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EASTERN NILE POWER TRADE PROGRAM STUDY

AfDB

MARKET AND POWER TRADE ASSESSMENT

VOL 4 - SUDAN

FINAL MAIN REPORT

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with participation of:

- EPS (Egypt)
- Tropics (Ethiopia)
- YAM (Sudan)

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PHYSICAL UNITS

bbl	barrel	(1t = 7.3 bbl)
cal	calorie	(1 cal = 4.1868 J)
Gcal	Giga calorie	
GWh	Gigawatt-hour	
h	hour	
km	kilometer	
km²	square kilometer	
kW	kilo Watt	
kWh	kilo Watt hour	(1 kWh = 3.6 MJ)
MBtu	Million British Thermal Units	(= 1 055 MJ = 252 kCal)
	one cubic foot of natural gas produces approximately 1,000 BTU	
MJ	Million Joule	(= 0,948.10^{-3} MBtu = 238.8 kcal)
MW	Mega Watt	
m	meter	
m^3/d	cubic meter per day	
mm	millimeter	
mm^3	million cubic meter	
Nm^3	Normal cubic meter, i.e. measured under normal conditions, i.e. 0°C and 1013 mbar	
	(1 Nm^3 = 1.057 m^3 measured under standard conditions, i.e. 15°C and 1013 mbar)	
t	ton	
toe	tons of oil equivalent	
tcf	ton cubic feet	
°C	Degrees Celsius	

General Conversion Factors for Energy

To:	TJ	Gcal	Mtoe	MBtu	GWh
From:	multiply by:				
TJ	1	238.8	2.388×10^{-5}	947.8	0.2778
Gcal	4.1868×10^{-3}	1	10^{-7}	3.968	1.163×10^{-3}
Mtoe	4.1868×10^{4}	10^{7}	1	3.968×10^{7}	11630
MBtu	1.0551×10^{-3}	0.252	2.52×10^{-8}	1	2.931×10^{-4}
GWh	3.6	860	8.6×10^{-5}	3412	1

ABBREVIATIONS AND ACRONYMS

ADB	African Development Bank
ADF	African Development Fund
CC	Combined Cycle
CCGT	Combined Cycle Gas Turbine
CIDA	Canadian International Development Agency
CT	Combustion Turbine
DANIDA	Danish Development Assistance
DFID	Department for International Development (UK)
DIDC	Department for International Development Cooperation (GoF)
DSA	Daily Subsistence Allowance
EEHC	Egyptian Electricity Holding Company
EEPCO	Ethiopian Electric Power Corporation
EHV	Extra High Voltage
EHVAC	Extra High Voltage Alternating Current
EIA	Environmental Impact Assessment
EIRR	Economic Internal Rate of Return
EN	Eastern Nile
ENCOM	Eastern Nile Council of Ministers
ENSAP	Eastern Nile Subsidiary Action Program
ENSAPT	Eastern Nile Subsidiary Action Program Team
ENTRO	Eastern Nile Technical Regional Office
ENTRO PCU	Eastern Nile Technical Regional Office Power Coordination Unit
FIRR	Financial Internal Rate of Return
GEP	Generation Expansion Plan
GTZ	German Technical Co-operation
HPP	Hydro Power Plant
HFO	Heavy Fuel Oil
HV	High Voltage
HVDC	High Voltage Direct Current
ICCON	International Consortium for Cooperation on the Nile
ICS	Interconnected System
IDEN	Integrated Development of the Eastern Nile
IDO	Industrial Diesel Oil
IMF	International Monetary Fund
JICA	Japanese International Co-operation Agency
JMP	Joint Multipurpose Project
LNG	Liquefied Natural Gas
LOLP	Loss of Load Probability
LPG	Liquefied Petroleum Gas
LRFO	Light Residuel Fuel Oil

LTPSPS	Long Term Power System Plan Study
MENA	Middle East, North Africa Countries
MIWR	Ministry of Irrigation & Water Resources (Sudan)
MWR	Ministry of Water Resources (Ethiopia)
MWRI	Ministry of Water Resources and Irrigation (Egypt)
MSD	Medium Speed Diesel (TPP)
NBI	Nile Basin Initiative
NEC	National Electricity Corporation (Sudan)
NECC	National Electricity Control Centre (Egypt)
NELCOM	Nile Equatorial Lake Council of Ministers
NELSAP	Nile Equatorial Lake Subsidiary Action Program
NG	Natural Gas
NGO	Non Governmental Organization
NORAD	Norwegian Aid Development
NPV	Net Present Value
O&M	Operations and Maintenance
OCGT	Open Cycle Gas Turbine
OPEC	Organization of the Petroleum Exporting Countries
PBP	Pay Back Period
PHRD	Policy & Human Resource Development Fund
PIU	Project Implementation Unit
PRSP	Poverty Reduction Strategy Paper
RCC	Regional Electricity Control Centre (Egypt)
RE	Rural Electrification
SAPP	Southern Africa Power Pool
SIDA	Swedish International Development Agency
SSD	Slow speed diesel (TPP)
STPP	Steam Turbine Power Plant
STS	Senior Technical Specialist
TAF	Technical Assistant Fund
TPP	Thermal Power Plant
UA	Unit of Account
UNDP	United Nations Development Program
WB	World Bank

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1. OVERVIEW

Sudan is a multi-cultural, multi-ethnic and multi-lingual society, an afro-Arab country occupying a remarkable strategic position in the centre of the Africa continent that marks a melting pot between Arabs and sub-Sahara peoples. It shares its extensive borders with nine countries of northern, eastern, central and western Africa. Such juxtaposition engenders a mix of trade, culture, social, ethnic and other human ties built throughout history

The electrification ratio of the Sudan (percentage of households with electricity supply) is one of the lowest in the world, estimated at about 19% (made up from about 16.3% metered NEC connections, 2.3% connections to private supply companies and 0.2% un-metered connections).

Sudan utility

The National Electricity Corporation is the governmental entity responsible for generation, transmission and distribution of electric power in the Sudan. NEC's power system comprises mainly the National Grid and a number of isolated diesel power stations.

The electricity system within Sudan consists of the main National Grid, a number of isolated off-grid systems and some existing private generation companies. NEC's main grid system is divided into the Khartoum, Central, Eastern and Northern areas.

The towns of Atbara and Shendi in River Nile state, which were previously supplied by local off-grid generation, were connected to the National Grid as part of the Merowe transmission reinforcement scheme in the second half of 2005.

Current generation supply

Over the period 1997 – 2005, the energy generated increased from 2 150 GWh in 1997 to 3 768 GWh in 2005, an annual compound growth of 7.3% per year. Before the year 2003 demand exceeded supply at a certain time of the year (April – August), as a result the consumers subjected to long periods of power cuts which resulted in high economic losses especially in industrial and agricultural sectors.

At the times of capacity shortages NEC was forced to carry programmed and un- programmed power cuts. These cuts mainly carried in the summer season when the demand is at peak load and the hydro output is low.

In 2003, Gerri I and Gerri II combined cycle power generating facilities were commissioned adding to the grid about 386 MW generating capacity. The supply exceeds the demand and the power cuts are mainly limited to failures in transmission and distribution.

At the time being the total capacity available for dispatch on the National Grid is about 826 MW, of which some 59% is conventional thermal plant and the remaining 41% is hydroelectric plant.

The table here below, sets out the generation mix on the National Grid as at July 2006 and provide a summary of installed and available capacities from the existing on-grid power plants.

Power Plant	Plant Type	Fuel Type	Net Capacity (MW)
Khartoum North ST's	Thermal	HFO	157.0
Khartoum North GT's	Thermal	Gas Oil	50.4
Garri 1 CCGT's	Thermal	Gas Oil	164.0
Garri 2 OCGT's	Thermal	Gas Oil	84.0
El Fau Diesel	Thermal	Gas Oil	10.0
Kassala Diesel's	Thermal	Gas Oil	7.9
Girba Diesel's	Thermal	Diesel	4.0
Kuku GT's	Thermal	Gas Oil	19.0
Total Thermal Plant			**496.3**
Roseires	Hydro		280.0
Sennar	Hydro		15.0
Kashm El Girba	Hydro		18.1
Jebel Aulia	Hydro		28.1
Total Hydro Plant			**341.2**
Net Installed Capacity			**837.5**
Thermal Capacity Part			59%
Hydro Capacity Part			41%

Table 3.1-1 - Current generation supply

Committed projects

According to NEC master plan, the following power plants have been identified as committed contributors to the Sudan generation expansion plan.

- Khartoum North Units 5 and 6 (100 MW each – 2008)
- Conversion of Garri 2 power station to combined cycle operation (200 MW – 2008)
- Kilo X GT (80 MW - 2007)
- Garri (3) steam plant (540 MW - 2010)
- Garri (4) steam plant (100 MW – 2007)
- Port Sudan steam plant (405 MW – 2009)
- Kosti steam plant (500 MW – 2010)
- El Bagair steam plant (540 MW – 2010)
- Kassala diesel plant (50 MW – 2007)

- Al Fula steam plant (540 MW – 2010)
- Merowe hydroelectric plant (1 250 MW – 2008)
- Sennar extension hydroelectric plant (1 250 MW – 2008)
- The heightening of the Rosieres hydroelectric plant, with Dinder (135 MW – 2012)

Transmission

The Sudanese system consists mainly in 110 and 220 kV lines. The system includes a 800 km 220 kV double circuit line from Roseires HPP, located in the south close to Ethiopia border, to Khartoum along to the Blue Nile River. A 110 kV double circuit ring supplies Khartoum, that represents 50% of the total load. This 110 kV ring is connected to the 220 kV system with two 220/110 kV substations at Eid Babiker and Kilo X.

In the coming year 2007, the network will be reinforced with a 500 kV double circuit line from Merowe HPP (installed capacity 1 250 MW) to Khartoum and a 500 kV single circuit line between Merowe and Atbara located on the Nile, 300 km north east of Khartoum.

In the next years, NEC intends to extend its 220 kV system by about 2 000 km of new lines.

Power Trade

At present there is no international power trade in the Eastern Nile region comprising Ethiopia, Eritrea, Sudan and Egypt. This is partly because until today there was no transmission facilities to enable such trade.

The situation will be changing soon with the Ethiopia – Sudan interconnection project (see Module 3 Vol 4).

2. ORGANISATION OF THE REPORT

Module 2 deals with the assessment of the existing market and power trade situation in the Egypt, Ethiopia and Sudan.

This Module is organized in four Volumes:

- Volume 1: Overview of Module M2.
- Volume 2: Market of Power Trade assessment for Egypt.
- Volume 3: Market of Power Trade assessment for Ethiopia.
- Volume 4: Market of Power Trade assessment for Sudan.

Each volume analyses the existing situation in each country along the following items:

- Review of the electricity sector.
- Assessment of existing generation mix (TPP, HPP, geothermal, etc).
- Assessment of existing power trade.
- Assessment of existing transmission system.

The present Volume 4 presents the Market and Power Trade assessment in Sudan.

3. REVIEW FO THE ELECTRICITY SECTOR IN SUDAN

3.1 ECONOMY BACKGROUND INFORMATION

3.1.1 GENERAL BACKGROUND

Sudan is a multi-cultural, multi-ethnic and multi-lingual society, an afro-Arab country occupying a strategic position in the centre of the Africa continent that marks a melting pot between Arabs and sub-Sahara peoples. It shares its extensive borders with nine countries of northern, eastern, central and western Africa. Such juxtaposition engenders a mix of trade, culture, social, ethnic and other human ties built throughout history.

Sudan is the largest country in Africa and the ninth largest country in the world. It covers an area of 2,505,805 Km^2 located between latitudes 3^oN and 24^oN and longitudes 21^oE and 39^oE extending from the arid hot north to the wet tropic of the south and several different ecological and environmental zones. It is about 2 000 km long from North to South and 1 800 km wide from East to West. In addition to the Red Sea which forms some 700 km of the northern part of its eastern borders, the country is bordered by nine African countries: Egypt and Libya in the North; Chad and Central Africa in the West; D.R. Congo; Uganda and Kenya in the South; and Ethiopia and Eritrea in the East. The vast area is mostly flat plain includes stretches of tropical forests, marshlands, mountains in the southern and central parts to savannah, stone and sand deserts and mountains in the north, east and west.

The most remarkable feature of Sudan is the Nile River and its tributaries crossing the country from the south to the north.

Agriculture remains the backbone of Sudanese economy, with an estimated contribution of 45.6% of GDP, 55% of employment and 80% of export earnings. The main export items are livestock, sesame, cotton, groundnuts and Arabic gum.

