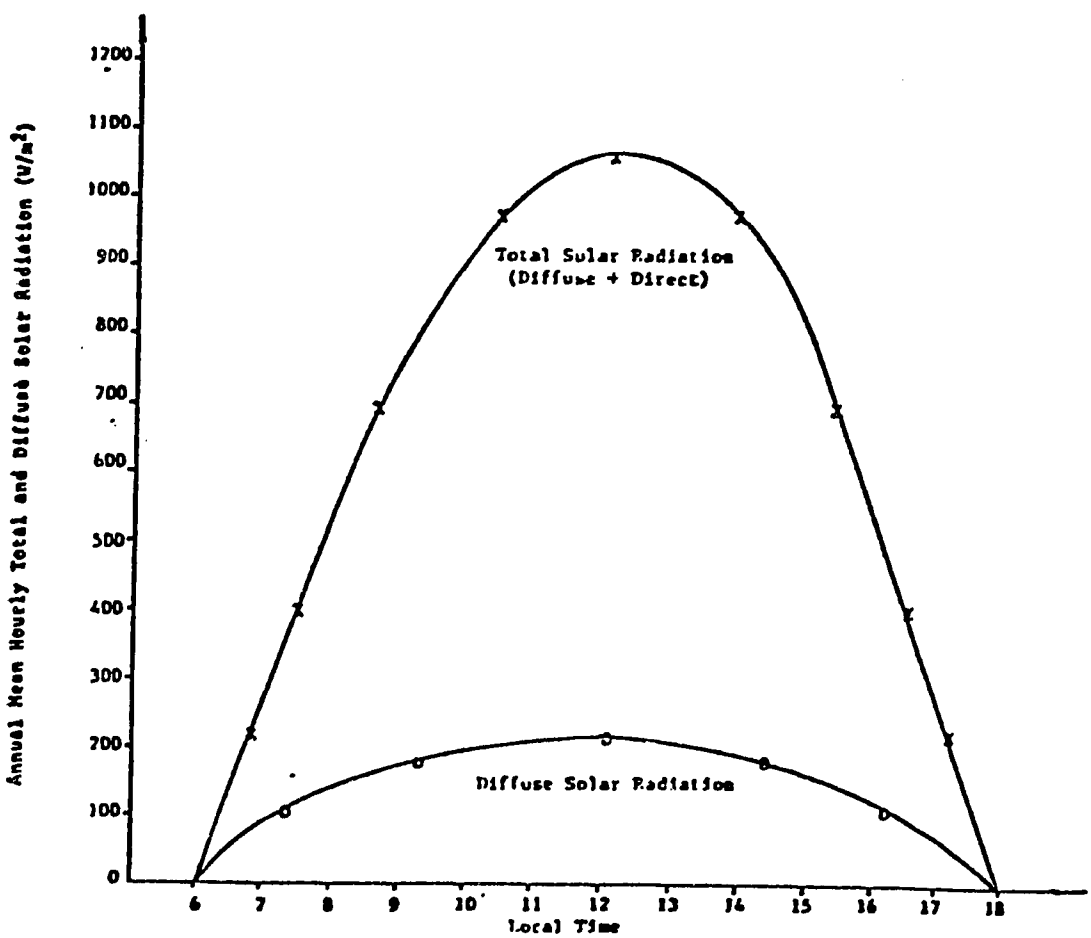

Figure 3.1: Variation of Annual Mean Hourly Total and Diffuse Solar Radiation in Khartoum (Shambat Meteorological Data, 1979)

TABLE 38

TOTAL ENERGY CONSUMPTION 1980 EASTERN REGION

Fuel Sector	Hydro Power	Benzine/ Avgas	LPG	Kerosene Jet Fuel	Gasoil Tons	Diesel Tons	Furnace Oil	Wood	Charcoal	Other Bio-Mass	Vegetable Oil	Purchased Electricity
1. Industry	--	--	--	*	--	--	13,358	8,213	--	17,400	--	732
2. Agriculture	--	--	--	--	25,480	--	--	--	--	--	--	396
3. Transport	--	26,880	--	--	47,112+	--	+	--	--	--	--	--
4. Commercial Government Services	--	--	--	--	746+	--	--	5,713	15,228	--	--	1,326
5. Construction Oil Exploration	--	--	--	--	+	--	--	--	--	--	--	--
6. Households	--	--	485	6,032	4,160+	--	--	265,740	167,760	24,430	--	1,722
7. NEC Electricity Generation	1,791	--	--	--	1,486	9,483	--	--	--	--	--	--
Total	1,791	26,880	485	6,032+	78,984+	9,483	13,358+	279,666	182,988	41,830	--	4,176

* Less than 300 tons
\+ Additional Fuel Consumption included on Table 8: Remainder - All Regions

TABLE 39

TOTAL ENERGY CONSUMPTION - NORTHERN REGION 1980
(TOE)

Fuel Sector	Hydro Power	Benzine/ Avgas	LPG	Kerosene Jet Fuel	Gasoil Tons	Diesel Tons	Furnace Oil	Wood	Charcoal	Other Bio-Mass	Vegetable Oil	Purchased Electricity
1. Industry	--	--	--	*	1,664	5,093	14,706	7,740	--	--	--	34
2. Agriculture	--	--	--	--	9,256	--	--	--	--	--	--	155
3. Transport	--	5,250	--	+	19,240+	--	+	--	--	--	--	--
4. Commercial Government Services	--	--	--	--	658+	--	--	4,725	9,461	--	--	748
5. Construction Oil Exploration	--	--	--	--	+	--	--	--	--	--	--	--
6. Households	--	--	42	1144	2,392+	--	--	77,830	91,440	22,670	--	973
7. NEC Electricity Generation	--	--	--	--	1,465	2,559	3,722	--	--	--	--	--
Total	--	5,250	42	1144+	34,675+	7,652	18,428+	90,295	100,901	22,670	--	1,910

* Less than 300 tons
\+ Additional Fuel Consumption included on Table 8: Remainder - All Regions

TABLE 40

TOTAL ENERGY CONSUMPTION 1980 - KHARTOUM REGION
(TOE)

Fuel Sector	Hydro Power	Benzine/ Avgas	LPG	Kerosene Jet Fuel	Gasoil Tons	Diesel Tons	Furnace Oil	Wood	Charcoal	Other Bio-Mass	Vegetable Oil	Purchased Electricity
1. Industry	--	--	*	*	8,940	889	23,494	29,326	--	--	--	9,861
2. Agriculture	--	--	--	--	728	--	--	--	--	--	--	1,318
3. Transport	--	133,980	--	+	116,064+	--	--	--	--	--	--	--
4. Commercial Government Services	--	--	--	--	160+	--	--	3,179	10,908	--	--	4,728
5. Construction Oil Exploration	--	--	--	--	+	--	--	--	--	--	--	--
6. Households	--	--	4,155	4,680	2,600+	--	--	75,250	172,800	--	--	16,389
7. NEC Electricity Generation	--	--	--	--	6,571	2,266	37,730	--	--	--	--	--
Total	--	133,980	4,155	4,680	134,963+	3,155	61,224+	107,755	183,708	--	--	32,296

* Less than 300 tons
\+ Additional Fuel Consumption included on Table 8: Remainder - All Regions Unknown and possibly significant

TABLE 41

TOTAL ENERGY CONSUMPTION 1980 - CENTRAL REGION
(TOE)

Fuel Sector	Hydro Power	Benzine/ Avgas	LPG	Kerosene Jet Fuel	Gasoil Tons	Diesel Tons	Furnace Oil	Wood	Charcoal	Other Bio-Mass	Vegetable Oil	Purchased Electricity
1. Industry	--	--	--	*	10,400	408	48,366	18,146	--	68,600	--	10,197
2. Agriculture	--	--	--	--	48,672	--	--	--	--	--	--	4,926
3. Transport	--	25,515	--	+	61,413	--	+	--	--	--	--	--
4. Commercial Government Services	--	--	--	--	3,914+	--	--	9,322	16,826	--	--	2,093
5. Construction Oil Exploration	--	--	--	--	+	--	--	--	--	--	--	--
6. Households	--	--	35	3,224	8,736+	--	--	647,150	425,520	154,400	8,500	2,609
7. NEC Electricity Generation	61,748	--	--	--	1,758	116	168	--	--	--	--	--
Total	61,748	25,515	35	3,224+	134,893+	524	48,534+	674,618	442,346	223,000	8,500	19,825

* Less than 300 tons
\+ Additional Fuel Consumption included on Table 8: Remainder - All Regions

TABLE 42

TOTAL ENERGY CONSUMPTION 1980 - SOUTHERN REGION
(TOE)

Fuel Sector	Hydro Power	Benzine/ Avgas	LPG	Kerosene Jet Fuel	Gasoil Tons	Diesel Tons	Furnace Oil/ Tons	Wood	Charcoal	Other Bio-Mass	Vegetable Oil	Purchased Electricity
1. Industry	--	--	--	--	*	--	--	9,933	--	--	--	--
2. Agriculture	--	--	--	--	3,744	--	--	--	--	--	--	--
3. Transport	--	3,255	--	--	8,744	--	--	--	--	--	--	--
4. Commercial Government Services	--	--	--	--	+	--	--	36,599	11,966	--	--	138
5. Construction Oil Exploration	--	--	--	--	+	--	--	--	--	--	--	--
6. Households	--	--	--	+	1,352+	--	--	1,223,780	261,360	201,330	--	388
7. PEWC Electricity Generation	--	--	--	--	2,280	--	--	--	--	--	--	--
Total	--	3,255	--	+	16,120+	--	--	1,270,312	273,326	201,330	--	526
Imports From Kenya	--	5,000	--	2,500[2]	10,000[3]	--	--	--	--	--	--	--

* Less than 300 tons

\+ Additional Fuel Consumption included on Table 8: Remainder - All Regions
Mobil, Caltex, Shell, Total and Agin all solid fuel to Southern Sudan. Figures quoted here are rough estimates based on interviews in Nairobi with Mobil in July 1982 and Caltex and Shell in July 1981.