Export of oil started in August 1999 and refined oil-products and natural gas in July 2000. The economy has been growing in the last years at a faster rate than many other countries in the region. However, income distribution has not improved and poverty alleviation remains one of the main concerns of social and economic policies.

The Sudan has been among the world's poorest countries. Traditionally, its economy has been mainly agricultural - a mix of subsistence farming and production of cash crops such as cotton. With the start of significant oil production (and exports) beginning in late 1999, however, Sudan's economy has started to change dramatically, with oil export revenues now accounting for around 70% of the Sudan's total export earnings. The Sudan no longer relies on expensive imported oil products, and this has helped the country's trade balance, while foreign investment has started to flow into the country.

3.1.2 GROSS DOMESTIC PRODUCT (GDP)

Achieving sustained growth in Sudan has been hampered by prolonged political instability – evidenced by two rather long conflicts (1955 – 1972 and 1983 – 2005) which largely explain the dismal economic growth record of the country since it gained independence in 1956.

With only a few exceptions, registered GDP growth has been extremely weak or non-existent. The deterioration of basic infrastructure and the lack of access to aid and foreign finance. Infrastructure bottlenecks, including deterioration of transport and irrigation systems and shortage of electricity have been severe. Nevertheless, there are strong indications that the economy improved in the 1990s after years of decline, reflected in the average five percent growth of real GDP throughout the 1990s. However until the discovery and first shipment of oil in 1999, Sudan represented a standard model of an extremely poor, stagnant dual economy. The discovery of oil has dramatically changed the structure of the Sudan economy.

During the period 2001-2005, the economy registered an average growth rate of 6% per year – reaching 8% in real terms in 2005. Rising from US$ 13.3 billion in 2001 to US$ 27.7 billion in 2005 nominal GDP more than doubled. The IMF forecasts a growth rate of 13% during 2006, 10% during 2007 and around 8.5% for the following 3 years. Starting with 185,500 bpd in 2000 current oil production has gone above 500,000 bpd. On the other hand although oil production is considered to be the main determinant of GDP performance, non-oil production is also expected to rise.

Year	2001	2002	2003	2004	2005
GDP (Market prices–billion SD)	3,449.7	3,943.3	4,534.4	5,411.7	6,510.7
GDP (US$ billion)	13.3	15.0	17.4	21.0	27.7
Real GDP growth	6.4	6.5	6.0	7.7	8.0

Table 3.1-1 - Sudan GDP growth (2001 - 2005)

3.1.3 SECTORIAL ANALYSIS

Sudan enjoys an extremely diversified ecological system that provides immense fertile land of about 80 million hectares, a large number of livestock (about 121 million heads of sheep, goats, cattle and camels), natural pastures of about 24 million hectares, forest area of about 64 million hectares in addition to considerable water resources from rivers, seasonal streams and rains with annual amount of 109 billion cubic meters of water, in addition to underground water (an estimated 39 billion cubic meters).

These arable vast lands, with their environmental diversity, provide favorable conditions for the production of different crops and animal breeds. Animal products registered increasing share in the export earnings since the end of the seventies.

In addition to its agricultural and animal resources, Sudan abounds with potential mineral wealth, of which petroleum is the most important with 900 million barrels of proven reserves and prospect for additional reserves. Petroleum is now being exploited commercially. The production and export of gold are increasing while numerous minerals such as iron, copper, manganese, zinc, mica and chromites, together with other non-mineral resources such as plaster, limestone and black sand are also available in appreciable quantities and potentially tradable. This could pose a real addition to the industrial base of the country.

The industrial sector still depends mainly on agriculture which represent an important source of raw materials like vegetable oil, sugar, cotton, leather, animal feed and tobacco. The increased exploitation of these available natural resources will increase the agro-industrial potential investment opportunities and encourage the development of manufactured agricultural production and improving its efficiency. In spite of the recent developments in Sudan's industrial sector (25.4% of GDP in 2005) and in the mining sector (10.8% of GDP), Sudan still remains basically an agricultural country. In 2004 the latter sector provided 55% of employment, supplied basic food for the entire population and a considerable share of the raw material for the local industry.

Noticeable changes have taken place in health policies during the last decade. New health programmes of vaccination and immunization have realized with 80% coverage. There are also programmes in the filed of diarrhea control, family planning, maternity and infancy services, AIDs control, Malaria and health nutrition education.

Railways are the main transport mode for goods and passengers. Currently the length of rail line is about 5 896 km, with carrying capacity raise from 1.4 million tons to 2 millions tons. Such capacity could have been doubled if the planned investment especially in communications and maintenance were realized.

Length of the road network reached about 5 000 km of which 2 700 are asphalt roads. Some continental, primary, secondary and tertiary roads are being financed and constructed by own resources.

There are three sea ports at the Red Sea namely Port Sudan, Swakin and Bashayir. These ports are being developed and expanded to accommodate the progressive development in the volume of international sea traffic. There are also three international and ten local airports linking the country with the outside world and the neighboring states.

A great leap forward occurred in the filed of telecommunication following privatization of the communication sector. Optical fibers network circuits and the capacity were increased. Also a major shift occurred in its filed of satellite communications through the use of digital technology.

3.1.4 MACRO-ECONOMIC INDICATORS

Real growth has expanded at an average of more than five percent throughout the 1990s with higher percentage growth rates in the last three years. Through the years the agricultural sector has maintained its primary importance in the economy, accounting for about 45.6% of total GDP.

Outside of the increased diversification taking place within the agricultural sector, the major new source of growth is from the onset of oil production. Oil production provides an important boost to the economy. Al Jaili oil refinery was inaugurated in July 2000 and currently Sudan is exporting crude oil, refined petrol and natural gas.

Year	2000	2001	2002	2003	2004	2005
Oil Revenue	559	579	762	1 529	1 950	2 481

Table 3.1-2 - Oil Revenue in Million US$

Growth during the 1990s was led mainly by agriculture, construction activities in the oil sector. Investments in oil in the last three years contributed significantly to the growth process. The general economic improvement has also been helped by other government measures, such as the containment of fiscal deficits, putting a limit to monetary growth and reduced rate of inflation which was running at over 100% in the mid 1990s.

Year	2000	2001	2002	2003	2004	2005
Targeted	7	7	7	7	6.5	7.5
Actual	8.1	4.9	8.3	7.7	8.5	8.5

Table 3.1-3 - Average Inflation Rate (2000 - 2005)

From the year 2000 and until June 2005 the exchange rate of the Sudanese currency has remained rather stable at SD 250 = US$. Since then the Dinnar had slowly but continuously risen in value reaching SD 216= US $ by mid July 2006. Although the appreciation of the Dinnar will help in containing inflation (running at 8–10% during the last 5 years) it will impact negatively on direct foreign investment and reduce competitiveness of the country's non-oil export.

Year	2000	2001	2002	2003	2004	2005
SD	257.14	258.35	263.39	260.98	257.91	245.3

Table 3.1-4 - Exchange Rate (US$ against the Sudanese Dinnar) (2000 - 2005)

Being aware of the negative impact of an unchallenged appreciation of the currency, the Central Bank has recently perused a policy of setting limits on currency trading banks and the purchase of surplus foreign currency held by commercial banks.

3.1.5 EXCHANGE RATE TRENDS AND COMPETITIVENESS

Since late 2004, improved market fundamentals coupled with a move towards a market-driven exchange rate have led to an appreciation of the Dinnar. In 2005, the economy grew at fast pace and higher oil prices led to a 35% increase in oil exports. In addition, foreign direct investment rose sharply from US$ 1.8 billion in 2003 to US$ 3.8 billion in 2005. During the last year, the currency appreciated by 12% and 17% in nominal and real effective terms, respectively.

Beyond the effects of growth and foreign exchange inflows, higher levels of government spending have also put pressure on natural goods' prices and contributed to the real appreciation. Prices of non-traded goods (housing, water, and electricity) grew at an average rate of 11% in 2004 – 2005, while prices of traded goods (food, clothing, and other consumer goods) grew by an average of 6%.

3.1.6 SUDAN TRADE BALANCE

Trade performance also suggests that competitiveness may be deteriorating, although other factors have also played a role. In 2005, the volume of non-oil exports (mainly agricultural products and livestock) fell. Exports volumes were also affected by supply constraints (inadequate capacity at the port, deterioration in the road infrastructure), conflict in livestock – rich areas, and higher domestic demand.

Looking ahead, the oil sector boom coupled with strong fundamentals will likely exert further up-word pressure on the equilibrium real exchange rate. This highlights the importance of removing structural bottlenecks and improving the business environment to preserve competitiveness in non-oil export ad import – competing sectors.

Year	2000	2001	2002	2003	2004	2005
Exports(FOB)	1 806.7	1 698.7	1 949.1	2 542.2	3 777.8	4 824.3
Imports (FOB)	1 366.4	2 024.8	2 179.2	2 536.1	3 586.2	5 946.0
Trade Balance	440.3	- 326.1	-230.1	6.1	191.6	-1121,7

Table 3.1-5 - Sudan Trade Balance (2000 - 2005) millions US$. Source: Bank of Sudan

The sustainable growth of GDP was accompanied by qualitative change in economic structure. The relative contribution of productive sectors increased from 59.5% in 1996, to 65.6% in 1999, whereas the services sector contribution decreased from 40.5%, to 34.4% in the same years. This structural change was due mainly to both plant and animal traditional production combined growth rates. Their contribution increased from 32% in 1995, to 37% in 1999.

Of the various factors that played a significant role in the achievement of economic successes are:

1. The impacts of the vigorous reform policies applied had unleashed the economic potential of the economy.

2. The success of macro-economic policies in improving controls and distortions characterizing the decade of the 1980s. as a result resources were mobilized towards productive sectors and away from tertiary activities.
3. Favorable climatic conditions for seven successive seasons.
4. The stability in the system of rule and administration, despite foreign hostilities and the stoppage of external financial assistance.

3.1.7 ECONOMIC REFORMS

A comprehensive economic reform program was implemented in Sudan from the mid 1990s. This program was not supported by external financial assistance or technical support because of regional conflicts and the government's default in meeting existing debt service commitments. The economic reform program progress on five broad fronts:

Successful macroeconomic stabilization

Significant progress has been made in stabilizing the economy. Sudan's stabilization represents a rare case of a successful stabilization in a developing country without external financial assistance. The fiscal deficit fell sharply, and inflation decelerated from three digits in 1996 to single digit in 2000. Since tax reform efforts yielded only modest tax collection results, and there could be virtually no recourse to foreign and domestic borrowing, the fiscal adjustment fell principally on expenditure. Public expenditure decline relative to GDP from 18.4% average per annum during 1986-1990 to 9.4% during 1996-2000. As a result of this drastic downsizing of the public sector, financing for social and infrastructure services was sharply reduced.

Restoring incentives

Exchange rate and trade reforms were intensified after 1997; including liberalizing of the controls, followed by unification of the exchange rate in 1998 and paving the way for manage floating rates. Restriction on imports were lifted except those related to security and public health. Export controls and retention on export earnings were removed. The tariff structure was simplified; the tariff bands were reduced from 13 in 1996 to 4 currently, and the maximum tariff rate cut by 75%. Further reforms, including institutional and marketing reforms focused on the agricultural sector remain.

Financial sector

Since 1992, the Sudan based its financial system completely on Islamic principles, involving prohibition of interest rates according to sharia law. Since 1997, while retraining Islamic banking, Bank of Sudan started dismantling restrictions and liberalized the financial system, including removal of most credit ceilings. The Bank accounting system and regulations on capital adequacy were strengthened. Program for central bank monitoring of non-performing loans was established in 1999. Bank portfolios of non-performing loans remain to be cleaned and capital adequacy ratios to be strengthen.

Privatization

The restructuring and privatization of public enterprise aimed to reinforce the macroeconomic reforms by reducing the size of the public sector, and limiting subsidies and contingent liabilities on the budget. Of the 107 state owned companies listed for privatization in 1992, only 19 were sold to private investors. The investment code was amended to give guarantee against nationalization and to provide fiscal incentives. The reforms gave impetus to private investments, including in the petroleum sector, transportation, pharmaceuticals and horticulture. Other than its slow pace,

criticism of the privatization program relates to the acquisition of enterprises by people who are supposedly political connected. Large scale enterprises in sectors, such as in aviation, electricity, transport, large scale irrigation, and banking remain to be privatized.

External debt management

External debt arrears continued to accumulate during the period of macroeconomic reforms. At the end of year 2001 Sudan's stock of foreign debt amounted to US$ 20.7 billion, or 160% of GDP. An estimated 85% of US$ 20.7 billion stock of debt is payments arrears. About 64% of the total debt is owed to bilateral creditors. Because of the size of the debt, Sudan has not been able to service it as scheduled. Moreover, because of the size of the debt and scale of arrears, coordinated support from the international community will be required to solve the situation.

3.1.8 THE OVERALL PERFORMANCE OF THE ECONOMY

Achieving sustained growth in both sectors, agriculture and industry in Sudan have been hampered by many difficulties i.e.

- Brain drain.
- Deterioration of basic infrastructure.
- Lack of foreign aid.
- Lack of foreign investment.
- Severe shocks of floods and droughts.

Nevertheless there are broad indications that the economy improved in the 1990's after years of decline. Improvement of the economy will lead to better services for the people of the Sudan and in reticular water supply.

3.1.8.1 Sudan's Foreign Trade

In 2005 Sudan's total value of trade (imports and exports) reached about US$ 11.6 billion – an increase of 65.8% above its 2004 level.

The production and export of oil lead to another dramatic change in Sudan's trade pattern – accounting for more than 86% of total export earnings in 2005.

Prior to oil production the country's traditional exports of cotton, sesame, groundnuts and livestock accounted for over 75% of the country's export earnings. However, low productivity and rising production costs (in case of cotton) unfavorable weather (in case of sesame) and the conflict in Darfur (in case of livestock) resulted in the stagnation and/or decline in the exports of these commodities.

Item	2003	2004	2005	% of total (2005)
Crude Oil	1,934.0	2 957.2	3 948.3	81.8
Petroleum Products	113.7	144.3	230.7	4.8
Cotton	107.7	93.6	107.3	2.2
Gum Arabic	35.4	66.6	107.6	2.2
Sesame	74.4	178.6	118.6	2.4
Livestock	97.7	138.0	114.9	2.3
Gold	58.6	50.4	61.6	1.3
Others	107.6	99.1	135.3	2.8
	2 528.3	**3 777.8**	**4 824.3**	

Table 3.1-6 - Sudan Exports (2003 - 2005) Million US$

The impressive increase in exports, however, was overshadowed by an even larger increase in the country's imports. Imports in 2005 were 65.8% above their 2004 level resulting in a large trade deficit.

Combined with negative income and non- merchandize balances, the economy faced a huge current account deficit of US $ 1.9 billion.

	2001	2002	2003	2004	2005	Change (%) (2001-2005)
Exports	1,699	1,949	2,542	3,778	4.824	27.7%
Imports	1,395	2,294	2,536	4,075	6,757	65.8%
Trade Balance	+ 304	- 345	+ 6	- 297	- 1,932	
Overall Trade	3,094	4,243	5,078	7,853	11,580	47.5%

Table 3.1-7 - Sudan Trade Account (2001 - 2005) Million US$

Item	2004	% of total	2005	% of total	% change
Foodstuffs	519	12.7	811	12.0	56.4
Beverages and tobacco	40	1.0	43	0.6	6.5
Raw materials	198	4.9	426	6.3	111.6
Chemicals	327	8.0	493	7.3	50.7
Manufactured goods	997	24.5	1,628	24.1	63.4
Machinery and equipment	1.81	26.5	1,972	29.2	82.5
Transport equipment	739	18.1	1,150	17.6	55.5
Textiles	175	4.3	234	3.5	3.5
Total	**4,075**		**6,756**		**65.8**

Table 3.1-8 - Sudan Imports 2004 - 2005 Million US$

The sharp increase of imports in 2005 is mainly due to:

- A rise in foodstuffs imports of 56.3% resulting from low local food of production in 2004 on one hand and to meet the food requirements of the conflict regions on the other.
- An increase of 115.6% in imports of raw materials necessary for the expanding industrial sector.
- The expansion of the oil sector and the country's infrastructure lead to a rise of 82.5% in the machinery and equipment item.
- The appreciation of the Dinnar resulted in an overall rise in the demand for imported goods.

3.1.8.2 Capital Inflows

The significant increase in Sudan's import bill in 2005 briefly outlined above, however, was partly redressed by high capital inflows.

Since the start of oil production in 1999 foreign direct investment has been rising at extremely high rates – reaching US$ 2.3 billion in 2005, almost 6 times their 2000 level of US$ 392.2 million.

Year	Amount	Rate of Increase %
2000	392.20	
2001	574.00	46.4
2002	713.18	24.2
2003	1,349.19	89.2
2004	1,511.07	12.0
2005	2,304.64	52.5

Table 3.1-9 - Foreign Direct Investment (2000 - 2005) Million US$

3.1.8.3 Fiscal Policy

The table **3-10** shows deficits of Central Government revenue, expenditure and balance for the years 2001-2005. The programme of fiscal reform adopted by the Government in agreement with the IMF was successful in lowering the budget deficit from its high levels during most of the nineties (11.2% of GDP in 1991/92) to manageable levels (less than 1% of GDP during 1997-2002 and a surplus of 1% in 2003). The following two years (2004-2005) have witnessed rising budget deficits as spending pressures increased mainly due to the war in Darfur and wage increases.

Although Projections for 2006 indicate large increases in revenues due to higher oil production and prices and higher tax collections, these are likely to be more than offset by high expenditure growth. In mid 2006 it was clear that a delay in the commercial exploitation of some new oil wells resulted in a sharp decline in anticipated revenues.

In order to compensate and to meet mounting expenditure the Government resorted to drawings from the " Oil Equalization Fund," loans from banks and the issuing of new Government securities.

3.1.8.4 Investment Encouragement Legislation:

A number of legislative and institutional reforms have recently been adopted aiming at attracting investment.

The Investment Encouragement Act 2003 (IEA) provides generous concessions to investors (national or foreign) including:

(a) 5 – 10 years tax exemption.

(b) Free or subsidized land cites.

(c) Accessible transfer of profits and repatriation of capital.

(d) Exemption from custom duties on imported capital goods.

Also, a recent reorganization of the Investment Bureau is aimed at what is referred to as a "one–stop–shop" where all investment procedures and approvals are looked into.

One obvious measure of the success of the IEA is the noticeable increase in local and foreign direct investment with the latter constituting 40–45% of total fixed investment in 2005.

3.1.9 MACRO –ECONOMIC INDICATORS (2000-2005)

	Year 2000	Year 2001
Real Rate of Growth of GDP %	8.3	6.7
Inflation Rate (Average) %	8.5	4.8
Unemployment Rate %	16	18
Exports (in US$ million)	1 808	1 698
Imports (in US $ million)	1 553	1 585
Current Account (as % of GP)	-2	-2
Rate of Growth of Money Supply %	33.8	26
Average Exchange Rate (SD/US$)	257.1	257.3

Table 3.1-10 - Macro-economic indicators

ITEM / year	2000	2001	2002	2003	2004	2005
Total population in Millions	31.1	31.9	32.7	33.6	34.4	35.3
Real GDP Bill SD (81/82 prices)	1 346	1 428	1 520	1 609	1 735	1 874
Real GDP Bill SD(current prices)	3 377	3 371	3 888	4 439	5 163	6 050
GDP Growth Rate (%)	8.3	6.4	6.5	6.0	7.7	8.0
Total Consumption (Bill SD)	2 820	2 798	3 577	3 924	4 132	5 167
Total Consumption % to GDP	0.84	0.83	0.92	0.88	0.8	0.85
Total Investment (Bill SD)	557	573	700	895	1 241	1 462
Total Investment % to GDP	0.17	0.17	0.18	0.2	0.24	0.24
Government Investment (Bill SD)	52.2	76	140	185	312	312
Private Investment (Bill SD)	505	497	560	710	929	1149
Non Oil Exports (MUS$)	455.9	322	438.3	494.5	677.3	636.9
Imports (MUS$)	1 366.4	2 024.8	2 152.8	2 536.1	3 586.2	5 945.9
Trade Balance (MUS$)	440.3	-326.1	-203.7	6.1	191.6	1121.7

Table 3.1-11 - Economic indicators (2000 - 2005) *Source: Ministry of Finance & National Economy*

3.2 ENERGY RESOURCE POTENTIAL AND BALANCES

3.2.1 OIL

Resources and reserves

Extensive petroleum exploration began in the mid-1960s and significant finds were made in the Upper Nile region. The activity was originally concentrated offshore in the Red Sea. Oil exploration in Sudan was previously limited largely to the central and south central regions, which represent about 15% of the national oil reserves.

The GoS announced in June 2000, plans to begin oil exploration in northwest Sudan, the Blue Nile Basin in south-eastern Sudan, and the Red Sea area.

The Country Analysis Briefs published by the Energy Information Administration (EIA) indicates that, as of January 2006 Sudan contained proven conventional oil reserves of 600 million barrels (Oil and Gas Journal), more than twice the proven 262 million barrels estimated in 2001. Additionally, EIA, states that the Sudanese Energy Ministry estimates total oil reserves to be in the region of 3 billion barrels. Due to conflict, the exploration of oil has been limited to the central and southern regions of Sudan, however, it is estimated that vast potential reserves are held in regions of northwest Sudan, the Blue Nile basin and the Red Sea area.

Production

Commercial quantities of oil began to be produced in the last quarter of 1999 and are transported via a new 1 600 km pipeline from Bentiu to a new export terminal just south of Port Sudan. This pipeline also supplies a new 50,000 US barrels per day (bbl/d) refinery at Geili, about 50 km north of Khartoum, saving Sudan abut $100 million per year in imported petroleum products.

Crude oil production averaged 227,500 barrels per day (bbl/d) during 2002, a figure that has been rising steadily since the completion of the export pipeline in July 1999.

In 2005, oil production averaged 470,700 bbl/d, an increase of 63% on the 2004 production levels of 287,988 bbl/d. Oil production is set to increase by 15 per cent to 540,000 bbl/d by the end of 2006 and is forecast to reach 710,000 bbl/d by the end of 2008.

According to the Energy Information Administration, Sudanese oil consumption increased 15% between 2004 and 2005 to 82,000 bbl/d.

In 2005, 70% of Sudan's total export revenues came from oil exports.

Exports

In January 2003, Sudan agreed to begin providing Ethiopia with approximately 3 100 bbl/d. Plans call for Ethiopia to eventually import as much as 60% of its oil needs from Sudan.

In August 2000, the Sudan's Sudanese Petroleum Company announced plans to lay pipelines to supply Eritrea and Ethiopia with petroleum derivates from Khartoum refinery.

Oil pipelines

Three separate oil pipelines had been commissioned in Sudan by mid-2006 with a total capacity to transport 1.1million bbl/d.

HEGLIG-OBEID-KHARTOUM-PORT SUDAN PIPELINE:

The construction of a 28 inch diameter oil pipeline extending to some 1,610 km is considered one of the major achievements in the oil sector in the Sudan. This pipeline delivers crude oil from the GNPOC production fields (Blocks 1, 2 and 4) in the south west of the Sudan to Port Sudan on the Red Sea. The route takes the pipeline through the towns of Dilling and El Obeid, supplying the El Obeid refinery with some 15,000 bbl/d, where the route then takes it in a north-easterly direction crossing the River Nile north of Khartoum and supplying the Al Gaili refinery with some 50,000 bbl/d.

The pipeline then heads north to the town of Atbara and finally east to Port Sudan. The carrying capacity of this pipe line is 250,000 bbl/d. With the additional construction of new pumping stations, the capacity can be extended to 400,000 bbl/d.

AL FULA–KHARTOUM PIPELINE:

The Al Fula to Khartoum crude oil pipeline was established in 2003 to transport the crude oil from block 6 allocated to the Chinese National Petroleum Company International – Sudan (CNPIS) and Sudapet. The 24 inch diameter pipeline covers a distance of nearly 715 kilometres and has a maximum capacity of 200,000 barrels per day. The first stage of the line was executed with a capacity of 8,000 to 16,000 barrels per day, and it will be increasing gradually until it reaches 40,000 barrels per day. The second phase of the line will be built by China Petroleum Pipeline Engineering (CPPE).

FALUJ–KHARTOUM-PORT SUDAN PIPELINE:

The Faluj–Port Sudan crude oil pipeline was commissioned on 10 April 2006. It is mainly established to transport the product from blocks 3 and 7 assigned to Petrodar Company. The 32 inch diameter pipeline is approximately 1 400 kilometres long and has a maximum capacity is approximately 500,000 barrels per day.

Rail and road transportation

About 20% of the country's requirement for oil products is transported by pipeline.

Road transport (trucks) is the main mode of transport used contributing some 70% of the movements. About 9% of the bulk transport is transported by rail. Bulk transportation by river barge has had a limited application.

About 89% of the total power station fuel requirement is transported by road and the balance is transported by rail.

All future power station will be supplied directly form the crude pipeline, except the most remote.