2 Largely jet fuel

3 Assumed to be primarily used in transportation and generators. Largest customers are international aid agencies.

TABLE 43

TOTAL ENERGY CONSUMPTION 1980 - KORDOFAN REGION
(TOE)

Fuel Sector	Hydro Power	Benzine/ Avgas	LPG	Kerosene Jet Fuel	Gasoil Tons	Diesel Tons	Furnace Oil/ Tons	Wood	Charcoal	Other Bio-Mass	Vegetable Oil	Purchased Electricity
1. Industry	--	--	--	--	1,352	--	233	15,179	--	4,740	--	--
2. Agriculture	--	--	--	--	3,848	--	--	--	--	--	--	--
3. Transport	--	4,200	--	+	10,847+	--	+	--	--	--	--	--
4. Commercial Government Services	--	--	--	--	1,293+	--	--	28,567	19,181	--	--	189
5. Construction Oil Exploration	--	--	--	--	+	--	--	--	--	--	--	--
6. Households	--	--	--	1,560	4,784+	--	--	505,250	316,800	1	--	344
7. PEWC Electricity Generation	--	--	--	--	2,257	--	946	--	--	--	--	--
Total	--	4,200	--	1,560+	24,381	--	1,179+	548,996	335,981	4,741	--	533

+ Additional Fuel Consumption included on Table 8: Remainder - All Regions

? Unknown and possibly significant

TABLE 44

TOTAL ENERGY CONSUMPTION 1980 - DARFUR REGION
(TOE)

Fuel Sector	Hydro Power	Benzine/ Avgas	LPG	Kerosene Jet Fuel	Gasoil Tons	Diesel Tons	Furnace Oil/ Tons	Wood	Charcoal	Other Bio-Mass	Vegetable Oil	Purchased Electricity
1. Industry	--	--	--	--	624	--	--	7,330	--	3,780	--	60
2. Agriculture	--	--	--	--	2,808	--	--	--	--	--	--	--
3. Transport	--	1,575	--	--	9,693+	--	+	--	--	--	--	--
4. Commercial Government Services	--	--	--	--	1,222+	--	--	23,412	14,213	--	--	207
5. Construction Oil Exploration	--	--	--	--	+	--	--	--	--	--	--	--
6. Households	--	--	--	882	3,432	--	--	571,900	327,600	1	--	233
7. PEWC Electricity Generation	--	--	--	--	2,371	--	--	--	--	--	--	--
TOTAL	--	1,575	--	882+	20,150+	--	+	602,642	341,813	3,781	--	500

\+ Additional Fuel Consumption included on Table 8: Remainder - All Regions

1 Unknown and possibly significant

TABLE 45

ENERGY CONSUMPTION 1980 - REMAINDER - ALL REGIONS
TOE

Fuel Sector	Avgas	LPG	Kerosene & Jet Fuel	Gasoil	Furnace Oil
Rail Transport	--	--	--	27,664	21,024
River Transport	--	--	--	2,392	--
Air Transport	6,300	--	46,384	--	--
Pipeline	--	--	--	2,808	--
Commercial Generators	--	--	--	832	--
Household Generators	--	--	--	4,680	--
Construction Oil Exploration	--	--	--	34,320	--
Industry	--	800	--	--	--
TOTAL	6,300	800	46,384	72,696	21,024

TABLE 46

SUMMARY OF ENERGY RESOURCES CONSUMED BY REGION
(TOE)

Region	Hydro	Petroleum Products	Wood	Charcoal	Other Biomass	Purchased Electricity	Total
Eastern	1,791	153,734	279,666	182,988	41,830	(4,176)	660,009
Northern	0	67,191	90,295	100,901	22,670	(1,946)	281,057
Khartoum	0	342,160	107,755	183,708	--	(32,296)	633,623
Central	61,748	212,725	647,618	442,346	231,500	(19,825)	1,595,937
Southern	0	19,375	1,270,312	273,326	201,330	(388)	1,764,343
Kordofan	0	31,320	548,996	335,981	4,740	(533)	921,037
Darfur	0	22,607	602,642	341,813	3,780	(500)	970,842

in Chapter IV, p. 74) shows that while 54% of the Khartoum region energy consumption is met by petroleum products, these account for less than 1% of consumption in the South, Kordofan, and Darfur. Supplies of petroleum products are scarce in every region (particularly during times of shortage), with Port Sudan, Khartoum, and the Central Region having easiest access, and with more distant regions obtaining petroleum products only with great difficulties.

Large variation is also evidenced in the consumption of traditional energy products, in many ways a more valid comparison of the disparities in available resource base and household energy use patterns than imported petroleum, which is more an indicator of the level of development of the modern sector of the economy. Firewood and charcoal supplies, and prices, are strongly linked to regional factors. Charcoal accounts for 36% of total energy use in the Northern Region, where firewood is relatively scarce, but only 15% of total energy use in the Southern Region, where fuelwood supplies are available locally, permitting economic transport without prior conversion to charcoal. The regional variation in energy consumption patterns indicates that individual fuels presently are concerns of widely ranging priority in different areas. National energy planning must take this regional specificity of consumption into account. The next step to be taken in the formulation of policies sensitive to regional interests is to try to assess to what extent these variations in consumption reflect corresponding variations in demand. Once a greater understanding of demand is achieved, programmes can be designed as much as is to accommodate regional interests and priorities.

CHAPTER IV

ENERGY PROJECTIONS AND SENSITIVITIES

In projecting levels of future energy consumption, one must make a number of assumptions about the interactions between energy use and the economy. Two principal forms of interaction are at issue:

- The interaction between economic output and the level of energy consumption (that is, the coefficients of energy use as output increases); and
- The interaction between energy demand, foreign exchange availability and economic performance.

In Sudan, both interactions will be critical to the energy and economic future of the country -- and both are highly uncertain. Because the current situation is characterized by so many strategic bottlenecks, it is extremely difficult to project stable, long run relationships between energy use and economic activity (that is, energy use coefficients). The observed relationships between energy use and economic output in 1980 or 1982 are not necessarily indicative of any structural relationship. For example, the textile industry -- which accounts for approximately 13% of the value added in Sudanese industry -- is comprised of a number of public and private factories based largely in Khartoum, Wad Medani and Port Sudan. All face a number of financial, managerial and physical bottlenecks. The plants in Port Sudan, however, are free of one critical bottleneck that plagues the others -- frequent disruptions in electricity supplied by the PEWC (NEC) Central Grid -- because they use their own diesel generators. This and other advantages (access to the port and assured petroleum supplies, for example) allow factories in Port Sudan to operate at capacity utilization levels approaching 70%, while those in Khartoum average closer to 30% percent. Energy use per unit of output is much higher at very low levels of capacity utilization and the Port Sudan plants therefore operate at higher rates of energy efficiency. Assuming a 10% growth in textile output, the corresponding increase in energy consumption would strongly depend on whether it came from improved capacity utilization or from the addition and location of new capacity. Similarly, in a situation of acute foreign exchange scarcity, it is difficult to project either new capital investments or whether sufficient fuel will be available for new project investments to operate. For example, will Maspio Cement be able to purchase sufficient fuel to take advantage of its sizeable plant expansion?

Thus, either a purely "demand driven" approach to calculating future energy consumption or a projection based solely on the expectations of foreign exchange availability would be of limited value. The approach taken here is to calculate the future energy requirements of the Sudan by carefully analyzing others' economic projections, current plans and projects by sectors, and reasonable energy use coefficients for all major energy consuming activities in the country. The resulting energy demand, in particular that of petroleum, is subsequently integrated into a macroeconomic analysis in order to assess the economy-wide impact of supplying that energy. Thus we do not necessarily depict a sustainable scenario, but we do present the energy consumption implications of present development plans and, in so doing, reveal the physical and economic difficulty of meeting stated goals.

Following preparation of Base Case economic and energy demand projections, the Project Team incorporated sectoral growth rates, together with crude oil and oil import requirements for the period 1982-1992, into the World Bank's macroeconomic model. In this manner, economy-wide impacts of the current expansion in the industrial base, increases in agricultural exports, increases in debt service payments for new capital investments, increases in foreign exchange requirements for petroleum and other imports, etc. can be analyzed in one consistent framework. Estimates of macroeconomic impacts are made for alternative cases with and without oil exports.

It is important to point out that the assumptions regarding the economic impact of projected oil exports are extremely rough and must be regarded as preliminary. The President announced the decision to support financing and construction of a 22" pipeline to export up to 100,000 barrels per day one week before final publication of this report. The economic impact of oil exports can vary widely depending upon such variables as pipeline capital costs and terms of pipeline financing, the rate of future increases in world oil prices, and what percentage of oil export revenues is used to repay past external debt arrears as opposed to being available for future economic development. None of these or other variables currently is known. For this reason, we have prepared economic estimates with no oil exports and then provide preliminary estimates of economic growth rates, imports, etc. for a range of assumptions regarding the above variables. The Government should extend this analysis in much more detail in the coming months.

Since oil exports are presumed not to commence until 1986 and it is assumed that there will be no impact of pipeline financing until then, the estimates to 1985 are unaffected by assumption regarding oil exports.

Economic Basis For Energy Projections

The economic projections on which the energy projections in this report are based are not intended to be independent forecasts of economic activity. Instead, they draw heavily on two levels of information sources:

- Existing projections made by those organizations deeply involved in planning future investment, foreign exchange and other requirements of the economy. These include the Ministry of Finance and Economic Planning, the Bank of Sudan, the World Bank, the International Monetary Fund, and others.

- Specific investment and output plans, obtained from both public and private sources and from extensive NEA and Project surveys over the past year and a half.

The combination of information from these sources has yielded a number of inconsistencies, and these have been resolved by using judgment as to the likely course of events. Every effort is made to make assumptions explicit, and to present "sensitivity" cases varying those assumptions, so that those whose judgments differ can gauge the impact of the economic assumptions on projected energy demand.

Growth rates for agriculture are drawn largely from World Bank studies, which have been modified to take into account anticipated changes in feddans cultivated and yield. These variables have then been used to gauge future energy requirements in this sector. The industrial sector growth rates used here are significantly

higher than those used in the World Bank's and other studies, especially over the period from 1982 - 1986, because of anticipated specific increases in industrial output in subsectors where sizeable capacity expansion has already taken place, is already underway or has been firmly committed. Obvious examples of such growth include The Maspio Cement factory (whose capacity has been expanded from 210,000 MT/yr to 430,000 MT/yr) and the Kenana sugar complex (whose output is slated to reach 400,000 MT/yr of refined sugar by 1984). Growth rates in the general commercial sector have been based largely on the World Bank's projections. The transport subsector has been broken out separately, because of its importance to overall energy demand. Transport sector growth rates are derived from levels of industrial, agricultural and other demand for transport services.

A concise summary in tabular form of the major assumptions on which this and the other energy projections in this chapter are based is shown in Table 47.

TABLE 47

BASE CASE ENERGY DEMAND PROJECTIONS: MAJOR ASSUMPTIONS

Sector	Subsector or Activity	Assumptions
Transportation	Freight (total)	-Total ton-km in proportion to major agriculture output and GDP
	Road	-Increasing share of total ton-km
	Rail	-Slow growth, decreased share total ton-km
	River	-Major expansion during 1980's
	Pipeline	-1980 levels of throughput
Transportation	Passenger (total)	-Pass-km grow at 5% p.a.
	Road	-Increased share of total, esp. minibuses
	Rail, River	-Growth as in freight
	Bus (diesel)	-Slow growth
Agriculture	Irrigation	-Growth in irrigated feddans under cultivation by crop (EAP projections)
	Agricultural Operations	-Growth in mechanized feddans under cultivation by crop

TABLE 47 (Continued)

Sector	Subsector or Activity	Assumptions
Industry	Cement	-370,000 tonnes production by 1985
	Textiles	-135 million yards in 1985, 154 million yards in 1990
	Sugar	-400,000 tons in 1985, 500,000 tons in 1990
	Oil and Soap	-151,000 tons in 1985, 179,000 tons in 1990
	Bitumen	-50,000 tons by 1985/86
	Fertilizer	-100,000 tons of urea per year (1983)
	Miscellaneous	-Growth in Industry share of GDP
	Brickmaking	-Propor. to population growth
	Bakeries	-Propor. to urban population growth
Commercial, Gov't and Services	Water Pumping	-Prop. to population growth
	Road Construction	-Average km of road completion/yr currently under construction
	Petroleum Exploration	-Rigs in operation
Households	LPG	-Supply (and imports)
	Kerosene and Gasoil	-GDP and urban population growth rates
	Charcoal	-Charcoal growth rate greater than wood, tied to urban pop. growth.
	Wood	-Slower than charcoal, grows with total pop.
	Other biomass	-Same as wood
	Purchased Electricity	-7.5% p.a. increase
Electricity Generation	Total Growth in Consumption	-Determined by installed capacity of generation
	Blue Nile Grid	
	Hydro	-Roseires 5,6 (1984), 7 (1988/89)
	Steam	Kh. North 1,2 (1983/84), 3,4 (1988/89)
		Burri Rehab. (1983/84)
	Gasoil	Burri Extension (1983)
	Port Sudan	15MW French Project (1983)
		15MW Gasoil (1983/84)
	Other Systems	Additional 16MW by 1985; additional 23 MW by 1990

The resulting population and sectoral economic growth rates used as the basis for our economic projections are summarized in Table 48 below:

TABLE 48

POPULATION AND SECTORAL ECONOMIC GROWTH RATES

	1980	1985	1990
1. Population			
° Urban	4,665	6,558	9,065
° Rural	14,015	14,232	15,872
Total	18,680	20,790	24,937

2. Sectoral Growth Rates (% per year)

	1982-1983	'84	'85	'86	'87	'88	'89	'90	'91	'92
Agriculture	2.5%	3%	3.5%	4%	4%	4.5%	4.5%	5	5	5
Industry	10.5%	10.9%	11%	11%	7%	6%	4%	4	5	5
Commerce/Other	1.5%	2%	2.5%	3%	3.5%	3.5%	4%	4	4	4
Transport	(individual modes derived from above growth rates)									

More detail on the economic projections can be found in the "Base Year (1980) Energy Supply-Demand" Annex.

Base Case Energy Projection

The Base Case Energy Projection is based on the above economic projections, to which a consistent set of energy efficiency coefficients -- based on historic experience and expected future efficiency improvements -- have been applied. These coefficients are described in detail in the Annex. We stress again that these "Base Case" projections are before any consideration of the impact of oil exports.

Before impact of oil exports, energy demand is projected to grow from nearly 7 million TOE in 1980 to 8.7 million TOE in 1985 and 10.3 million TOE in 1990 as shown in Tables 49 and 50. Tables 51 and 52 show the same projections expressed in physical units (tonnes, Gwh). The NEC is projected to enlarge generation from 932.4 Gwh (80,300 TOE) in 1980 to 2127.3 Gwh (183,200) in 1985, and 2666.0 Gwh (229,600 TOE) in the year 1990, for annual growth rates of 18.0% and 4.6% in 1980-1985 and 1985-1990 respectively. Table 53 shows the balance of energy inputs to electric generation, electric generation output, and electricity sales. The fuel inputs are obtained from the detailed expansion plan for new generation equipment.

TABLE 49

PROJECTION OF ENERGY CONSUMPTION
('000 TOE), 1985

	Hydro-power	Benzine Avgas	LPG	Kerosene Jetfuel	Gasoil and Diesel	Furnace Oil	Wood	Charcoal	Other Biomass	Vegetable Oil
Industry				55.6	94.9	269.6	108.1		263.6	
Transport		250.6		59.7	292.9					
Agriculture					119.6					
Comm' Gov't Services Const. Oil Exploration					54.2		51.3	53.2		
Households			10.9	40.8	29.1		381.20	2166.0	548.3	9.6
NEC Electric Generation	101.9				168.5	122.9				
	101.9	250.6	10.9	156.1	759.2	392.5	540.6	2219.2	811.9	9.6

TABLE 50

PROJECTION OF ENERGY CONSUMPTION 1990
('000 TOE)

	Hydro-power	Benzine Avgas	LPG	Kerosene Jetfuel	Gasoil and Diesel	Furnace Oil	Wood	Charcoal	Other Biomass	Vegetable Oil
Industry	-	-	-	55.6	106.8	293.7	127.3	-	301.6	-
Transport	-	341.7	-	80.2	404.4	-	-	-	-	-
Agriculture	-	-	-	-	127.8	-	-	-	-	-
Comm' Gov't Services, Constr.- Oil Exploration		-	-	-	52.5	-	60.3	61.9	-	-
Households	-	-	17.6	81.3	22.5	-	4316.8	2661.1	620.9	10.9
NEC Electric Generation	120.0	-	-	-	199.6	203.5	-	-	-	-
	120.0	341.7	17.6	217.1	913.6	497.2	4504.4	2723.0	922.5	10.9

TABLE 51

PROJECTION OF ENERGY CONSUMPTION 1985
('000 tonnes except where noted)

	Hydro-power (Gwh)	Benzine Avgas	LPG	Kerosene Jetfuel	Gasoil and Diesel	Furnace Oil	Wood	Charcoal	Other Biomass	Vegetable Oil
Industry				53.47	90.98	280.8	251.3		1318.	
Transport		238.7		57.45	315.96					
Agriculture					115.0					
Comm' Gov't, Services, Constr. Oil Exploration					52.09		119.2	73.9		
Households			9.85	39.26	28.0		8866	3008	1713.3	9.6
NEC Electric Generation	1183				162.0	128.0				
	1183Gwh	238.7	9.85	150.18	764.03	408.8	9236.5	3081.9	3031.3	9.6

TABLE 52

PROJECTION OF ENERGY CONSUMPTION 1990
('000 tonnes except where noted)

	Hydro-power (Gwh)	Benzine Avgas	LPG	Kerosene Jetfuel	Gasoil and Diesel	Furnace Oil	Wood	Charcoal	Other Biomass	Vegetable Oil
Industry				53.47	102.66	305.9	296.0		150.8	
Transport		325.4		77.2	388.84					
Agriculture					122.9					
Comm' Gov't Services, Constr. Oil Exploration					50.45		140.2	86.0		
Households			15.86	78.22	21.66		10,039	3696.	1,940.3	10.9
NEC Electric Generation	1393				191.9	212.0				
	1393Gwh	325.4	15.86	203.89	878.4	517.9	10,475.2	3782.0	2,091.1	10.9

TABLE 53

NEC ELECTRICITY BALANCES ('000 TOE) [1]

1980

Hydro	211.7	(0.3)	63.5		22.5	Households
Gasoil	21.2	(0.30)	10.8	80.3 (74) 59.7	20.9	Heavy Industry
Diesel	14.4				9.5	Government
Furnace Oil	42.5	(014)	6.0		6.8	Agriculture

1985

Hydro	339.7	(0.3)	101.9		51.8	Households
Gasoil and Diesel	168.5	(0.3)	50.6	183.2 (0.75) 137.4	48.0	Heavy Industry
					21.9	Government
Furnace Oil	122.9	(0.25)	30.7		15.7	Agriculture

1990

Hydro	400.0	(0.3)	1200		64.9	Households
Gasoil and Diesel	191.9	(0.3)	57.6	229.6 (0.75) 172.2	60.3	Heavy Industry
					27.4	Government
Furnace Oil	212.0	(0.25)	53.0		19.6	Agriculture

1 Electricity sales by sector are allocated in future years in the proportion of 1980 sales.

The share of petroleum products in total energy consumption grows from 11.3% in 1980 to 18.0% in 1985 and 19.4% in 1990. Demand for petroleum products grows from 965,920 tonnes in 1980, to 1,571,860 tonnes in 1985, and 1,946,450 tonnes in 1990, at annual rates of 10.2% p.a. in 1980-85, and 4.37% p.a. in 1985-90, respectively. The high growth rate in the first half of the decade is, for the most part, due to the growth in petroleum fuels used in the expansion of electric generation and to new industrial projects now under construction or in the final stages of development. The growth in furnace oil will be substantial, more than doubling demand, to 409,000 tonnes by 1985 and 518,000 tonnes in 1990. Large growth is also expected in kerosene/jet fuel, due to a slow resumption of supplies to domestic lighting, the demands of domestic air travel, and the expected requirements of a planned bitumen (asphalt) plant in Port Sudan.

Petroleum Products Balance

The growth in demand for petroleum products is coupled to a continued deterioration of throughput at the Port Sudan refinery, resulting in substantial increases in imports of petroleum products. A small contribution is expected from the 1500 barrel per day Bentiu topping plant (using domestic crude) to be built by Chevron. As can be seen in Table 54, direct imports of refined petroleum products are projected to grow rapidly from a total 384,000 tonnes in 1981 to 624,000 tonnes in 1985. In addition, the foreign exchange earned from exports of furnace oil drops off completely; the projection shows that domestic demand for furnace oil will surpass production by the middle of the decade even with the Bentiu plant supplying 40,000 tonnes to the Kenana Sugar Complex.

Refined petroleum product imports continue to grow towards 1990 to a total of some 1.1 million tonnes. This amount is 30% higher than projected production at the Port Sudan refinery; that is, more than 55% of domestic consumption of petroleum production will be met by direct product imports. Rehabilitation of the Port Sudan refinery, which is shown as decreasing its throughput gradually as the equipment gets older, potentially could increase domestic output by some 350,000 tonnes and help alleviate the need for product imports for several years; but the economic viability of such rehabilitation has not been assessed.

Expansion of NEC Electric Generation

The demand projections presented herein ignore the demands for electricity due to natural population increases, increased construction activity, or industrial growth. Instead, the growth in electricity has been determined from the growth in installed generation capacity of the NEC as appraised by a realistic look at several capacity expansion documents. This approach is considered preferrable to that of a purely demand-driven approach because of the large unmet demands that currently exist, the problems of timely completion and the dispersed nature of the NEC system.

The electric supply system in the Sudan is undergoing a rapid expansion. The most important trend is the increasing reliance on petroleum products for electricity generation, from little more than 20% in 1980 to neary 50% in 1990. An important factor in this increase is the rapid growth in decentralized regional systems which, by virtue of their small size, are almost all diesel (gasoil) turbine units. Another factor is the introduction of a large scale steam plant in Khartoum North, whose output will approach that of the Roseires dam by the end of the decade. Output of Roseires is also expected to double; but, despite such growth, the thermal system expansion will cause the share of hydroelectric generation to drop considerably.

TABLE 54

PETROLEUM PRODUCTS BALANCE PROJECTION

1985	Total Consumption	Port Sudan[1] Refinery Output	Bentiu Output	Direct Imports
LPG	9.9	4.2	0.4	5.3
Benzine/Avgas	238.7	117.5	5[2]	121.2
Kerojet	150.2	115.7	4.0	30.5
Gasoil/Diesel Oil	764.3	313.0	18.8	432.5
Furnace Oil	408.8	330.0	43.8	35.0
TOTAL	1571.9	880.4	67.0	624.5
LPG	15.9	3.7	0.4	11.8
Benzine/Avgas	325.4	103.9	-	221.5
Kerojet	208.9	102.2	4.0	102.7
Gasoil/Diesel Oil	878.4	276.6	18.8	583.0
Furnace Oil	517.9	292.1	43.8	182.0
TOTAL	1946.5	778.5	67.0	1101.0

(1) Assumes throughput decreases at 2.5% pa from 1980 levels, and that the product mix is the same as in 1980.
(2) 5500 tonnes of naphtha will be produced.
(3) In addition, Kosti would produce 137,000 MT p.a. of petroleum coke.

The most important elements of the NEC expansion plan for the Blue Nile Grid are the Khartoum North steam plant (60 MW by 1984 and an additional 60 MW by 1989), the Roseires hydroelectric plant (10 MW by 1983, followed by an extension of 80 MW by 1985 and an additional 40 MW by 1989) and the Burri gasoil plant extension (40 MW) and rehabilitation. The growth in generating capacity in Port Sudan is taken as 6 x 5 MW diesels that should come on the line before 1985. The other systems increase by 16 MW to 1985 and an additional 23 MW to the year 1990. Table 55 summarizes total installed capacity for 1980 and the projection years. Installed capacity grows to about 450 MW in 1985 and to 565 MW by 1990. These figures are obtained from analyses provided by our team members and are in general agreement with current PEWC expansion plans for the Blue Nile Grid (Power III and Power IV documents) but fall considerably short of the PEWC's projected expansion in Port Sudan and other systems.