3.2.2 COAL

No significant coal reserve is available in Sudan. All the coal which will be used in the generation of electricity would be need to be shipped into Sudan from South Africa, the Far East or Australia.

Accordingly, Port Sudan is the favoured location for potential new coal-fired steam power plant in order to reduce transport and handling cost.

3.2.3 NATURAL GAS

There exits possibility that gas reserves in the Read Sea area could be of a sufficient level to allow them to be economically recoverable. Estimates of the total Natural Gas reserves in the Bashayer and Suakin in the Red Sea are quoted by Acres and the Energy Information Administration as about 3 tcf. If this were the case then electricity generation could be one of the major uses of Natural Gas.

Considering these uncertainties, and the time for exploration of the resource and the development of the necessary infrastructure, the Consultant assumes for the present Study that no Natural Gas is available in sufficient quantity for power generation in thermal plant.

3.3 ELECTRIC SECTOR BACKGROUND INFORMATION

3.3.1 ELECTRIFICATION IN 2005

The electrification ratio of the Sudan (percentage of households with electricity supply) is one of the lowest in the world, estimated at about 19% (made up from about 16.3% metered NEC connections, 2.3% connections to private supply companies and 0.2% unmetered connections).

The contribution would expect to increase dramatically in the coming decade according to the government strategy to supply more than 75% of the population with electric power during the coming 25 years. Consumption of the major Hydropower project (1 250 MW) at Marawee in 2008 will significantly help to achieve this goal.

Electricity is supplied mainly by NEC, but there are also small private generators in main towns that are not supplied by NEC. Many industrial and large commercial operations have standby generation, and some industries have their own continuous generation.

The quality of supply in the grid system is much superior to that of the off-grid systems, which suffer from insufficient installed capacity, lack of spare parts, inadequate maintenance, and fuel shortages.

3.3.2 ANALYSIS OF THE ELECTRICITY SYSTEM

The electricity system within Sudan is comprised of the main National Grid, a number of isolated off-grid systems and some existing private generation companies.

NEC's main grid system is divided into the Khartoum, Central, Eastern and Northern areas.

- The Khartoum transmission ring supplies most of the urban areas of Khartoum state, and also feeds south about 90 km along the east bank of the White Nile via a 33 kV distribution line to Al Geteina in the White Nile state.
- The Central Grid supplies areas near the Blue Nile south of Khartoum as far as Singa, including Giad industrial city. A 33 kV distribution line also feeds villages west from Wadi Medani as far as Elmanagil and Elgurashi. The grid also supplies Kosti and Rabak from

Sennar on the Blue Nile, and then north along the White Nile as far as Al Dueim. Damazen Town (Roseires) is fed by the Roseires Hydropower station, which is connected to the 220 kV grid by 220 kV lines.

- The Eastern grid is connected to the Central grid by a 110 kV line running east from Wadi Medani to Al Gadarif, and then north-east (66 kV) to New Halfa and Kassala via Khashm el Girba Hydropower station.

The towns of Atbara and Shendi in River Nile state, which were previously supplied by local off-grid generation, were connected to the National Grid as part of the Merowe transmission reinforcement scheme in the second half of 2005.

3.3.3 TRANSMISSION

The existing transmission system consists of 2003 km of transmission lines, of which 830 km are at 220 kV level, 880 km at 110 kV level, 293 km at 66 kV levels respectively. There are a total of 32 substations in the system, of which 9 are at 220 kV, 22 are at 110 kV (9 around Khartoum), 7 are at 66 kV level. Isolated networks are in distribution.

Three 500 kV transmission circuits are about to be commissioned to evacuate the generation from Merowe dam (1 250 MW) towards east and south (to Khartoum), to the 220 kV network.

Including the above 500 kV lines, the master plan report shows that between the year 2006-2009 the following will be constructed.

Voltage level	**Length**
110 kV	121 km
220 kV	3535 km
500 kV	*611 km*
Total	**4267 km**

3.4 INSTITUTIONNAL SETTINGS

3.4.1 ORGANISATION OF THE SECTOR

The Ministry of Energy and Mining has overall responsibility for managing the energy sector including policy formulation and regulation of all operating entities, public corporations as well as the private sector.

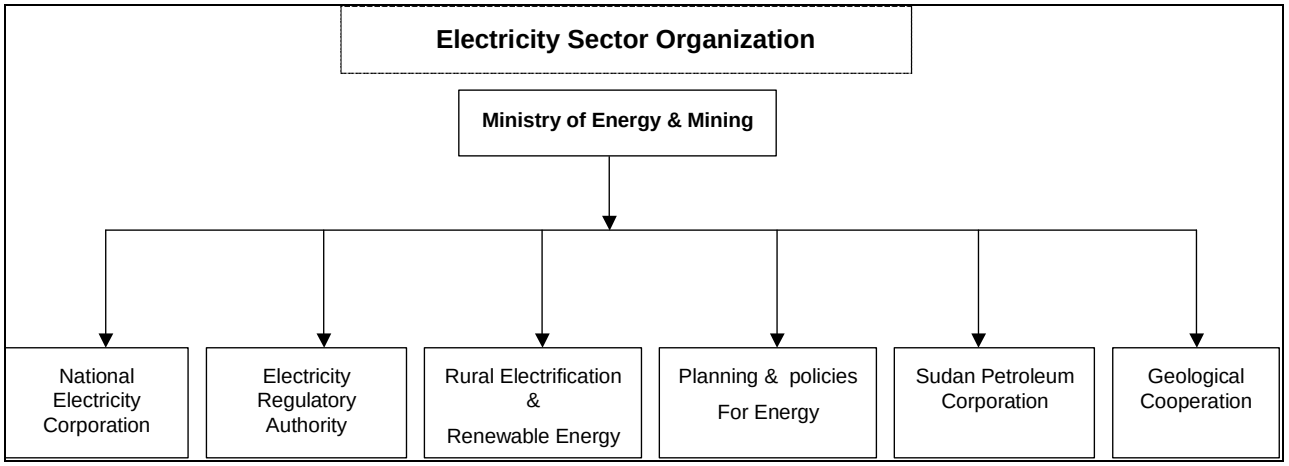

Figure 3.4-1 - Electricity Sector Organization

The Petroleum Administration (Sudanese Petroleum Corporation (SPC)) monitors petroleum exploration activities. The Petroleum Affairs Board, a high level body responsible for all contract negotiations, is presided over by the Minister of Energy and has representatives from the Ministry of Finance and Planning.

NEC is the governmental entity responsible for generation, transmission and distribution of electric power in the Sudan. NEC's power system comprises mainly the National Grid and a number of isolated diesel power stations. Public domestic electricity was first supplied to Khartoum in the year 1908. In the year 1982 NEC was established. Its responsibility is electricity generation; transmission; distribution; selling and revenue collection for the National Grid. In addition there are 16 isolated thermal power stations to towns in different regions of the country.

3.4.2 SECTOR STRATEGY

3.4.2.1 Context

The electrification ratio of the Sudan (percentage of the population with electricity supply) is very low and estimated at about 15% of the country. 70% of the available electric energy is consumed in cities (mainly in the capital Khartoum).

The power sector in Sudan has been constrained for a number of years by unavailability of domestic and external finance required for adequate expansions of generation, transmission and distribution capacities, however the Government of Sudan has set an ambitious program to electrify 75% - 80% of the country by year 2020 to promote agriculture, industry and social development and to improve the standard of living of the people.

To address these issues and requirements of the set electrification programs, the Government backed up by the Investment Encouragement Act, and the Electricity Act has allowed the private sector, to participate in electricity production.

NEC as the utility responsible to implement the government polices in the electricity sector, had its plans (projects) to double the installed generation capacity in the coming few years, to eliminate suppressed demand in the National Grid and to start meeting the supply and expansions required to fulfill the government policy to electrify 80% of population.

NEC is conducting a long term plan to arrange the requirement of electrification of the country. Inline NEC is preparing its medium term plan for coming five years inclusive the short plan, of which the expansion plans for generation and transmissions.

3.4.2.2 Sector main issues

To achieve the main strategy goals its required:

1. to install 12 000 MW of generation within 25 years timeframe giving priority to the hydro as far as possible.
2. to extend the National Grid at the suitable voltage levels 500 kV, 220 kV and 110 kV to cover the targeted areas of which settlement areas centres in the Southern States, Kordofan States, and war-hit States comes first giving emphasis for sustaining peace.

On an other hand, the Sector is part of the country infrastructure correlated to and interfaced with others specifically transportation, accordingly development of electricity is well tied to logistics of fuel.

Indeed, for optimising reasonable tariff, cheaper fuels should be burned in generation and in this regard residual fuels comes first as for the case of Sudan. Sudan is not producing sufficient fuel of the said type where Sudanese crude oil is a soft one; hence importation is a mandate to generate least cost electricity.

The present infrastructure of transportation as for the railways or road tankers is only sufficient for around 4,000 MW generations from imported heavy fuel via Port Sudan to Khartoum as electricity load centre. So the Government awareness on doubling the line and roads from Port Sudan to Khartoum is essential to avail fuel in sufficient quantities.

The other option for development of transportation infrastructure is to burn Sudanese Crude directly; otherwise NEC may be obliged to use gas oil instead with its heavy impact on tariff as a result to gas oil high price.

The above arrangements is a call for the Government to apply measures and create effective instruments that can allocate sufficient finance to the sector to meet its objectives and obligations, these efforts and instruments could be summarized as follows:

- Pursuing efforts to secure full finance for the implementation of the large hydroelectric power projects already having designs.
- Introduction of new funding instruments such as the BOT System.
- Continue rehabilitation and expansion of electricity Generation and transmission networks.
- Commencement of the execution of the committed thermal Electricity stations.

3.4.2.3 First government actions

During the past few years, NEC has formulated a number of development plans in generation, transmission and distribution for the National and Isolated Grids in order to eliminate load shedding and supply constrains. These plans fell short of achieving their objectives mainly because of financial constrains, which had narrowed investments in the energy sector.

To address these constrains the Government of Sudan has launched the Electricity Act 2001 and the Investment Encouragement Act 2003.

In 2001, Electricity Act was issued, when the monopoly of NEC is lifted, specifically in electricity generation and distributional activities.

Any private company or person has the right to generate and distribute electricity. Furthermore the Investment Act has more attractive incentives to encourage foreign & local investors.

Embarking on the Acts, the Government of Sudan has set an ambitious program aiming at reforming the electricity sector to remove distortions hindering the sector's ability to generate revenues.

The program had called for the rationalization of NEC's investment plans to bridge financing gap by encouraging the participation of the private sector in the generation, transmission and distribution of the electricity.

At the same time the Government of Sudan has strived to secure funds for the sector as far as can be available, which was not sufficient to cover the gap. Although NEC has achieved some progress in the development of the sector but this is done mainly in the north of Sudan as regional conflicts have hindered NEC to extend its interest deep in the south.

Sudan being a vast country and relatively sparsely populated has created difficulty to extend the national grid to the far west and east. By the implementation of peace agreement and support to implement Marawee Dam, its associated transmission lines and also the fact that people are looking eager to welfare life presented in the developing rural areas to urban.

It shall be a requirement and challenge to the country and NEC to extend its services in quite big jumps to catch the growing demand.

3.5 CROSSCUTTING ISSUES

The diversity of the Sudan's geography and climate in particular is reflected in its people, who are multi-cultural, multi-ethnic, and multilingual.

About 15% of this land space is cultivated, 18% is woodland or forest and the remaining is desert or semi-desert. Current estimations put the population at an excess of 35.4 millions with an annual growth rate estimated at 2.% and a population density of 14 persons per km^2. Though this figure masks wide differences – the effective population density on the arable land exceeds 50 persons per km2 while 67% is rural and 33% urban.

Area (per million sq. Km)	2.5
Longitudes	3.5^{o} - 23^{o} North
Latitudes	33^{o} - 21^{o} East
Total Population	35.4 million
Dependency Ratio	0.6%
Crude Birth Rate	37.8%
Crude Death Rate	11.5%
Infant Mortality Rate (per thousand)	125
Annual Population Growth Rate	2.6
Sex Ratio (Males/Females, 1993 Census)	100:103
Ratio of Rural Population	66.7%
Ratio of Urban Population	33.3%
Economically Active Population (+15)	52.4%
Total Fertility Rate	5.7%
Illiteracy Rate of Total Population (1993 Census)	53.4%
Education Rate of Total Population (1993 Census)	46.6%
Life Expectancy at Birth	53.3%
Child Immunization Rate	80%
Health Services coverage rate	70%
Number of Beds per 1000 people	0.9 beds
Drinking Water coverage rate	59%

Table 3.5-1 - Demographic and social indicators

4. ASSESSMENT OF THE EXISTING GENERATION MIX OF SUDAN

4.1 CONTEXT

The purpose of this task is to assess and describe the technical characteristics of the existing power generation facilities.