Balance of Payments Implications of Base Case and Alternative Oil Export Scenarios

External debt in 1980 was estimated to be $3 billion, including $1.5 billion in bilateral loans (primarily from Saudi Arabia, Kuwait and the NAE), $600 million from multi-lateral donor agencies, and the remainder (about $900 million) from commercial banks or supplier credits. Much of the $400 million in supplier credits were not intended to be credits and merely constitute arrears in payments to suppliers. At the end of 1980, arrears in foreign debt repayments reached an estimated $1.3 billion--or roughly 30% of Gross Domestic Product. At the mix of concessional and commercial terms on which total debt was contracted, annual debt service payments should have been on the order of $280 million in 1980. This figure would have been over 40% of total exports in that year. However, a Paris Club agreement in late 1979 rescheduled non-commercial debt, and the effective 1980 debt service burden was on the order of $144 million. 1981 indebtedness rose about 20%, with most of the increment provided on concessional terms. The 1982 balance of payments deficit, after IMF and other capital flows, has been projected to be around $324 million, although current re-estimation of external debt is likely to increase this figure.

TABLE 55

PROJECTION OF INSTALLED CAPACITY, NEC SYSTEMS
(MW)

	1980(1)	1981(1)	1985	1990
Blue Nile Grid				
Hydro	135.0	135.0	225.0	265.0
Steam	17.5	17.5	77.5	137.5
Diesel	17.4	26.0	66.0	56.0
Port Sudan				
Diesel	7.6	7.6	37.6	37.6
Other Systems	22.0	30.4	46.4	69.4
	199.5	216.5	452.5	565.5

(1) Real (actual) capacity per PEWC Staff Report: Electric Power Status Report, March 1982.

Since 1980, as Sudan's balance of payments position has deteriorated, the Government, IMF, and others have made a determined effort to identify all public and private external debt obligations. Also, substantial additional debt has been incurred over the past two years. As a result, the estimate of total external debt increased to $5.2 billion by mid-1982, and more recently (September 1982) total external debt as of June 30, 1982 has been calculated to be $7.0 billion. This last figure has been used as the basis for our projection of future debt service requirements.

The current account balance of the Sudan will be affected during the 1980's both by increases in imports of crude oil and petroleum products and by export revenues or import substitution effects resulting from domestic crude oil exports starting (it is assumed) in mid-1985 by Chevron Oil Co. To calculate these impacts, Base Case projections value of the petroleum imports has been added to the World Bank projections of imports and exports of other goods and to the Bank's projections of capital movements, disbursements, amortization of debt and other factors in order to arrive at a "base" balance of payments figure for each year between now and 1992. This "base" projection assumes no exploitation of domestic oil reserves and thus is not a true "base case." It does incorporate rather optimistic (but plausible) World Bank assumptions regarding Sudan's future export performance, particularly in the agricultural sector (where sizeable increases in average, yields and world prices are assumed). It also assumes fairly generous donor concessional assistance and capital financing.

Next, we recomputed the "base case" balance of payments projections to account for the effects of oil imports, using a number of alternative assumptions regarding export prices, the government's share of export earnings, and likely increases in imports as a result of the increased national income generated. Except where otherwise noted, each oil export case assumes that (a) the required pipelines (a 22" export pipeline with an 8" return pipeline) cost $800 million and are financed at 11% over 15 years (yielding an annual debt service charge of $98 million) and (b) oil exports rise nearly from 15 million barrels per year in 1986 to 30 million barrels in 1990 and thence to 36 million barrels in 1992, (c) a 2% per year increase in real oil prices, and (d) a 50% government share of oil export revenues. The alternative oil export cases are summarized below:

- Assumptions as above, no resulting increase in total imports.
- Assumptions as above, total (non-petroleum and petroleum) imports increase by 13% of the increase in the total export value due to oil exports.
- Assumptions as above, total imports increase by 26% of the increase in total export value (assumes import elasticity of .13 as for Case 2, income multiplier of 2 on added exports).
- Same as Case 2 but no increase in real oil prices.
- Same as Case 2 but 60% government share of oil export revenues.
- Same as Case 2 but petroleum imports reduced by 10% (energy conservation case).

We caution that not enough is yet known about the details of pipeline financing costs, possible changes in government/Chevron sharing agreements, etc. and there has not yet been sufficient analysis of likely effects of oil exports in stimulating higher demand for imports. As a result, our estimates must be regarded as preliminary and indicative. Within the next two months, the simple macroeconomic and other non-oil exports -- means that foreign exchange will continue to be the primary limiting factor in both economic development and energy strategy long after oil exports commence. This has important implications for the country's energy policies.

Finally, we would point out that energy conservation can make an important difference but that no amount of plausible energy conservation or switching from petroleum to other energy sources (solar, wind, biomass, etc.) could "solve" the country's balance of payments problems. As shown in Table 56, a 10% reduction in petroleum imports versus the Base Case reduces the trade deficit by less than $100 million (Case 6). Even a 30% reduction, which would cut into productive enterprises (and exports) very substantially, would reduce the trade deficit by less than $250 million (less than 18% of the Case 2 trade deficit). It also should be recognized that the Base Case itself presumes significant conservation; government inability or unwillingness to institute demand management measures could increase the trade deficit by as much as this $250 million amount or even. This lack of demand discipline is a temptation to which some other oil exporting countries have succumbed and which -- like the temptation to ignore agriculture as oil exports increase -- the government must resist.

Implications of Projections of Use of Non-Commercial Energy

The impacts of the projected increases in use of wood and other biomass cannot easily be quantified, partly because it is difficult to project how much switching from fuelwood to dung, agricultural residues, and other biomass will take place (and where) and partly because the environmental/resource conservation impacts of deforestation are a function of both fuelwood use and agricultural land clearing. The projection of increased biomass use, taken together with the forestry survey results discussed elsewhere in this report and evidence in Sudan and elsewhere of the rapid soil deterioration which accompanies deforestation, suggest to the Project Team that the "fuelwood crisis" (or, more accurately, the "deforestation crisis") could be at least as serious as the much more visible balance of payments crisis facing the country. Indeed, widespread soil degradation as a result of deforestation and diversion of dung and other soil nutrients conceivably could affect a much higher percentage of Sudan's population than would continued balance of payments difficulties.

TABLE 56

ALTERNATIVE BALANCE OF PAYMENTS, PROJECTIONS
(nominal value, millions of U.S. dollars)[1]

PAYMENTS ACCOUNTS	1982	1985[2]	1990 Base Case (no oil exports)	30 MM Bbls/year, 50% Govt. Share[3] 2%/year / Real Oil Prices: No / Total Imports (1)	/ Imports 13% of oil Exports (2)	/ Imports 26% of oil Exports (3)	Case 2 But No / Real Oil Prices (4)	Case 2 But With: 60% Govt. Oil Export Share (5)	10% Lower Petro. Imports (6)
I. CURRENT ACCOUNT									
Exports									
Non-Petroleum Exports	887	1263	2174	2174	2174	2174	2174	2174	2174
Petroleum Exports	0	0	0	897	897	897	773	1076	897
Total Exports	887	1263	2174	3071	3071	3071	2947	3250	3071
Imports									
Non-Petroleum Imports	-1500	-2067	-3527	-3527	-3622	-3717	-3622	-3622	-3633
Petroleum Imports (excl. P.S.)[4]	- 396	- 529	- 795	- 795	- 817	- 839	- 817	- 817	- 735
Total Imports	-1896	-2596	-4322	-4322	-4439	-4556	-4439	-4439	-4368
Trade Balance	-1009	-1333	-2148	-1251	-1368	-1485	-1492	-1189	-1288
Other Current Inflows (net)	253	429	819	819	819	819	819	819	819
Current Account Balance	- 756	- 904	-1329	- 432	- 549	- 666	- 673	- 370	- 469
II. BALANCE OF PAYMENTS									
Debt Service	- 620	-1087	- 788	- 875	- 875	- 875	- 875	- 875	- 875
Capital Flows (net)	781	410	84	84	84	84	84	84	84
Payments Gap	- 595	-	-2022	-1223	-1340	-1457	-1464	-1161	-1260

1) Based on IBRD/IMF projections to 1985 adjusted for Base Case changes in sectoral growth rates and energy use efficiencies, revised external debt estimates, and impacts of pipeline financing and oil exports. Projected to 1990 and 1992 by E/DI.
2) Assumes pipeline debt servicing and oil exports commence early 1986.
3) Based on current Gov/Chevron agreement plus estimate of Chevron deduction of Field development expenses.
4) Port Sudan Refinery exports of fuel oil are included as deduction from petroleum import costs.

CHAPTER V

MAJOR ISSUES AND OPTIONS

Numerous issues have been identified during the course of the Sudan Energy Policy and Planning Project. This section briefly addresses the primary issues in each major end-use and supply sector. Expanded analysis of these and other issues is provided in the main report.

Transport

Private Passenger Travel

Customs Department statistics show a doubling in the number of passenger vehicles imported into the country between 1976 and 1981. Passenger vehicle registrations have also doubled in that same period, with over 60% of all passenger vehicles in Sudan registered in Khartoum alone. Khartoum area passenger vehicles consumed over 60% of all benzine used in the country in 1980. A recent U.S. study showed that official benzine prices are lower in Sudan (even at official exchange rates) than in any of the 29 countries surveyed in Africa (Egypt was not included.) Long petrol queues notwithstanding, low benzine prices encourage consumption. NEA surveys conducted in 1981 and 1982 in the Khartoum area showed an average private vehicle load factor of 2.8. More alarming was the average load factor of taxis, a very low 1.62 persons per vehicle, excluding the driver -- compared with 11 and 9.14 for mini-buses and "boxes" (small pick-ups converted for carrying passengers) respectively. Sudanese import regulations, particularly with respect to workers returning with vehicles from abroad, encourage the importation of private passenger vehicles. The NEA and the Project commissioned an extensive legal review of laws and regulations governing the importation of energy-intensive goods (Appendix X), which showed that a Sudanese worker, student, military officer or diplomat returning from abroad after certain periods of time could bring a personal vehicle into the country virtually duty free. Increasingly, consumption of fuel for such vehicles will necessitate reduced consumption of economically more productive fuels such as gasoil. The government will have to consider options for controlling vehicle imports, controlling growth in consumption (preferably by raising prices), and/or requiring some users (e.g. these with CD plates) to pay in hard currency.

Inter-Regional Dispatching

Road transport has assumed growing importance in Sudan as the network of paved roads has been expanded and as the performance of the railways and river transport has deteriorated. The primary direct impact of increased road transport has been on the rapid increase in gasoil and benzine consumption over the past five years. The completion of the Port Sudan-Khartoum highway in 1980 has had a strong influence on this increase. Statistics show dramatic increases in the importation of large, medium and small trucks in anticipation of completion of the Port Sudan-Khartoum highway. While at full load lorries (small trucks of 6 tons or less), are less energy-efficient per ton-kilometer than larger (particularly 12-25 ton) trucks, it has been found that "lorries" tend to operate at much higher capacity utilization than the larger trucks. One of the reasons for this is that smaller trucks tend to be owner-operated rather than company-operated, and it is in the owner's interest to maximize his load factor. Most of the larger trucks are

company-operated and driven by hired labor. Given poor long-distance communications and the near-absence of any regional or inter-regional dispatching system in the Sudan, the larger trucks often operate at full load one way and return to point of origin either empty or less than full. Therefore, one option for improving the energy efficiency of truck transport would be to encourage the establishment of an inter-regional dispatching service (or services) at major points along the Port Sudan-Khartoum axis, such as Khartoum, Wad Medani, Gedaref, Kassala and Port Sudan. These centers will probably evolve on their own; but, in the meantime, much fuel-inefficient activity will continue, particularly given the relatively low price of fuel and easy availability of gasoil in Port Sudan, where most of the large trucking firms have their depots.