This task has been carried out on the basis of existing studies and close co-operation with experts and counterpart staff of NEC corporation.

In the specific case of Sudan, according recommendation of NEC utility, for obvious matter of homogeneity between the complementary studies, the Consultant has based this analysis upon last NEC Long Term Power Plan Study (PB Power 2006).

The main documents used to determine the existing generation mix and the associated constraints are listed here below:

- Demand forecast report and appendices (LTPSPS 2006 - July 2006)
- Data book Hydrology and hydroelectric Power plant (LTPSPS 2006- April 2003)
- Generation Data book (LTPSPS 2006 - October 2006)
- Generation Plan report (LTPSPS 2006 - October 2006)
- Draft Transmission Planning Report (LTPSPS 2006 - November 2006)

Important note: The perimeter of this study encompasses all the demand of the interconnected grid of Sudan. That is to say that the Consultant included all the forecasted interconnection of isolated grid to the main grid according the study of Sudan Long Term Power Plan.

These regional interconnections are presented in the demand projection chapter (M3 Vol 4 report).

4.2 OVERVIEW OF THE EXISTING AND COMMITTED GENERATION MIX IN THE MAIN GRID

4.2.1 INSTALLED CAPACITY IN THE MAIN GRID – DESCRIPTION OF THE CURRENT SITUATION

At the time being the total capacity available for dispatch on the National Grid is about 826 MW, of which some 59% is conventional thermal plant and the remaining 41% is hydroelectric plant.

In the table here below, the Consultant set out the generation mix on the National Grid as at July 2006 and provide a summary of installed and available capacities from the existing on-grid power plants.

Power Plant	Plant Type	Fuel Type	Net Capacity (MW)
Khartoum North ST's	Thermal	HFO	157.0
Khartoum North GT's	Thermal	Gas Oil	50.4
Garri 1 CCGT's	Thermal	Gas Oil	164.0
Garri 2 OCGT's	Thermal	Gas Oil	84.0
El Fau Diesel	Thermal	Gas Oil	10.0
Kassala Diesel's	Thermal	Gas Oil	7.9
Girba Diesel's	Thermal	Diesel	4.0
Kuku GT's	Thermal	Gas Oil	19.0
Total Thermal Plant			**496.3**
Roseires	Hydro		280.0
Sennar	Hydro		15.0
Kashm El Girba	Hydro		18.1
Jebel Aulia	Hydro		28.1
Total Hydro Plant			**341.2**
Net Installed Capacity			**837.5**
Thermal Capacity Part			59%
Hydro Capacity Part			41%

Table 4.2-1 - Installed capacity in the main grid

4.2.2 HISTORICAL GENERATION PER TYPE

The historical generation per type since is related in the following table:

Years	Hydro	Perc. %	Thermal	Perc. %	Total
1997	1053.6	46%	1242.98	54%	**2296.58**
1998	1086.9	49%	1119.73	51%	**2206.63**
1999	1210.37	50%	1213	50%	**2423.37**
2000	1183.3	45%	1458	55%	**2641.3**
2001	1267.6	45%	1572.4	55%	**2840**
2002	1287.2	42%	1806.3	58%	**3093.5**
2003	1163.2	35%	2190.7	65%	**3353.9**
2004	1106.78	32%	2346.01	68%	**3452.79**
2005	1261.26	33%	2528.39	67%	**3789.65**

Table 4.2-2 - Historical generation (GWh) per type

The graph here below presents the past evolution of the generation per type of generation.

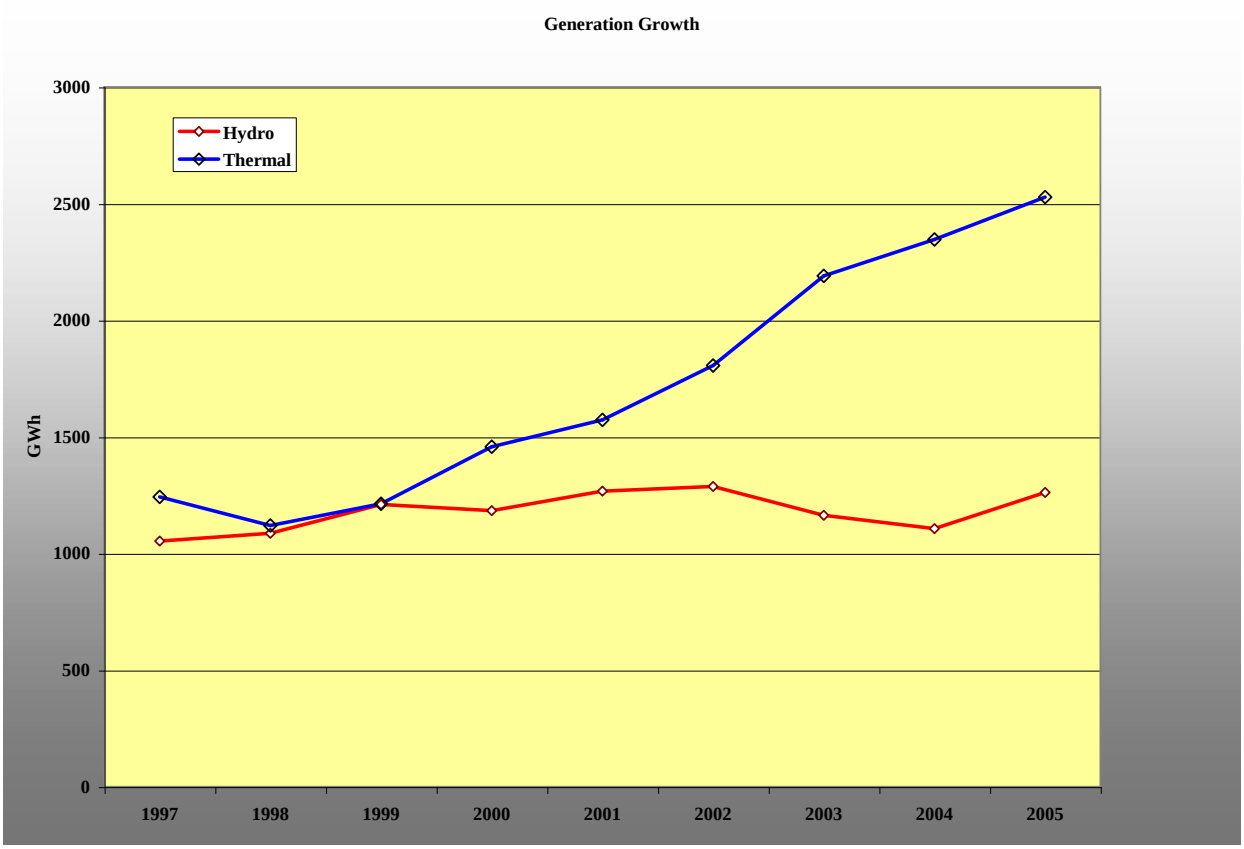

Table 4.2-3 - Generation growth

4.3 EXISTING THERMAL POWER PLANTS IN THE MAIN GRID

In the following sub-sections the Consultant presents a brief description of the main characteristics of each of the thermal power stations connected to the main National Grid. The tables set out the assumed operational data, cost and performance parameters for each generating unit.

4.3.1 KHARTOUM NORTH

The Khartoum North plant is located on the right bank of the Blue Nile, roughly opposite the now abandoned Burri Power Station, but some 4 km away from the actual river bank. The present installation consists of four HFO-fired steam units and four gas oil-fired gas turbines.

HFO-fired steam units:

- Two steam units were installed in 1984/86 and are rated at 33 MW with a gross available capacity of 27.7 MW each.

- Two additional steam units were installed in 1993 and are rated at 60 MW with a gross available capacity of 50.8 MW each.

All four units are designed to burn HFO 3 500 Redwood and are capable of operating at base load, particularly during the dry season.

According to the indication of NEC, HFO 1 500 is currently preferred to HFO 3 500 because HFO 1 500 leads to lower maintenance costs and consequently, a reduction in the need for foreign exchange.

The total gross available capacity of the steam units at the Khartoum North station is approximately 157 MW.

Gas oil-fired Gas Turbine:

There are also three operational gas turbine units at Khartoum North Power Station, each fired on gas oil.

- Unit 1 is rated at 20 MW with a gross available capacity of 16.8 MW and was installed in 1992.

- Units 3 and 4 have an installed capacity of 25 MW each and were both installed in 2001. These two units which are both operational, have net available capacities of 16.8 MW each. Unit 2 is now retired.

Retirement date:

Steam units 1 and 2 are assumed to retire at the end of 2014 and units 3 and 4 are assumed to retired at the end of 2022.

GT unit 1 is assumed to retire at the end of 2009, while units 3 and 4 are assumed to retire at the end of 2014.

4.3.2 GARRI 1 CCGT POWER PLANT

The Garri 1 power plant is a gas oil-fired combined cycle gas turbine (CCGT) power project located at El Gaili, which is located approximately 78 km north of Khartoum. The six unit station comprises of four 'Frame 6B' 40 MW gas turbines (GT's) and two 30 MW steam turbines (ST's). This provides an overall installed ISO capacity of 220 MW. These six units make up two combined cycle modules (two GT's and one ST per combined cycle module). The current total sent out capacity of this CCGT power project is 164 MW.

Garri 1 CCGT is assumed to retire at the end of 2027.

4.3.3 GARRI 2 OCGT POWER PLANT

The Garri 2 power plant is an open cycle gas turbine (OCGT) plant with a total installed capacity of 84 MWSO and is located at the same site as the Garri 1 units at El Gaili. The total capacity is split equally between three GE Alstrom GT units.

The Garri 2 site receives its fuel (gas oil) direct from the nearby refinery. Demand in the area is also expected to grow due to the planned expansion of the existing industrial area.

This plant is supposed to be converted into CCGT in 2008.

4.3.4 KASSALA DIESEL STATION

Located in the town of Kassala, approximately 400 km east of Khartoum city, this power plant comprises of only 2 operational diesel units with a total sent out capacity of 2.6 MW (1.3 MW each).

Units 1 to 5 and unit 7 have recently been retired and are, therefore, no longer considered available for generation. NEC have decided that units 6 and 7 are due to retire at the end of 2010.

4.3.5 EL FAU DIESEL POWER STATION

Commercial operation of the El Fau diesel power station by NEC commenced in mid-2004. At this moment the power station consists of only two medium speed diesel units with a total installed capacity of 13.2 MW. Unit 2 is currently unavailable, but is expected to be returned to service in 2007. When both units are available, the total available sent out capacity will increase to 10 MW. Both units will be retired at the end of 2009.

4.3.6 KHASHM EL GIRBA DIESEL STATION

Located in the town of Khashm El Girba, approximately 60 km south-west of Kassala, this power plant comprises of two diesel generators. Unit 1 is rated at 2.9 MW (2 MW sent out) and was installed in 1984. The second unit is rated at 4.5 MW (2 MW sent out) and was installed in 1990. According to NEC, both units will be retired at the end of 2009.

4.3.7 KUKU GAS TURBINE STATION

The Kuku site is located adjacent to the main road which runs along the right bank of the Blue Nile, about 2 km upstream of Khartoum North. The plant comprises of two gas turbine units, one nominally rated at 10 MW and the other at 14.4 MW. Both units were installed in 1985 and are mobile type units mounted on road going trailers. Unit 1 is restricted to 9 MW sent our while Unit 2 is restricted to 10 MW sent out capacity.

According to NEC, both units will be retired at the end of 2006.

4.3.8 TECHNICAL CHARACTERISTICS - SUMMARY TABLE

The whole technical and economic characteristics of these thermal power plants are synthesised in the Appendix (See Sudan Tables M2 Sheet “Existing TPP”).

4.4 COST OF FUEL TRANSPORTATION

The economic cost of fuel is affected by the Sudan being a net importer or net exporter of oil products. The derivation of the economic cost of fuel to be used in the LTPSPS starts with the international price of crude oil and oil products expressed either in terms of international carriage-

insurance-freight (cif) or freight-on-board (fob) prices. It is then adjusted for the cost of delivering fuel to the power stations. Furthermore, in the Sudan, fuel can be transported by pipeline, road, rail or barge. The intention of NEC is to locate the Power Stations as near as possible to the fuel source (crude pipeline) to minimise the cost of transport and assure continuity of supply (for example the Kosti and El Fula power stations) by connecting to the crude oil source via the NEC owned pipeline.