Weight Limits

A road transport issue that will soon have far-reaching energy implications is the lack of enforced weight limits on the Port Sudan-Khartoum Road. Currently, many of the larger vehicles are operated (at least in one direction) with loads greater than the road was designed to take. Serious road damage is already apparent on the older stretches. If such abuse continues, large stretches of the highway will be potholed in a few years, dramatically lowering the fuel efficiency benefits which accrue from tarmacked roads. National and regional load limit laws are applied in a piecemeal fashion, if at all. No truck-weighing stations exist in Sudan. NEA field survey teams learned that trucks are monitored by private contractors, contracted by provincial authorities to collect tolls at places along the highway where such stations could be located and not easily avoided (such as the Hantoub Bridge on the Blue Nile in Wad Medani). The contractors realize a share of the tolls, which are calculated at extremely low rates per vehicle (25 piasters for a truck, regardless of size, at Hantoub, for example), and give the rest to local authorities. They have no enforcement authority and are not charged with making determinations of vehicles' loads. One need only look at the conditions of the highways in other countries (such as Tanzania), where little or no enforcement of highway load regulations has occurred, to gain an idea what may happen to Sudan's new highways in the near future, without such enforcement.

River Transport

Many studies conducted over the past several years (by the Ministry of Transport and Telecommunications, USAID, Chevron-Bechtel, etc.) have pointed to the shortcomings of Sudan's present river transport system. All have pointed to Sudan's natural endowment with some 5,000 kilometers of navigable waterways. An estimated 70% of all Sudanese live within 30 kilometers of a navigable canal or river. Moreover, major rail and highway terminals are located on the Blue and White Niles or their tributaries. River transport is practical for bulk freight transport because of the relatively small capital investment required to develop and sustain it as well as what should be its low energy cost. While most goods transport now is East-West while the river system is North-South, new trade--particularly with the South--is likely to occur once the river transport system is improved. Were the private sector to move a fraction as rapidly into the river transport sector as it has in the road transport sector, (and there are signs that it is poised to do so), Sudan could witness a major expansion in the volume of freight moved by water and a corresponding reduction in the energy required for such transport.

Rail Transport

Sudan's railways remain by far the most energy-efficient form of transport per ton kilometer in the country. Yet, as has been thoroughly documented and addressed in numerous studies and rehabilitation programs (most notably the World Bank's four railway assistance programs over the past two decades), Sudan's rail system is in serious trouble. Total quantities of goods transported by rail have been steadily decreasing since the early 1970's, primarily due to the small gauge of the track, poor maintenance of track and equipment, and severe labor and management problems. People increasingly have turned to road transport. The government's infrastructure development program invested one-third of all development funds in roads and telecommunications over the past five years, thus encouraging people to make use of the roads, versus only 550 million in railroad improvement. Private investment in road transport in the past four years was twice the total investment in railroads over the last decade. The low parity price of gasoil until March 1981 further encouraged the use of road transport, making it more competitive relative to rail. Government rail transport tariff policies have further decreased the competitive position of the railroad. The last price revision for rail transport of bulk items came into effect in March, 1980, well before the petroleum price increases of March and November, 1981, and the unification of the pound exchange rate in November, 1981. Rail tariffs are insufficient to provide for sound operation, maintenance, and management.

The SRC also has hurt itself and the country by its decision, in response to growing loss of traffic to trucks, to try to compete head-to-head with heavy trucks on short hauls. It is on these short hauls that it is least cost-competitive and, in terms of fulfilling national needs, least necessary. The railroad provides the best access to the rich agricultural areas of the West, and concentration on these long-haul routes both would strengthen the economic and infrastructure base of this area and should provide a more attractive economic return to the SRC as transport requirements grow in response to agricultural expansion and rehabilitation and completion of feeder roads to major railheads (Nyala, El Obeid, etc.). The railroad also will (or should) be indispensable in supporting construction of the oil pipeline. Unless rail tariff policies and the SRC's current policy of trying to compete head-to-head with heavy trucks on short hauls in the East are changed the rails may never recover.

Households

Kerosene

A recent GPC report on kerosene examines points raised elsewhere in this report--particularly substitution of gasoil and charcoal for kerosene--and recommends making more kerosene available to domestic consumers. This step probably would be difficult politically since it would decrease Refinery production of benzine and jet fuel. If there were some assurance that there would be a commensurate decrease in household gasoil consumption, an increase in kerosene production or imports would appear to be justified economically. However, given the high demand for cooking and lighting fuels in other sectors, such assurance does not appear probable.

Fuelwood and Deforestation

As discussed throughout this report, increasing wood and charcoal consumption has been a contributing factor--together with land clearing for mechanized rainfed agriculture--in the acceleration of deforestation in areas such as Blue Nile Province and southern Kassala Province. Thermal efficiency of cooking with wood and charcoal is extremely low, as is efficiency of charcoal conversion. More efficient cookstoves and cooking methods and charcoal kilns would reduce deforestation pressures and reduce the time or money costs of woodfuel use. This in turn conceivably could enable some of the rural poor who have switched to using animal dung and crop residues--removal of which is likely to reduce the fertility of their land--to be able to afford to use woodfuels once more. Thus, from a number of points of view it would appear highly desirable to support the development, testing, and dissemination of more efficient cookstoves, cooking methods, and charcoal production. Such effort, which could be part of several new donor-financed renewable energy or forestry projects, should take advantage of the very substantial private sector activity already existing in these areas. We recommend that cookstove improvement initiatives focus on urban rather than rural cookstoves, for a number of reasons:

- Widespread media accessibility makes it easier to disseminate information.
- Craftsmen's guilds, cooperatives, etc. are found in urban areas.
- These should be economics of scale in extention/dissemination effort, given large population concentration.
- Marketing of urban stoves is tied to the money economy, and charcoal is sold through the money economy, making it easier to reach users.
- Urban areas use proportionally more charcoal (versus wood), and therefore consume more wood-equivalent per person.

Experience throughout Africa suggests that the government should view cookstove and charcoal production improvement as a gradual, long-term process which is unlikely to make significant inroads into Sudan's deforestation problems in this decade.

LPG

The GPC has recently approved expansion of the LPG distribution network in Sudan to provide greater service to Khartoum while establishing supply points in Kassala, El-Obeid and Atbara. Further proposals to substantially expand the present limited LPG network need to be examined critically. Are the capital cost and increased level of petroleum product imports justified--relative to other uses of limited external capital and uses for other petroleum products such as gasoil --in view of the fact that such LPG is to be used only for cooking, and only by a small (and well-to-do) fraction of the population?

Residential Electricity Use

As noted in preceding sections, for at least the next two years the Sudan will face a widening gap between electricity demand and the NEC's ability to satisfy that demand. Beyond that time, once new generating plants come on line the country may face a different problem, namely that it will be unable to pay for sufficient imported petroleum fuels both to supply all the NEC powerplants and to satisfy all non-electric power fuel demands. In both these periods, the Government will have to examine closely its policies regarding tariffs, load shedding and fuel allocation priorities, and incentives or disincentives to the purchase of energy-using equipment. One area which deserves attention in this respect is residential air conditioning, where demand has been growing rapidly and units currently imported or produced in-country appear to be quite energy-inefficient relative to both air conditioners available elsewhere and competing air coolers produced in the Sudan.

The rapid growth in air conditioning load is now seriously affecting the NEC's ability to supply its residential consumers in many areas of the Blue Nile Grid (BNG) and is rapidly changing the whole system's load profile. The NEA, with the assistance of the NEC, has estimated the power demand and energy consumption of these units. Air conditioner installations have been growing at an average of 20-30% per annum since 1977 with some 8,100 units installed from 1977 to 1982. Refrigerator installations have been growing steadily at a fast pace since the early 1970's and have averaged some 10,000 units per year since 1977. Air cooler (evaporative cooler) installations have also been growing at a rapid but steady rate since the early 1970's, with some 6,000 units being installed annually since 1977. The NEA and NEC estimate that some 8,000 air conditioners are currently installed and functioning in the Khartoum area (Blue Nile Grid), while approximately 31,000 air coolers and 50,000 refrigerators (8-14 cubic feet size, with 85% of 10 or 12 cubic feet capacity) are currently operating on the BNG. Energy consumption from air conditioners constitutes approximately 50% (51 MWh in 1981) of the total energy consumed by these three types of goods and some 25-30% of total residential energy consumption in 1981.

The following assumptions were used to derive these estimates; namely, air conditioners operate:

6 hours/day--2 months/year
9 hours/day--3 months/year
12 hours/day--3 months/year

or a total of 2,286 hours per year. Doubtless, these are fairly conservative assumptions. Air coolers are assumed to operate the same number of hours per year while refrigerators are assumed to operate 24 hours per day, 365 days per year.

Domestic production figures for the years 1977 through 1981 were obtained from the two local manufacturers in Sudan. Import statistics for these goods were obtained for the same years. It was assumed that all units imported or manufactured locally during this five year period were operating in 1981 (also a conservative estimate, as Sudan imports each year enough compressors and other critical spares for these units to service only some 15-20% of all units imported during this period). These assumptions yield the following estimates for 1981:

TABLE 57

	UNITS IN OPERATION	ENERGY CONSUMPTION(MWh)	AVERAGE LOAD(MW)	% AVE LOAD
Air conditioners (16,000-18,500 BTU)	8,150	51.000	22.30	72.6%
Refrigerators (8-14 cubic feet)	50,900	46.200	5.27	17.1%
Air Coolers (2,200-4,000 BTU)	21,180	7.250	3.17	10.4%
TOTAL	80,230	104.450	30.74	100.1%

SOURCES: Coldair Industries, Sheet Metal Industries, Customs Dept., Dept. of Statistics.

Project surveys of major industrial plants indicate that, while energy is an important constraint, there also are other key constraints to improvements in production and capacity utilization in many industries, such as shortages of skilled labor, poor management, lack of hard currency with which to buy needed equipment or spares, and the like. Indeed, in many industries, management cited energy supplies as their major constraint while at the same time they were either engaged in or contemplating major extensions to their plants. Also, for some public corporations, the reason they cannot secure adequate fuel supplies is that they simply do not have enough money for fuel purchases. Sectoral generalizations are also difficult. Some textile plants, for example, were visited where shortages of or disruptions in energy supplies were key constraints to improved production, while other textile plants were visited where other inputs (labor, spares, management) were the key constraints. Nevertheless, improved delivery and reliability of electricity supplies to most of the large textile mills on the Blue Nile Grid, assurance of more reliable fuel delivery to the cement plants, etc. would allow for significant improvements in production and plant capacity utilization. The NEA now has sufficient plant-by-plant data--and continues to collect new data--to permit the Government to identify specific plants where assuring more reliable energy supplies would make a major difference to the country's economy. The capability also exists to analyze the potential economic benefits of providing improved/augmented fuel supplies or electricity to such plants versus providing such fuel suppliers or electricity to alternative users (e.g., an agricultural scheme). Simultaneously with such analysis, the NEA, GPC, NEC, and others would have to work together to determine how, in fact, priority supplies to high-return users could be assured.

Residual Fuel Oil Utilization

There are several key issues regarding utilization of furnace oil from the Port Sudan Refinery. One is the current, expensive utilization of 1500" rather than heavier 3500" residual by-product from the refinery. The second is the domestic demand for furnace (residual) that is forecast over the next several years.