The primary purpose of this Sub-section is to draw upon existing data on the oil and gas sector in the Sudan and develop fuel price assumptions to serve as the basis for assessing the economic viability of using oil as a fuel for power generation when compared to other resources such as hydro.

	Transportation Cost (SD/t/km)		
Mode of Transportation	HFO	Diesel	Gas Oil
Transport by Road	12.43	15.70	13.90
Transport by Rail	11.76	11.76	11.76

	Transportation Cost (US $/t/km)		
Mode of Transportation	HFO	Diesel	Gas Oil
Transport by Road	0.06	0.07	0.06
Transport by Rail	0.05	0.05	0.05

Table 4.4-1 - Transportation cost

Power Station	Source of Fuel	Mode of Transport	Distance (km)	Cost of Transport ($/tonne)								Transport Costs used for this Study ($/tonne)			
				By Road				By Rail							
				Crude	HFO	Diesel	Gas Oil	Crude	HFO	Diesel	Gas Oil	Crude	HFO	Diesel	Gas Oil
Port Sudan	Port Sudan	Road	30	1.71	1.71	2.16	1.91	0	0	0	0	1.71	1.71	2.16	1.91
Atbara	El Gaili	Road & Rail	245	13.97	13.97	17.64	15.62	13.22	13.22	13.22	13.22	13.89	13.89	17.16	15.36
Shendi	El Gaili	Road & Rail	109	6.22	6.22	7.85	6.95	5.88	5.88	5.88	5.88	6.18	6.18	7.63	6.83
Karima	El Gaili	Rail	765	0	0	0	0	41.27	41.27	41.27	41.27	41.27	41.27	41.27	41.27
Dongola	Port Sudan	Road	1702	97.05	97.05	122.58	108.52	0	0	0	0	97.05	97.05	122.58	108.52
Wadi Halfa	El Gaili	Rail	880	0	0	0	0	47.47	47.47	47.47	47.47	47.47	47.47	47.47	47.47
El Obeid	El Obeid	Road	30	1.71	1.71	2.16	1.91	0	0	0	0	1.71	1.71	2.16	1.91
Um Ruwaba	El Obeid	Road & Rail	160	9.12	9.12	11.52	10.20	8.63	8.63	8.63	8.63	9.07	9.07	11.20	10.03
Nayala	El Obeid	Road & Rail	405 / 700*	39.91	39.91	50.41	44.63	21.85	21.85	21.85	21.85	37.93	37.93	47.27	42.13
El Fasher	El Obeid	Road	700	39.91	39.91	50.41	44.63	0	0	0	0	39.91	39.91	50.41	44.63
El Geneina	El Obeid	Road	1100	62.72	62.72	79.22	70.14	0	0	0	0	62.72	62.72	79.22	70.14
Juba	Al Shagara	Road	1488	84.84	84.84	107.16	94.88	0	0	0	0	84.84	84.84	107.16	94.88
Waw	El Obeid	Road	1045	59.58	59.58	75.26	66.63	0	0	0	0	59.58	59.58	75.26	66.63
Malakal	Al Shagara	Road*	768	43.22	43.22	54.59	48.33	0	0	0	0	43.22	43.22	54.59	48.33
Khartoum	El Gaili	Road	70	3.21	3.21	5.04	4.46	0	0	0	0	3.21	3.21	5.04	4.46
Khashm el Girba	Al Shagara	Road	543	30.96	30.96	39.11	34.62	0	0	0	0	30.96	30.96	39.11	34.62
Kassala	Abu Gabra	Road	557	31.76	31.76	40.11	35.52	0	0	0	0	31.76	31.76	40.11	35.52
Garri	Garri	Pipeline	0	0	0	0	0	0	0	0	0	0	0	0	0
Girba	Abu Gabra	Road	550	31.36	31.36	39.61	35.07	0	0	0	0	31.36	31.36	39.61	35.07
Al Fula	El Obied	Road & Rail	300	17.11	17.11	21.61	19.13	16.19	16.19	16.19	16.19	17.00	17.00	21.01	18.90
Kosti	El Obied	Road	300	17.11	17.11	21.61	19.13	0	0	0	0	17.11	17.11	21.61	19.13
El Bagair	Abu Gabra	Road	50	2.85	2.85	3.60	3.19	0	0	0	0	2.85	2.85	3.60	3.19
Rahad	Abu Gabra	Road	550	31.36	31.36	39.61	35.07	0	0	0	0	31.36	31.36	39.61	35.07

Table 4.4-2 - Transportation cost for oil products (2006 US Dollars)

4.5 EXISTING HYDRO GENERATION PLANTS OF THE MAIN GRID

4.5.1 OVERVIEW

With the exception of Bahr el Jebel in the extreme south of the country, near the border with Uganda, all significant hydropower potential is located on the Blue Nile or on the Main Nile downstream of the confluence with the White Nile at Khartoum. The river is characterised by annual floods, with flows from Ethiopia in August exceeding the low flows in March and April by a factor of 50, with a sediment concentration as high as 10 Mt/day.

In 2006, the existing HPP plants in Sudan are:

- ROSEIRES (280 MW) and SENNAR (15 MW), both located on the Blue Nile river.
- The KHASHM EL GIRBA hydroelectric power plant (12 MW), located on the Atbara River.
- JEBEL AULIA hydroelectric power plant (28.8 MW), located on the White Nile.

These HPP are discussed in more detail below.

4.5.2 RESERVOIR CHARACTERISTICS

The four existing multi-purpose reservoirs on the Nile River system in Sudan are used primarily to store water for irrigation purposes.

Note: Since the filling period, the storage volume of reservoirs has been reduced owing to accumulation of sediment and this process is continuing at varying rates in each individual reservoir.

The volume in the reservoirs has been reduced by 25% at Roseires and 40% at Sennar and Khashm el Girba[1].

4.5.3 ROSEIRES HPP ON BLUE NILE RIVER

Roseires is located on the Blue Nile about 70 km from the Ethiopian border.

It is at present the largest power plant in the Sudan with a total rated capacity of 280 MW.

The plant has undergone continuous rehabilitation and refurbishment which in recent years has included:

- Refurbishment of stator and rotor for Units 1 to 3 before 1990, runner blades in 1992.
- Generator rewinding for units 4 to 7 in 1997.
- Runner replacement at Units 5, 6 and 7 completed in February 2002.

[1] SMFA (2002) Sudan Ministry of Foreign Affairs Websitehttp:/www.sudmer.com/water%20in%20sudan.htm 16/3/2002.

Roseires reservoir is primarily intended for irrigation purposes.

At present there is no direct off-take of water from the reservoir for irrigation. All releases are through one or more of the power house low level sluices and the spillway to the natural river channel below, from which irrigation abstractions are made.

4.5.4 SENNAR HPP ON BLUE NILE RIVER

The Sennar Hydropower Plant is located on the left bank of the Blue Nile, about 175 km downstream from Roseires, and some 275 km upstream from Khartoum.

Although the Sennar barrage was completed in 1925, the hydroelectric plant was not built until 1962. The scheme comprises two generators each with an installed capacity of 7.5 MW. The generators are driven by Kaplan turbines operating at a head which varies between 17 m and 5.8 m.

Sennar reservoir is primarily intended for irrigation purposes.

4.5.5 KHASHM EL GIRBA ON ATBARA RIVER

The Khashm El Girba hydro power plant is located on the Atbara River with the dam located about 50 km north of the Ethiopian border. The main dam is of the concrete buttress type and the hydropower installation provides 12 MW of non firm supply to the grid in Kassala Region. The units were commissioned between 1961 and 1963.

Use of the output of these units was improved following interconnection with the main grid in 1990. The main concrete section of the dam houses the main machine hall, which contains two 4.12 MW generators each driven by a Kaplan turbine, together with four 1 900 hp electric motors driving supplementary irrigation pumps.

In a separate machine hall, there are three reversible axial flow pump/turbines, which are each rated at 2.07 MW in the generating mode and 1.9 MW in the pumping mode. On the left abutment there is a structure which provides an off-take for the irrigation canal.

Like the other two previous hydro sites on the system, this installation was primarily designed for irrigation purposes, power generation being a secondary consideration.

The operating regime of this plant can be summarised as follows:

- From July to August only the pumps operate.
- Between September and December the turbines generate.
- And when the water inflow is low, the turbines only operated as a peaking plant.

4.5.6 JEBEL AULIA 'HYDROMATRIX' PLANT ON WHITE NILE RIVER

The Jebel Aulia dam is located on the White Nile, about 40 km upstream of Khartoum and was completed in 1937.

The dam was originally built by Egypt for the purposes of flood control and enhancement of river flows during the low flow period. However, this role became largely redundant following the

completion of the Aswan High Dam in 1960 and in recent years, the dam has been converted into a hydroelectric generation plant.

The dam is constructed of masonry with a section some 445 m long having 60 sluices. A navigation lock is included, adjacent to the right bank.

The head between reservoir and tail water levels varies from 9.6 m at full reservoir and low discharges, to almost zero during the flood season. The head is affected by a raised tailwater which is caused mainly by the back-water effects of the Blue Nile flood.

A contract for hydro plant at Jebel Aulia was awarded to VATech Hydro who installed a total of 80 hydromatrix turbines in the existing dam between 2003 and 2005, to provide a total installed capacity of 28.8 MW.

4.5.7 TECHNICAL CHARACTERISTICS - SUMMARY TABLE

The whole technical and economic characteristics of these existing hydroelectric power plants are synthesised in the Appendix (*See Sudan Tables M2.xls Sheet "Existing and Committed HPP").*

4.5.8 CURRENT OPERATING RULES

Hydroelectric performance is determined not only by scheme design but also by the operating rules in force and, in the context of long-term planning, operation is conveniently defined in accordance with a variety of seasonal demand and reservoir rule curves.

The Roseires, Sennar and Jebel Aulia reservoirs provide seasonal regulation of river flows to meet the needs of flood control together with irrigation and electricity supply. Another constraint on reservoir operation is the need to preserve storage capacity by controlling reservoir siltation.

At Roseires this has dictated that the reservoir be held at minimum level each year until the bulk of the flood and entrained silt load has passed downstream, and then be filled at the very end of the flood season. Rules determining this operation have previously been reviewed in the context of the heightening of Roseires dam, and simulations for this study have now confirmed that they remain appropriate.

The filling rules adopted for the White and Blue Nile reservoirs are those reported in M&M1997 as modified in accordance with recent information from the MoI, and are outlined below.

JEBEL AULIA:

The first filling of the dam starts on 1 July each year from MoI of 372.50 m, and continues for one month reaching a level of 376.50 m by the end of July. This level is held for one month until the peak flood of the Blue Nile has passed. Then filling continues, reaching a maximum level of 377.4 m by early October where it is held until the beginning of 'draw-down' during the last period in March. "Draw-down" continues until the end of June when the reservoir returns to MoI of 372.50 m.

ROSEIRES AND SENNAR:

During the flood period July-August, Roseires is assumed to be held at the MoI of 467.60 m (which is the minimum level) with Sennar held at 417.20 m. Filling of Roseires commences during the last week of August as the earliest date in accordance with the following:

a) At the last week of August, if the flow from El Deim is below 350 mm^3/day or has risen above 350 mm^3/day and fell below that before the end of August.

b) After the end of August, if the flow at El Deim reached 350 mm^3/day and continued for three days.

c) On 26 September as the latest date if the river flows continued above 350 mm^3/day.

KHASHM EL GIRBA:

Initially a filling rule for Khashm el Girba reservoir was developed based on filling behaviour demonstrated in the reservoir level and inflow records for the period 1992 to 2001 which had been obtained from the MoI. Following the provision of further information by the MoI and then completion of the reservoir inflow record as described above, operating rules for use in this study have now been finalised, these being in outline as below.

Depending on whether the inflow has or has not increased to a defined value, reservoir filling commences towards the end of August or early September and is completed by the end of September.

From completion of filling until June, releases are made to satisfy irrigation demand and then, until the end of June, to suit energy demand while still meeting reduced irrigation requirements. These releases are made so that the reservoirs are empty at the end of June in anticipation of the arrival of increasing inflows.