All industries in Sudan which presently utilize furnace oil for their energy needs use a light 1500" residual which is a blend of the 3500" residual throughput from the Port Sudan Refinery with kerosene. This is an expensive way to supply fuel to industry. Several years ago, the Refinery was supplying industry with an even lighter fuel oil, 750", and then began to supply 1200" to cut costs. Later, the Refinery began supplying 1500" to further reduce costs of kerosene use. In theory, any factory which uses 1500" furnace could use 3500" with small modifications to its boilers. Even more important is the supply of furnace oil to industries that are now coming on line. For example, the Maspio (Atbara) Cement Plant expansion, Sudan-Ren Fertilizer Complex, and continued Kenana sugar plant expansion together will account for an additional 102,000 MT of furnace oil consumption by 1984. Current plans call for them to be supplied with 1500" furnace when all could fit their boilers to burn the 3500" fuel oil, at considerable savings for the country. Design specifications for the Khartoum North Steam Station (Electricity) call for use of 3500" furnace oil. However, project studies revealed that, on the one hand, Sudan Railways had no plans for transporting the additional residual (1500") fuel requirements of Maspio and Sudan. While on the other hand, no investigations have been made into the ability of Sudan Rail to transport the 3500" residual that will be required by the two NEC 30MW steam boilers at Khartoum North. The three key issues to be examined in these matters are:

- Can and will Sudan Rail supply the additional 100,000 MT of furnace required by these plants?
- Can and should Maspio and Sudan - rail burn 3500" residual rather than 1500" residual in their boilers?
- Can Sudan Rail transport the heavier and more viscous 3500" residual to these plants?

Supplying 3500" furnace to these plants would free up kerosene for other, particularly household, purposes and this in turn conceivably could lessen pressures on gasoil. This provides one prime example of the need for integrated, coordinated energy planning.

Another point arising out of the above-mentioned expansion plans is that by early 1984, after the four industrial and utility projects outlined above have come on line, Sudan will cease to export residual oil and will instead become a net importer. GPC planners forecast a residual shortfall even earlier. Sudan exported some 168,000 MT of residual (earning $25 million) in 1981. Residual exports have been decreasing steadily by approximately 7.2% per year since the mid-1970's due to increasing domestic consumption and less refinery throughput. This is discussed in more detail in the Petroleum section below.

Agriculture

Fuel Allocation to Major Schemes

As discussed elsewhere in the report, NEA estimates of actual fuel consumption for some agricultural schemes differ markedly from GPC fuel allocations to those schemes. The GPC currently is analyzing such discrepancies to determine what changes, if any, to its allocations should be made. The NEA and GPC also should address whether the basis for calculating allocations to such schemes should be modified. In the past, because of lack of data, the GPC has set each scheme's allocation on the basis of the previous year's allocations and each scheme's rationale for additional supplies. Now that the NEA has detailed fuel consumption factors per feddan by crop and by type of agricultural operation for each scheme, a basis exists for much more accurate estimation of each scheme's fuel needs.

The GPC also should address whether detailed allocation quotas remain appropriate in an environment where fairly rapid and sizeable changes in acreage, the mix of crops planted, yields, and other variables by agricultural scheme have become commonplace. The current system provides potential windfall profits to schemes whose production (and therefore fuel requirement) declines and who are thus able to sell some supplies to black market dealers. It also discriminates against the private agricultural sector, which must rely almost entirely on black market suppliers at prices two to ten times the official prices paid by the government schemes.

Fuel Distribution to Agriculture

Unfortunately, having an adequate allocation does not guarantee an agricultural scheme will get all the fuel it needs at the time it needs it. Seasonal gasoil shortages in agriculture were particularly severe in 1981-82 and seem likely to become a regular occurrence until there are more effective means of scheduling gasoil deliveries over the course of the year, storing gasoil in anticipation of peak demands, and clearing letters of credit for emergency gasoil deliveries should shortages loom. At the request of the Minister of Energy and Mining, the GPC has begun discussions with the oil distribution companies to determine what improvements are possible within the very serious foreign exchange constraints facing the country. The GPC, in conjunction with the NEA, also has substantially improved its projections of monthly variations in demand for gasoil and other petroleum products.

Petroleum

Projected Growth in Industry/NEC Fuel Consumption

A number of large energy-intensive projects which are near completion, under construction or presently planned to come on line by 1985 will have very significant fuel use impacts. These projects include:

- Doubling the production capacity of Maspio (Atbara) Cement Plant (1982):
  - 20,000 MT furnace oil/year
  - 12,000 MT gasoil/year
- Completion of the Sudan-Ren Fertilizer Complex (1982):
  - 50,000 MT naphtha/year
  - 52,000 MT furnace/year
  - 5,000 MT gasoil/year (for road transporting naphtha)

-Completion of Power III Project--Burri P/S Extension and Khartoum North 60 MW Steam Turbine P/S (1983-84):
84,000 MT furnace/year
52,000 MT gasoil/year
-Expansion of Kenana Sugar Complex (1982-84):
30,000 MT furnace/year
-Bitumen(Asphalt) Plant at Port Sudan (1985):
50,000 MT furnace/year
6,000 MT kerosene and gasoil/year

Satisfying the petroleum requirements of these facilities alone will raise Sudan's consumption of petroleum fuels by over 360,000 MT per year (over 30% of current annual consumption) by 1985. Additional projected fuel consumption from all other sectors and users will increase Sudan's oil imports further. If these new plants and projects are to operate, Sudan will be forced not only to import more gasoil, kerosene and benzene than in the past, but for the first time, the country--which in 1981 exported 165,000 MT of residual fuel oil worth 25 million--will have to import substantial quantities of residual as well.

Petroleum Imports Allocation

As demand for petroleum fuels increasingly outpaces supplies, it becomes more imperative to design an allocation system that operates smoothly and achieves its objectives. It appears essential both to supply petroleum products to consumers which are important to national security and which provide key social services (e.g., rural water pumping, hospitals, health clinics and so on) and to evaluate all other customers on a basis of maximizing economic efficiency and the productive use of petroleum products. For the next few years, Sudan will continue to import virtually all of its petroleum and pay for those imports in hard currency. Even after oil exports commence, oil import limitation will be necessary to help narrow Sudan's payments gap. Such imports need to be directed to uses which make the maximum contribution to national economic, social and national security objectives.

There are options that could help raise foreign exchange finance imports of petroleum fuels as well as encourage allocation of such fuels to customers contributing to economic development, since an availability of foreign exchange will remain the major contraint on the country to the purchase of all imports, not just petroleum.

The GPC, in cooperation with the Bank of Sudan and other government organizations, has begun to explore some of these options. For example, the GPC is encouraging selected large exporters to make their own arrangements, through their normal commercial banks, for letters of credit to purchase petroleum products from abroad. Such orders are consolidated by the private oil companies and expeditiously approved by the GPC, and supplies are purchased without the uncertainties of the Bank of Sudan having to accumulate the funds for a government L/C.

One can point to possible directions these and future initiatives could take. In particular, those customers that produce for export (thus generating hard currency to purchase more petroleum and other essential economic inputs) or those customers whose production displaces imports (import substitution) should be identified by the GPC as should those customers who do not directly contribute

to the nation's hard currency earnings. Such criteria would be difficult but not impossible to establish. For instance, those schemes and individuals who produce cotton are easily identifiable. Import substitution industries such as cement or textiles which produce non-luxury commodities and which indirectly earn foreign exchange (by saving it) are also easy to identify. Once these customers are identified, the government would have several options available to ensure necessary supplies to these key economic actors.

- A system of blocking the hard currency earnings to pay for the petroleum requirements) of an export-oriented customer could be initiated. For example, the NEA and GPC already have the data to determine the petroleum requirements for a scheme like Gezira (a major cotton exporter). Those requirements could be valued in hard currency and paid for through the foreign exchange earnings of the customer (which are known). In this manner, the more profitable a customer is (the more that customer exports), the more funds that could be blocked to purchase the fuel required by that customer.

- The same method perhaps could be applied to import-substitution customers. The foreign exchange saved by the customer through production could be valued and blocked. The petroleum requirements for the customer could be determined and those requirements met by the value of the foreign exchange saved by the customer.

- The current initiative whereby private sector hard currency earners are allowed to purchase their fuel requirements with foreign exchange deposited with their commercial banks in Sudan, thus relieving the GPC of some of the problems of opening letters of credit, could be expanded. These customers would have to demonstrate to the GPC, Bank of Sudan and Ministry of Finance that the hard currency thus used originated from exports and that it did not exceed the customer's requirements (which, again, the NEA and GPC can establish).

- Commercial banks and private Sudanese conceivably could be allowed to purchase petroleum fuels directly through foreign exchange (or a percentage thereof) deposited in those banks by Sudanese working abroad. This would allow more flexibility to a system of petroleum allocations that would give those customers not directly engaged in exports or import substitution access to more petroleum. Again, the GPC, Bank of Sudan and Ministry of Finance could set the limits for such purchases and could further establish authorized customers and purchases.

Any alternative petroleum import financing arrangements should be very carefully examined in light of Sudan's limited foreign exchange options and many pressing demands to ensure that other essential imports are not curtailed to satisfy petroleum needs. Total cooperation between all agencies and parties concerned with vital imports and meeting the nation's foreign exchange commitments needs to be assured. Moreover, any options which permit foreign exchange purchases of petroleum fuels outside the GPC's present allocation system must be studied carefully. There is a risk that allowing customers to use foreign exchange to purchase petroleum products will result in the use of the non-bank foreign exchange market, thus further draining available hard currency from official channels and decreasing the value of the pound, and/or that such purchases will be diverted to the black market. Also, were any of the above types of options

chosen to relieve petroleum shortages, extensive monitoring and evaluation would be necessary. Moreover, the commercial banks should be used for any such transactions in order to maintain control of the outflow of foreign exchange and better monitor prospective consumers.

Pricing

Another obvious policy option to encourage allocation of scarce petroleum fuels to economically-efficient, hard-currency generating/saving enterprises is to use the pricing mechanism. Although government raised official prices of petroleum fuels twice and also adjusted official exchange rates in 1981, petroleum fuels in the Sudan still are among the lowest priced in all of Africa. A recent U.S. study showed that domestic prices charged for various petroleum products (benzene, kerosene and gasoil) are lower (even at official exchange rates) in Sudan than in any of the 26 African countries surveyed. At present prices, demand is so much greater than supply that a thriving black market exists in areas away from the Central and Eastern Regions (and it exists there as well during times of shortages). While black market prices vary widely by time of year and geographic area, prices three to five times official prices year-round are not unusual for regions far from the Khartoum Port Sudan highway network; and, at times of seasonal shortage, black market prices often exceed ten times official prices.

While pricing above official exchange rate costs remains an unpopular option for various reasons such as social equity, the country's worsening balance of payments position and consequent need to limit non-essential imports of all kinds is likely to force reconsideration of pricing policies. Also, the government should study the possibilities of influencing consumption through discriminatory pricing (e.g., further increases in prices of super benzine with respect to regular), further restrictions on locations where certain customers, (e.g., taxis, boxes, private personal vehicles, etc.) may purchase fuels, differential taxing (through insurance, licenses, and so on) of private vehicles, improving the energy efficiency of urban transit (buses, boxes and taxis) through tax incentives, and so on. Without resort to pricing and/or these or other means, the government will increasingly depend on heavy-handed allocation systems. The growing differences between official and black market prices will accrue to profiteers rather than to the government, and the government will continue to lose both revenues and opportunities for encouraging more efficient energy use.

Scheduling of Crude Oil Imports

As discussed in Chapter V, the major reason for decreasing throughput levels at the Port Sudan Refinery--1981 throughput was 80% that of 1973--appears to be that the government finds it very difficult to secure letters of credit to finance crude oil imports. The resulting uncertainty in scheduling issuance of LC's and hence in scheduling crude oil deliveries means that the refinery, which has little storage capacity, often must shut down for lack of input. Some of the above "allocation" options conceivably could help generate more predictable hard currency flows for petroleum purchases. If, as is likely, the balance of payments position continues to deteriorate, the government also will have to address options, such as specially-funded foreign exchange accounts, to regularize crude oil purchase.

Electricity (including Self-Generation)

NEC System Improvement

The Project Team has produced two major reports addressing long-range capacity expansion and short-range reliability improvement needs, respectively, and helped identify immediate capital investments and management measures to improve supply reliability on the Blue Nile Grid. In view of the extensive discussion which already has taken place on these matters and the fact that a number of consultants--including Sir Alexander Gibbs, Merz and McLennan, Bechtel, and the Irish Electricity Supply Board--are providing more detailed analyses, the Project Team will only highlight a few major issues relating to the NEC:

- The gap between demand for electricity and NEC capacity will widen until new Power III generation units come on line. During this period, the Government will face increasingly difficult decisions relating to load shedding priorities. More attention needs to be given to the differential economic and sociopolitical effects of cutoffs to different users (oilseeds plants vs. textile mills vs. water pumps vs...) and load shedding priorities drawn accordingly.

- As recent outages demonstrated, new generation capacity is only one aspect of improving supply reliability. In addition, the BNG transmission and distribution system is extremely vulnerable to disruption; the NEC's routine maintenance and emergency repair capabilities are inadequate; and system communications and controls are rudimentary. The USAID-financed short-term reliability improvement program goes part way toward addressing these problems; but long-term investment in improving system operations and maintenance is needed.

- Some industrial plants currently have a very poor power factor. Others could achieve immediate reduction in electricity use with no capital investment. Still others have underutilized wastes which could be used as boiler fuel. It is worth conducting energy audits of large industrial energy users with relatively high capacity utilization rates. This can result in freeing up electricity for other uses far faster than new generation capacity can be brought on line--often at negligible cost.

NEC Capacity Expansion: Hydro vs. Thermal

As discussed elsewhere in this report, Sudan's hydrological profile does not lend itself well to baseload hydropower utilization. Variations on the Blue and Main Nile are so extreme that continual power generation requires very large dams placed in areas with large storage basins, few of which exist. Heightening the Roseires Dam by 10 meters will slightly relieve this extreme variation but will not eliminate the problem. Moreover, Sudan is but one of several parties to the Nile Waters Agreement. Because of high rates of evaporation in Central and Northern Sudan, any large body of water would be subjected to severe losses, reducing Sudan's usable share of the Nile. Finally, any large new dam both will be expensive and will take many years to bring to fruition. Thus, while feasibility studies should continue on High Merowe and other hydropower options, thermal generation of necessity must play an increasing role in Sudan's power development over at least the next decade.

Self-Generation

As discussed in this report, self-generation is a critical issue in Sudan. Key national issues raised by self-generation are:

Large amounts of gasoil are required for self-generation. Sudan paid $8.5 million for roughly 29,000 MT of gasoil (24,400 MT industrial, 45,000 MT private non-industrial) for self-generation in 1980. Until new NEC plants come on line, self-generation--and thus gasoil consumption--will have to rise. The implications for gasoil supply-demand problems needs to be addressed.

Until NEC generation capacity is increased several industries with large self-generating capacities could help alleviate the country's power shortages. Some industries already supply the NEC or local communities with surplus power: Maspio Cement to the NEC in Atbara with several megawatts, the Port Sudan Refinery to local customers and for the past two years the Kenana Sugar Complex to the Blue Nile Grid (up to 13 MW during July through early September). While conceivably Kenana could supply the BNG on a regular basis with over 10 MW during the summer months, serious difficulties have arisen between the NEC and Kenana in the past year. These difficulties should be ironed out prior to next summer when the BNG's shortfalls in supplies will be even greater than the past year. The NEC is investigating, through a private consultant, the possibilities of utilizing the power generating facilities of the other four sugar factories during the pass processing periods (in April and May) when they generate surplus electricity. This period coincides with minimum hydroelectric generation at the Roseires, Seninar and Khaslum El-Girba Dams. An additional 20 MW supplied by the five sugar factories during the summer months would have substantial economic effects.

The sugar industry consumed 35% of all furnace oil consumed by industry in 1980. The sugar industry should be nearly 100% energy self-sufficient by burning bagasse. However, the moisture content of bagasse presently burned in Sudan is approximately 50%, a high figure by world standards, and energy conversion efficiencies are low. The sugar factories could increase their energy efficiencies by pre-drying bagasse prior to firing it in their boilers, thereby reducing consumption of furnace oil. Drying the bagasse for two weeks would reduce its moisture content to 30% and reduce furnace fuel requirements by 25%, or 9,430 MT per year (in 1980). This would entail some handling problems and would reqire more labor and possibly some additional equipment but would result in a savings in foreign exchange of at least $2.0 million per year (at current world prices). Further savings in furnace fuel could be achieved by evaporator section and other process energy efficiency improvements in the plants themselves.

Forestry/Fuelwood

The nature of Sudan's forested areas varies widely from one geographic area to the next. Forestry "issues" vary, even within a single province. For instance, forested land lost to mechanized agriculture in the Blue Nile Province is a critical issue while it is not in nine of Sudan's twelve other northern provinces.

Within the Blue Nile, one would seek to plan the utilization of forests or the expansion of mechanized rainfed agriculture for purposes of watershed management in the areas around, for example, Damazin and Singa while seeking to plan forestry utilization in the eastern parts of the province for purposes of soil conservation. While provinces of Central Sudan are suffering from annual off-take far beyond sustainable yields, the Southern Sudan will enjoy a forestry surplus for at least the next decade; but this is not true for the hinterlands surrounding several large urban areas in the Sudan Region, most specifically Juba, Wau and Malakal. With this caveat, one still can identify important "national" issues, arising from the dramatic increase in charcoal consumption and expansion of mechanized rainfed agriculture.

Mechanized Rainfed Agriculture

Mechanized agriculture will continue to play an important role in Sudan's economic development. It is a vibrant sector which has responded quickly to growing demand for various crops. The area under cultivation in the mechanized agricultural sector will probably continue to expand over the next decade. However, while agriculture and forestry are competing for land use, they should not be viewed as mutually exclusive. In fact, experience throughout the world has shown that agricultural and forestry land use must work in harmony, with a long-term view of both sectors. Land that has been totally cleared of forests for agricultural purposes may show large yields for a few years, but the ecological imbalances wrought by clearing all trees will eventually have a telling effect. Soil erosion, will begin to wear away the agricultural base. The absence of trees as windbreaks will increase evapotranspiration (which is very high in most of Sudan), reducing crop yields. Such "land mining" is already prevalant in Kassala and Blue Nile Provinces and is now a growing concern in the White Nile and Southern Kordofan Provinces. This type of agriculture, in which land is cleared of virtually all trees, tractors plow up the soil, and crops are planted until the soil is exhausted and the farmers move on to new land (leased at low rates from government), is the modern version of the traditional "slash and burn" type of agriculture.

Forestry studies show that in areas above the 300mm isohyte, natural tree regeneration usually occurs with the soil returning to its natural fertility within six to ten years and most trees reaching full maturity in 15-30 years (in Central Sudan). If this cycle is interrupted early, as it increasingly is, the land never fully recovers its fertility and extensive soil erosion often results. Land "mined" below the 300mm isohyte may never recover its full fertility after the first cycle of land clearing and farming. This has occurred throughout North Central Kassala and is one of the primary causes for desert encroachment in the area. Mechanized cultivation in the province (which began in the early 1950's) has shifted southward each year, leaving behind thoroughly exhausted land.

Forestry Administration guidelines for mechanized rainfed schemes--requiring slopes and other fragile lands to remain forested, requiring a minimum percentage of land to be left in shelterbelts or other forest, etc--have been ignored virtually everywhere. Also, the fact that much of the wood cleared is not converted to charcoal needlessly increases pressures on other forested areas. This is not in the best interest of either the country or, in the long-term, farmers. In order to assure that continued expansion of mechanized rainfed agriculture is sustainable and to keep the maximum fuelwood production and soil/water conservation benefits of Central Sudan's remaining forest areas, more effective controls on land clearing must be instituted and enforced.

Forestry Extension, Enforcement, and Fuel Supplies

Foresters have been fighting a losing battle against deforestation in several provinces, especially in Kassala and Northern Kordofan, over the past two decades. For example, both provinces are too large and forested areas too dispersed for foresters to monitor the production of charcoal and are near enough to Khartoum to be subjected to the pressures for charcoal production. Foresters in Kassala estimated that illegal charcoal production is at least twice as high as legal production and that there is little that they can do about it. Rarely do foresters in the field have sufficient benzine to monitor forested areas and often local, provincial and regional policies prevent them from exercising effective control over forestry utilization. In other Northern Provinces--particularly the Blue Nile, Southern Kordofan and North and South Darfur--foresters are barely holding their own against increasing pressures to cut or clear forests. Forestry extension is at present virtually non-existent. Little extension training is provided. Even were forestry extension taught at the Forestry School in Soba or at the University of Khartoum, it would be nearly impossible for foresters to practice extension given the lack of fuel and spare parts to operate their vehicles. The problems foresters face in obtaining needed petroleum fuels supplies cannot be too strongly stressed. Hence, much greater control, monitoring and even rudimentary extension would come about by allocating more supplies of fuel to foresters in the field. When asked to evaluate the current Gum Belt rehabilitation program all foresters interviewed mentioned the vehicle fuel component of the program as one of its best features; for the first time in years, foresters in Northern Kordofan have enough fuel to get out into the fields on a regular basis. Also, Forestry Administration operating budgets are inadequate to meet even minimal extension and enforcement demands. Thus, foresters are unable to carry out even a "defensive" policy of protecting existing forestry reserves, much less to meet the demands of improved resource management, monitoring and policy enforcement. The Project Team considers it essential that the Forestry administration be empowered to carry out these key functions. The cost of deforestation in the rich agricultural lands of Central Sudan is many times the savings gained from continued budgetary neglect.

Integrated Land Use Management

The basic philosophy of the Forestry Administration in Sudan is to conserve forests. As such, this philosophy is essentially a defensive one and leads to a defensive policy. As problems (e.g., shortages of benzine and spare parts for Forestry Administration vehicles) mount, the nature of the policy becomes more and more protectionist. Moreover, this policy is often in direct conflict with and unable to react to competing demands for Sudan's land resources. In most parts of Kassala, for example, one finds shrinking islands of forested land surrounded by lands under cultivation (or previously under cultivation) which have often become semi-desert or desert, particularly in areas which receive less than 300mm of rainfall annually. Had the Forestry Administration been allowed to adopt and enforce a policy of forestry management for the whole province--as part of a larger effort in which the various units of government which are charged with land use management (soil and water conservation, range management, watershed management, etc.) and with land utilization (mechanized agriculture, public agrischemes, etc.) effected in a concerted manner, it is likely that considerably more land in Kassala would now be forested and the severe ecological effects now being experienced in the province would have been mitigated. As it is, without such integrated land use planning and management, it appears that other provinces are condemned to repeat the experience of Kassala.

Improved Charcoal Production

Improved charcoal production through the introduction of better, more efficient charcoal kilns could have a significant effect on deforestation. Charcoal production in Sudan at present is very inefficient. A cubic meter of wood yields an average of less than $0.16m^3$ of charcoal under current production methods. Improving those yields by an average of 50% would result in a net reduction in deforestation of approximately 23 million m^3 of growing stock each year. Most charcoal production is on a small scale, so that any new technology introduced to improve charcoal yields must be relatively inexpensive. A number of types of small efficient kilns have been introduced in other countries. Further, introducing such technology must be accompanied by active extention efforts aimed at disseminating the technology and advertising the results to other producers, working with and through the existing private sector producer-wholesaler/transporter network. Efforts to develop and disseminate improved charcoal kilns--particularly inexpensive kilns requiring little labor, for use in conjunction with land clearing for mechanized rainfed agriculture--should be undertaken as part of planned USAID, GTZ, and Dutch-financed projects.