4.6 COMMITTED CAPACITY ADDITIONS TO THE NEC GRID

According to NEC master plan, the following power plants have been identified as committed contributors to the Sudan generation expansion plan:

Power Plant	Plant Type	Installed Capacity (MW)	Date of Full Commercial Operation
Garri 2 - 4th GT	Thermal	40	2006
Garri 4 Steam U1 & 2	Thermal	100	2007
Kassala Diesel U1 - 5	Thermal	50	2007
Kilo X GT - 2 x GT	Thermal	40	2007
Garri 2 - 2xST	Thermal	80	2008
Khartoum North Steam U5 & 6	Thermal	200	2008
Port Sudan Steam U1-3	Thermal	405	2009
Kosti Steam U1 & 2	Thermal	250	2009
El Bagair Steam U1 & 2	Thermal	270	2009
Al Fula Steam U1 & 2	Thermal	270	2009
Kosti Steam U3 & 4	Thermal	250	2010
Garri 3 Steam U1 -3	Thermal	405	2010
El Bagair Steam U3 & 4	Thermal	270	2010
Al Fula Steam U3 & 4	Thermal	270	2010
Garri 3 Steam U4	Thermal	135	2011
TOTAL THERMAL PLANT		**3035**	
Merowe Hydroelectric	Hydro	1250	2008-2009
Sennar Extension	Hydro	50	2011
Rosieres Heightening with Dinder	Hydro	135	2012
TOTAL HYDRO PLANT		**1435**	
TOTAL COMMITTED CAPACITY		**4470**	
THERMAL CONTRIBUTION		**68%**	
HYDRO CONTRIBUTION		**32%**	

Table 4.6-1 - Committed capacity addition to NEC Grid

A total of 4 470 MW of installed capacity are to be added to the NEC grid between 2007 and 2012. Of this committed generating capacity, 68% is to be provided by thermal generating units while the remaining 32% is to be supplied by hydroelectric plant.

Each project is discussed in further detail in the following sub-sections.

4.6.1 COMMITTED THERMAL POWER PLANTS IN THE MAIN GRID

4.6.1.1 Khartoum North Units 5 and 6

NEC have decided to expand the Khartoum North site by building two additional steam units. These units (known as units 5 & 6) are committed to be installed and will be in full operation by the start of 2008. Both units will be identical and have an installed capacity of 100 MW. The plant will be fired on HFO.

4.6.1.2 Conversion of Garri 2 to combined cycle operation

NEC are committed to expanding the capacity at the Garri 2 power plant through the conversion of the existing open cycle gas turbines to combined cycle operation. This will entail the addition of a fourth 40 MW GT in 2006 and two 40 MW steam turbine sets in 2008. This will increase the total capacity available to be sent out from the Garri 2 CCGT power plant to 200.4 MW.

4.6.1.3 Kilo X GT

The Kilo X power plant site is located on the south-east of Khartoum. The original configuration for the Kilo X power station was for a 7x40 MW IPP low speed diesel plant. In September 2006, however, NEC changed the project to a fast track OCGT plant with an installed capacity of 80 MW.

4.6.1.4 Port Sudan coal-fired steam power plant

A new coal-fired steam plant is to be built in Port Sudan so that the new plant will be fully operational by 2009. The plant will consist of three identical units and provide 405 MW of installed capacity (385.5 MW sent out) in total. The location of a coal-fired plant at Port Sudan reflects the notion that all coal which is to be used in the generation of electric power would need to be shipped into Sudan.

Locating a coal plant on the coast at Port Sudan would therefore reduce any further transportation costs incurred by additional transportation of the coal within Sudan (presumably by rail and/or barge).

4.6.1.5 Kosti steam power plant

Located in the town of Kosti, approximately 270 km south of Khartoum on the banks of the White Nile, four identical crude oil-fired steam units are to be commissioned, each with an installed capacity of 125 MW (118.5 MW sent out). The first two units will be in full operation by the beginning of 2009, whilst the remaining two units will be in full operation at the beginning of 2010. The location of this committed power station - on the route of the recently commissioned (April 2006) Petrodar oil pipeline from the Melut Basin to Port Sudan - is a key feature of the generation development plan.

4.6.1.6 Garri 3 steam power plant

Block C at Garri is located next to the existing Garri 1 and Garri 2 power station sites. This committed project will provide four crude oil-fired steam units, each rated at 135 MW (128.25 MW sent out). The first three units are expected to be fully operational by the start of 2010 whilst the fourth unit is expected to be fully operational by the beginning of 2011.

4.6.1.7 Garri 4 steam power plant

Block D at Garri is the designated site for two smaller committed steam units. These two steam units will have an installed capacity of 50 MW each (47.5 MW sent out each). Unlike the other committed steam units at block C, however, these units will be fuelled by sponge coke and are thus considered separate committed generating plant additions to those at block C. Both units are expected to be in full operation from the beginning of 2007.

4.6.1.8 El Bagair steam power plant

Located in the state of Gazeerah, this plant will consist of four identical crude fired steam units, each rated at 135 MW (128.25 MW sent out each). Units 1 and 2 are expected to be fully operational at the beginning of 2009. Units 3 and 4 are expected to be fully operational at the beginning of 2010. Located in the vicinity of the Giad Industrial City, this power station will be located close to a centre of high demand.

4.6.1.9 Kassala diesel power plant

This plant will consist of 5 identical medium speed diesel units, each rated at 10 MW (9.6 MW sent out each). These units will be fuelled by HFO with supplies delivered by road and/or rail. It is believed that the construction of this power station is nearing completion and it is anticipated that this plant will be fully operational by the beginning of 2007.

4.6.1.10 Al Fula steam power plant

Located 260 km south-west of El Obeid in North Kordofan, this plant will consist of four identical crude oil-fired steam units, each rated at 135 MW (128.25 MW sent out). Units 1 and 2 are expected to be fully operational at the beginning of 2009. The third and fourth units are expected to be fully operational by the beginning of 2010.

4.6.1.11 Technical characteristics - summary table

The whole technical and economic characteristics of these here before presented committed thermal power plants are synthesised in the Appendix (See M2 V4 C1 Sudan tables.xls Sheet “Committed TPP”).

4.6.2 COMMITTED HYDRAULIC POWER PLANTS

Following discussions with NEC, the following hydroelectric power plants were considered to be committed to the LTPSPS generation plan:

4.6.2.1 MEROWE HYDROELECTRIC POWER PLANT

The 10 x 125 MW unit power plant downstream from Khartoum on the main Nile River is currently under construction. It is expected that 8 units will be commissioned in Q4 2008, with the remaining 2 units commissioned in Q1 2009. For planning purposes, the full capacity of the plant is assumed to be in full operation at the beginning of 2009.

4.6.2.2 SENNAR EXTENSION

The IPP extension to the Sennar project will consist of 4 x 12.5 MW units. It is expected these will be in full operation at the beginning of 2011.

4.6.2.3 ROSEIRES HEIGHTENING WITH DINDER

These combined projects are expected to be in full operation by 2012 and will add an additional 135 MW (3*45 MW) of installed capacity to the system.

4.6.2.4 Technical characteristics - summary table

The whole technical and economic characteristics of these here before presented committed hydroelectric power plants are synthesised in the Appendix (See M2 V4 C1 Sudan tables.xls Sheet "Existing and Committed HPP"). The data from RAPSO modelling are presented in Appendix M3 Vol 4.

4.6.3 FIRM AND AVERAGE ENERGY OF THE EXISTING AND COMMITTED HYDROELECTRIC SYSTEM

The following table presents the results of the RAPSO modelling (from LTPPS 2006 november 2006) of the existing and committed hydroelectric schemes. The table shows a summary of the average dependable power (MW), the 5% firm energy (in GWh per year) and the average energy (GWh per year) for the existing and the committed hydroelectric system :

Hydroelectric system :	Existing system	Existing + Merowe	Existing + Merowe + Sennar extension	Existing + Merowe + Sennar extension + Roseires heightened
Average depend. power	242 MW	1592 MW	1642 MW	1777 MW
95% firm annual energy	1377 GWh	6398 GWh	6518 GWh	7569 GWh
Average annual energy	1547 GWh	7228 GWh	7401 GWh	8575 GWh

Table 4.6-2 : Firm & average energy of existing and committed hydroelectric system

4.7 DESCRIPTION OF INFLOWS AND REFERENCE HYDROLOGICAL PERIOD

4.7.1 HYDROLOGY OF THE NILE

The Nile river system in Sudan comprises the Blue Nile and White Nile tributaries of the river that join together at Khartoum to form the Main Nile. The Atbara river joins the main Nile as it flows northwards into Egypt.

The Bahr El Jebel river originates from Lake Victoria, crosses the border close to Mongalla and enters the marshes of the area of Sudd of Bahr el Jebel where 50% of the flow is lost to evaporation before emerging and converging with the flow from Sobat river at Malakal. The Sobat river loses a part of its flow in the Machar marshes and the river flows northward to converge with Blue Nile downstream from Jebel Aulia at Khartoum.

The Blue Nile and its tributaries, the Dinder and Rahad, originate in the highlands of the Ethiopian Plateau. The Blue Nile flows from Lake Tana and cross the border Ethiopia/Sudan at Deim. Two dams impound the river: Roseires and Sennar before the confluence of two Niles at Khartoum.

The Atbara river flowing from its source located in Ethiopian highlands is one the major tributaries of Main Nile in Sudan.

The Main Nile flows northward to Egypt (reservoir of Aswan High Dam).

Flows entering the Sudan are measured at river gauging stations:

- near the Ethiopian border (El Deim),
- at Nimule and Mongalla on the Bahr el Jebel (South),
- on White Nile from Sobat and Bahr el Ghazal rivers and at Malakal, downstream the confluence of these rivers.

Flows on tributaries of Blue Nile Dinder and Rahad have been measured for long period.

In the same way, long term flows exist on Blue Nile close upstream the confluence.

The flows of Atbara river are known upstream the confluence with Main Nile and on its tributaries, Kubur and Setit river.

Downstream on the Main Nile, river gauging stations at Tamaniat, Hassanab and Dongola provide records of flows.