Other Renewable Energy

Other renewable energy resources--solar, wind, minihydro, and non-wood biomass--currently are not used to any significant degree. The major issues regarding these resources, as discussed elsewhere in this report and in specialized appendices, relate largely to what technologies appear most appropriate, what maintenance/service infrastructure is needed, and so forth. These will be addressed by the NEA and Energy Research Institute in conjunction with renewable energy development projects funded by USAID and GTZ.

This research and field testing phase is projected to last 3-5 years. During this period, initial groundwork for field dissemination is to be laid for those technologies offering short-time potential, after which broaden-scale dissemination could begin. This schedule would result in only a negligible contribution of these non-biomass renewable energy technologies in the 1980's.

A dramatic acceleration of this schedule--due to a substantial decline in hardware costs, widely recognized reliability improvements, increased private sector interest, etc.--does not currently appear likely but cannot be ruled out. One inspected private businessman, for example, is actively promoting "windfarms" employing 200 or more windmills to generate electricity to sell to the NEC. The government should stay abreast both of technology least developments and private sector interest and initiatives in this area.

CHAPTER VI

SUMMARY OF CONCLUSIONS AND RECOMMENDATIONS

The energy "crises" referred to in the Introduction chapter of this report are growing increasingly severe. Petroleum imports are becoming more difficult to obtain as foreign exchange becomes increasingly scarce. Disruptions in and shortages of power supplies are negatively affecting the Sudanese economy as industries curtail production for want of energy or turn to self-generation, thereby increasing demands on scarce petroleum resources. Rapid deforestation is causing severe short-term economic effects as the price of charcoal and wood products rises above the means of many. Its long-term soil deterioration effects seem likely to threaten the agricultural base of many currently productive Provinces.

These problems will worsen during the next few years. They are tied, both directly and indirectly, to the nation's serious balance of payments problems. In the short run, over the next three to five years, severe shortages of hard currency will place ever-greater premiums on what foreign exchange can be obtained for imports--petroleum needs are and will continue to be one of the many competing demands placed on Sudan's available foreign exchange supplies. As Sudan's power generation becomes increasingly power-dependent, foreign exchange scarcities will affect the country's ability to generate power to meet its growing needs. Sudan's hard currency scarcity results in large part from the disappointing performance of Sudan's agricultural sector, the primary foreign exchange earner. As efforts to improve agricultural performance escalate, more emphasis will be placed on the country's mechanized rainfed agricultural sector, thereby leading -- in the absence of land use planning and controls -- to increased pressure on and deterioration of Central Sudan's scarce forestry resources. This cycle illustrates how closely various energy supply and demand, economic, and environmental/resource management issues are related.

It is important to place these problems in a proper time context. Estimates of Sudan's petroleum reserves have increased substantially over the past few months, and it now seems quite likely that Sudan will be exporting oil by 1986 or possibly earlier. These exports will begin to have positive effects on Sudan's balance of payments position in 1986 and could, by 1990-1992, if demand for petroleum products and other inputs is constrained, have cut Sudan's projected balance of payments deficits by as much as 50%. However, several caveats must be placed on these statements. No matter how large Sudan's petroleum reserves may be, their effects will not be felt on the economy in the next three years which, from the standpoint of the country's external finances, is a very critical period. Moreover, if demand management measures are not implemented and domestic petroleum demand rises significantly above our projections (as has occurred in some other oil-exporting countries), as much as 20-25% of the potential gains from Sudan's oil resource wealth will be lost.

Highest Priority: Demand Management

The Project Team maintains that the energy and foreign exchange situation facing the country is so precarious that, in the short run, no investment project should go forward, no agricultural scheme should be planned, no road should be built without first examining the potential energy costs and/or savings implied by

such ventures. Clearly formulated policies and a rational evaluation process should be instituted to determine the energy consumption requirements, costs and benefits of all new projects envisioned over the next three to five critical years. During this period, the gap between petroleum product supply and demand at official prices will widen substantially. It therefore is imperative that Sudan institute policies and processes which constrain energy demand and direct scarce energy supplies to those uses which most contribute to national or regional economic and social welfare goals.

The Project Team recommends that the government aggressively adopt and implement pricing and allocation measures which ensure that supplies of petroleum products and petroleum dependent-electricity are directed to the most productive users. The country and the government must capture the economic and social benefits gained from energy. Pricing and allocation policies also should capture for the government and the country as a whole the scarcity profits concurrently going to black market dealers. It should be noted that two petroleum price increases, an exchange rate consolidation, and a subsequent devaluation have resulted in a near doubling in the nominal price of petroleum products since early 1981. Petroleum products currently are being priced approximately at cost, valued at the official exchange rate. Nonetheless, a recent study of petroleum prices in 29 African countries showed that Sudan, of all countries surveyed, had, even at official exchange rates, the lowest official prices for all major petroleum goods -- and Sudan's prices would be 30-35% less at market exchange rates. Joint NEA-GPC studies show black market prices for many petroleum goods prevailing at levels double and triple official prices in areas away from the Khartoum-Port Sudan highway axis.

The Project Team recommends modifying import policies, sales/excise taxes, etc. to discourage the import or sale of non-productive energy consuming equipment and to promote the importation or domestic production of more energy-efficient equipment. For example, under current laws workers, students, and others returning from abroad can bring in private passenger vehicles virtually duty-free, while no policies exist to promote importation of energy-efficient vehicles or to restrict those that are energy-inefficient (see "Review of Laws, Regulations.." Appendix F to this report). Project studies show that commercial and residential air conditioners (a total of some 8,000 units mainly located in expatriate residences, embassies and commercial establishments) which are both imported and domestically assembled comprise almost one half of peak residential load during six months (the most critical period for power supply) of the year. The same domestic companies that assemble these air conditioners also manufacture evaporative air coolers which are much less energy intensive (consuming 90% less energy on average), and much less expensive than energy-inefficient air conditioners and provide roughly the same degree of comfort.

Finally, the GPC should be encouraged and supported in its ongoing efforts to modify the present petroleum products distribution system. Desirable changes which the GPC currently is instituting or studying include substantially tightening the basis for allocation of petroleum goods to large agricultural schemes (which appear to be major sources of "leakages" to the black market), making it easier for those earning hard currency or directly displacing imports to procure needed fuels, more closely matching delivery and storage schedules with seasonal demand variations, and decreasing the administrative burden on the GPC itself.

Financing of Oil and Petroleum Product Imports

Despite heroic efforts by the GPC and the Bank of Sudan, it is becoming more and more difficult to open letters of credit to import needed fuels--and the situation will get worse over the next three years. The government should carefully explore all possible financing options--including allowing hard currency earning enterprises to purchase fuels with foreign exchange and requiring Embassies and expatriate personnel to pay for all petroleum fuels (and electricity) in foreign exchange. Studies show that Sudanese working abroad remit, whether directly in cash or indirectly through goods imports (often luxury items), over $400 million a year. Less than one quarter of this amount is channelled through commercial banks. If local commercial banks could capture an additional quarter of these funds and use them to purchase petroleum imports, it would relieve the central bank of considerable pressure while allowing Sudanese expatriates a means to put their money to work. The government could establish dedicated revolving hard currency accounts for fuel purchases--to allow a regular, predictable inflow of needed petroleum fuels. However, it is not likely that the government could attract the external financial assistance needed to establish such a dedicated foreign currency account unless it could show that it was taking effective demand management actions.

As Sudan's balance of payments position worsens over the next three to five years (before any real benefits from petroleum exports are realized), competing demands for available hard currency will grow proportionately. Total government cooperation is necessary to ensure rational, efficient rationing of this foreign exchange if de facto "beggar thy neighbor" actions, such as foregoing pharmaceutical imports for petroleum imports for example, are not to prevail. This, provides another important rationale for efficient energy demand management and monitoring policies.

Financing of Capital Projects and Operations/Maintenance

Balance of payments projections by the Project Team, as well as by the World Bank and others, indicate that it also will be increasingly difficult to finance large new capital projects and to acquire hard currency needed for other purposes. The impact on planned future large-scale energy projects--including Kosti and any large new hydropower project--needs to be assessed in greater detail. Also, the government and donors must resist the usual temptation to skimp on hard currency needed for efficient operations and maintenance of existing plant and equipment. This is particularly true of the NEC, where massive investment in expansion of generation capacity could be jeopardized if sufficient attention is not also paid to improving transmission and distribution, providing sufficient spare parts and maintenance training to keep new power stations operating reliably, and so forth. There are too many examples in Sudan and elsewhere of what happens to equipment when attention to maintenance and spare parts is neglected.

Forest Conservation and Integrated Land Use Management

Parts of Central Sudan are being deforested at a rapid rate, due primarily to expansion of mechanized rainfed agricultural and increased demand for charcoal. If the experience of Kassala--where vast new areas of semi-desert have been created on what was once thickly forested land--is not to be repeated elsewhere, then those provinces currently feeling (or most likely to feel) competing land use pressures must institute effective means of integrated land-use planning

and management. Proper planning can permit continued expansion of agriculture but--by properly using shelterbelts, retaining trees on slopes and other fragile lands, etc.--avoid the worst aspects of "land mining" such as is occurring in many provinces now. Proper management also will require making sufficient fuel available to enable provincial foresters to inspect planned agricultural sites, enforce land use institutions and provide extension services to encourage incorporation of trees into farming systems. Donor agencies funding agricultural projects should always make integrated land use and management key components of their projects.

The Ministry of Energy and Mining, in cooperation with the National Research Council, also intends to use new projects such as those financed by USAID and GTZ (W. Germany) to promote development and dissemination of more efficient cookstoves and charcoal kilns, in order to reduce long-run demand pressures on charcoal producing areas.

Energy Supply Options

Aside from domestic oil production--which this report assumes will begin in earnest by 1985--there are few other promising energy supply options. As discussed in later chapters, bagasse and other agricultural residues can be used more effectively, charcoal can be produced more efficiently, and some opportunities exist (primarily in the South) for small-scale hydropower units, which could make important contributions to local energy needs. The country's wind and solar resources are excellent; but the field testing, demonstration, and dissemination efforts needed (and being started this year by the Ministry of Energy and Mining and National Research Council) mean that it will be many years before those technologies will make any significant contribution toward meeting the country's energy needs.

Next Steps for the Project

The Sudan Energy Policy and Planning Project will continue until July 1983, after which it will be replaced by a larger, longer-term USAID-supported project encompassing technical assistance to the NEA, NEC, and GPC. During the time remaining on the present Project, we recommend that the Ministry of Energy and Mines foster debate of the issues and recommendation presented in Chapters V and VI of this report and timely decision-making. We also recommend that the NEA:

- Establish ongoing systems of data collection and analysis--using the microcomputer provided as part of the Project--to maintain an up-to-date picture of the energy consumption and supply situation facing the country;

- Revise the economic analysis sections of this report based on more detailed projection of oil export costs, revenues, and timing;

- Analyze in more detail the feasibility, costs, and energy supply-demand balance impacts of alternative national energy strategy options, such as aggressive energy conservation, substitution of renewable energy, etc.;

- Conduct much more detailed analysis, in conjunction with other appropriate government organizations, of specific pricing and allocation options to more efficiently channel petroleum products and electricity to their most productive uses;

- Conduct more detailed economic analyses of specific energy project investment proposals;
- Support the MEM in analysis of the energy use implications of non-energy investment;
- Collaborate with the Forest Department and regional and provincial governments to develop a more precise picture of deforestation problems and options by province; and
- Work with regional governments both to improve the regional energy data base and to identify and analyze policy options available to address regional energy problems.