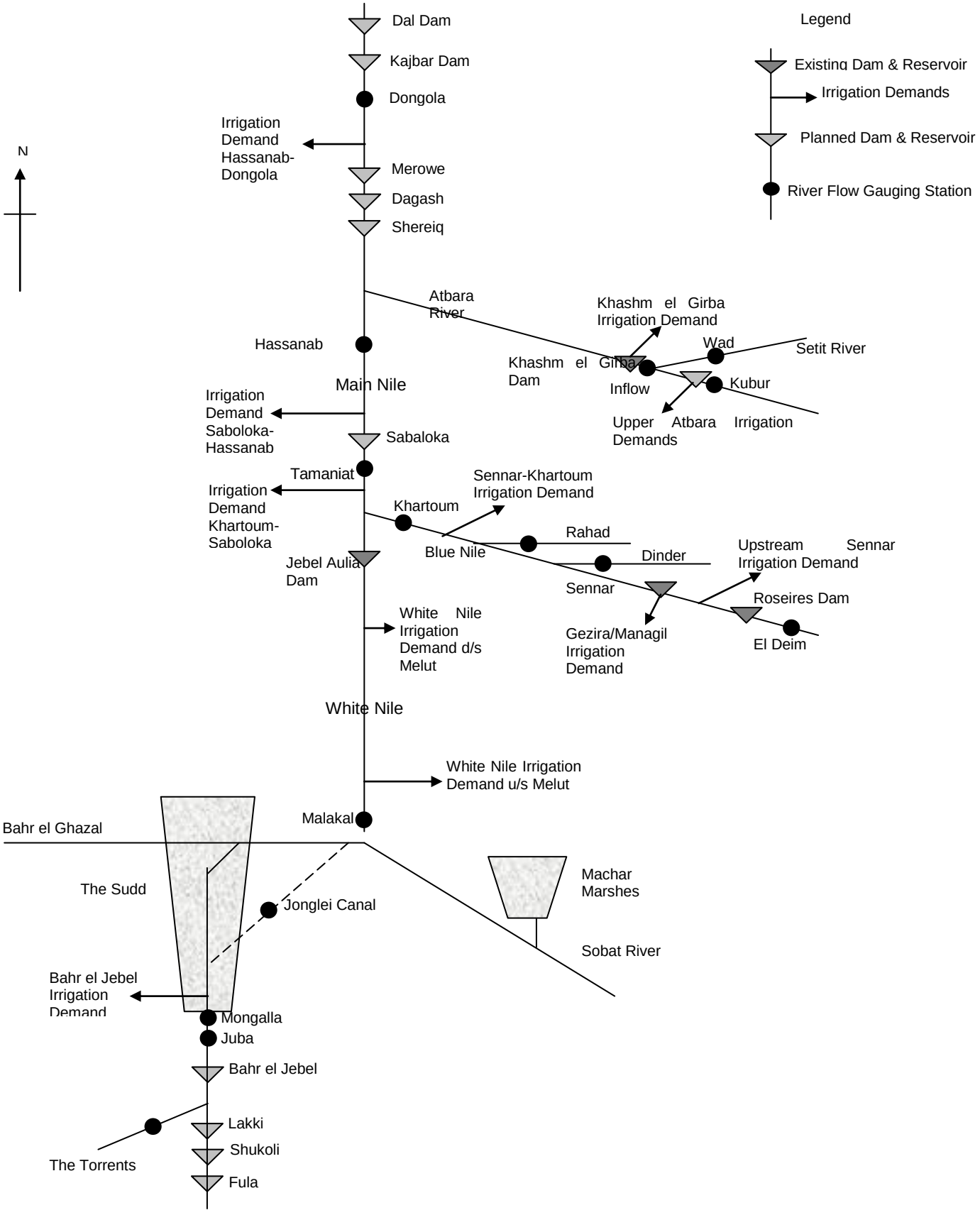

Figure 4.7-1 - Schematic Diagram of the Nile River in Sudan

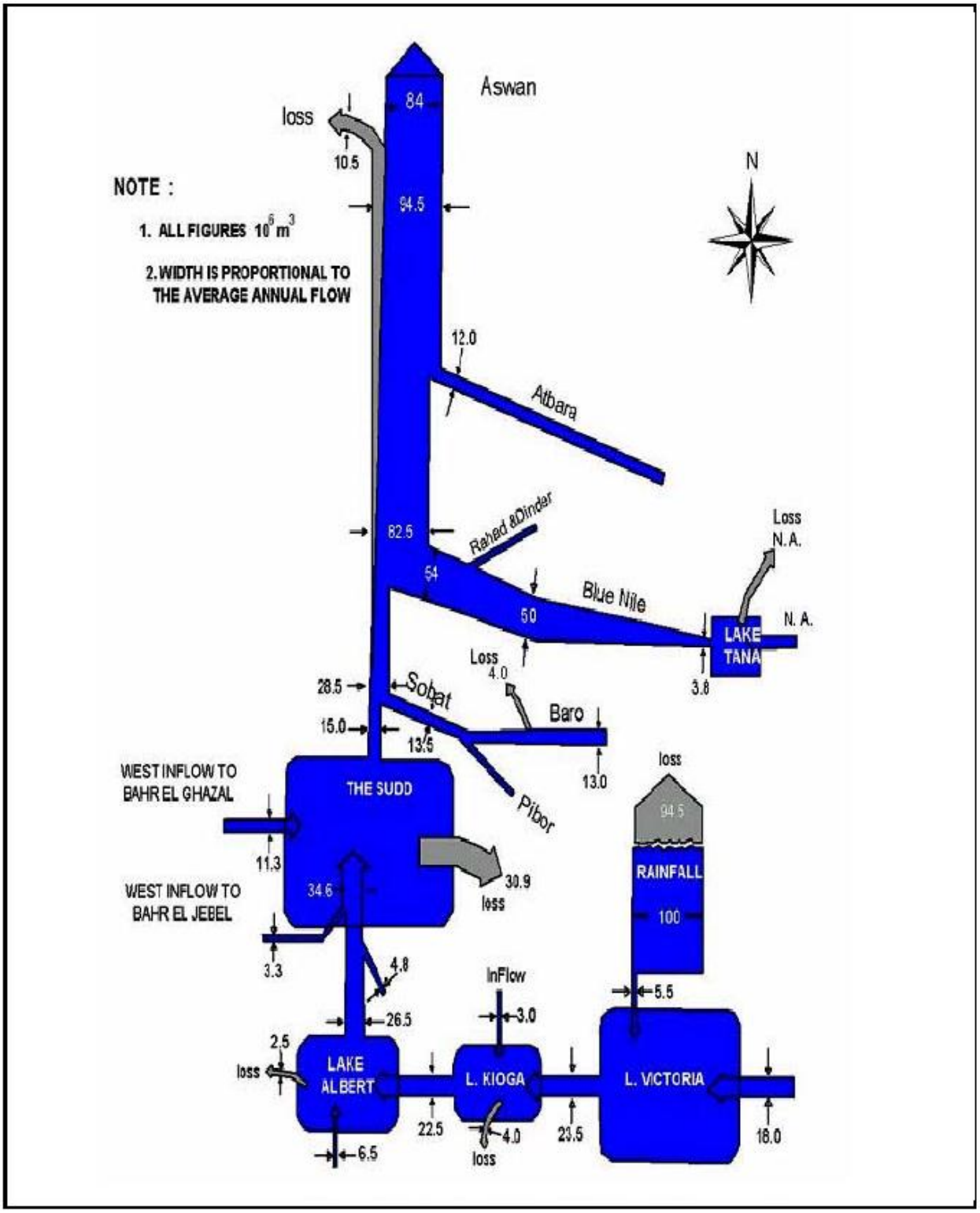

Figure 4.7-2 - Schematic Nile Flows (White and Blue Nile)

4.7.2 DATA BASE

The model used by the Consultant (Module 6) needs the monthly flow data at gauging station and monthly hydraulic data at existing and candidate hydro power plants.

A previous work was undertaken in the Sudanese Long Term Power Plan Study using the RAPSO model (developed by Pr ROBINSON). The Consultant suggests to use data (flow records, seasonal net evaporation) already selected for RAPSO model for its own model. The updates will be taken into account between 2002 and 2006 on the flow data sheets if needed (generally the periods of records are long and do not require to extend exhaustive records until 2006).

The hydraulic constraints and assumptions used in the economic model will be the same as those used by RAPSO model (eg. maximum volume for irrigation in Sudan, regional irrigation demand, commissioning of Jonglei canal).

The table here after summarizes the available data base for flows:

Basin	River gauging station	Actual Record	Type of Data	Compiled Flow Record
Bahr el Jebel	The Torrents between Nimule & Mongalla	1938-1957	Flow	1912-2001
	Mongalla	1912-1982	Flow	1912-2001
	Juba	1948-2000	Water level & flow	
White Nile	Malakal	1912-2001	Water level & flow	
	Jebel Aulia d/s	1992-2001	Water level & flow	
Blue Nile	El Deim	1912-2001	Flow	
	Roseires Dam d/s	1992-2001	Water level & flow	
	Sennar Dam d/s	1992-2001	Water level & flow	
	Dinder river	1912-2001	Flow	
	Rahad river	1912-2001	Flow	
	Khartoum	1992-2001	Flow	
Atbara	Setit river at Elhilew	1966-2001	Flow	1912-2001
	Kubur	1966-2001	Flow	1912-2001
	Showak	1937-67	Stage	
	Old el Girba Gauge	1912-67	Stage	
	Khashm el Girba Dam d/s	1992-2001	Flow	
	Khashm el Girba Dam Inflow	1912-2001	Flow	1912-2001
The Main Nile	Tamaniat	1992-2001	Flow	
	Hassanab	1992-2001	Flow	
	Dongola	1992-2001	Flow	

Table 4.7-1- Hydrologic Data Base

4.7.3 VARIABILITY OF INFLOWS

The following table shows the variability of Nile river and its tributaries (monthly inflows in mm^3)

Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual	
													Mean (Mm^3)	Total (Mm^3x10^3)
Inflows (July 1912 - June 2001)														
The Torrents between Nimule & Mongalla	0	0	0	4	12	13	15	26	22	11	5	1	9	3.3
Bahr el Jebel at Mongalla	81	75	72	76	88	88	93	107	109	106	100	88	91	33.2
White Nile at Malakal Flow	81	64	55	51	55	68	82	93	103	110	110	103	81	29.6
Blue Nile at Roseires/Wad el Aies & el Deim	25	16	12	11	20	57	221	497	407	215	87	44	136	49.7
Dinder River at Hillet Idris & Gwasi	0	0	0	0	0	0	10	32	33	13	2	0	8	2.9
Rahad River at Abu Haraz & el Hawata	0	0	0	0	0	0	4	11	12	7	1	0	3	1.1
Setit River at Elhilew	0	0	0	0	0	4	38	106	54	11	3	1	18	6.6
Atbara River at Kubur	0	0	0	0	0	3	22	62	39	9	2	0	12	4.4
Khashm el Girba Dam Composite Inflow	0	0	0	0	1	6	60	168	93	20	4	1	30	11.0
Calibration flows (July 1992 - June 2001)														
Jebel Aulia Dam Discharge	80	68	69	91	76	62	34	58	76	75	83	83	72	26.3
Roseires Dam Discharge	31	27	26	29	37	85	257	508	346	219	100	50	144	52.6
Sennar Dam Discharge	11	10	14	25	36	70	223	502	337	184	77	25	128	46.8
Blue Nile at Khartoum	23	12	14	37	36	47	151	451	376	203	102	43	127	46.4
Main Nile at Dongola	89	77	67	86	97	93	221	636	654	337	207	123	228	83.3
Main Nile at Hassanab	89	80	75	88	87	97	198	503	453	276	175	111	190	69.4
Main Nile at Tamaniat	91	78	79	106	102	114	210	529	463	281	174	112	198	72.3
Khashm el Girba Dam Discharge	0	0	0	0	1	9	86	190	99	22	3	0	37	13.5

Table 4.7-2 - Nile Monthly Variability

The following hydrographs are illustration of the Nile variability: very strong monthly variability of Blue Nile and low variability of White Nile and a very strong yearly variability of Blue Nile.

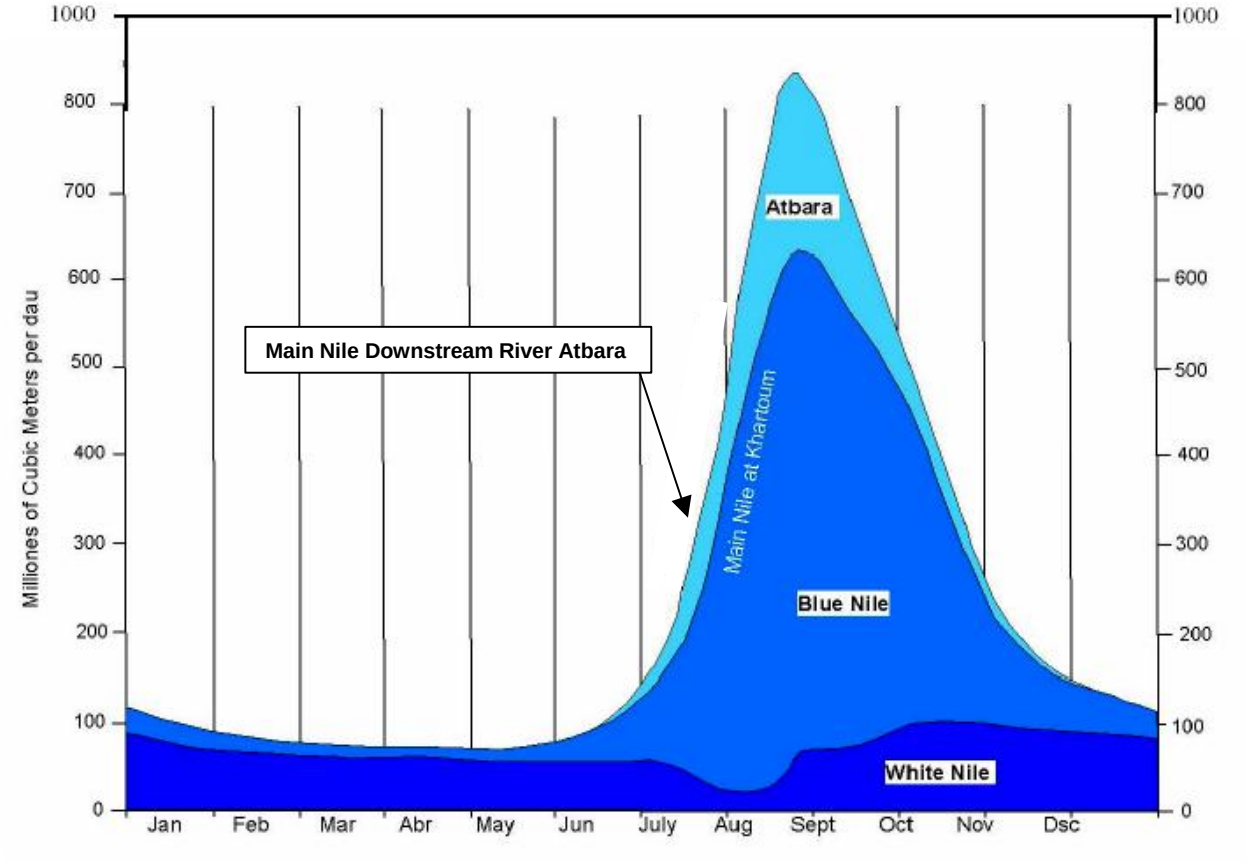

Figure 4.7-3- Hydrograph of the Nile System

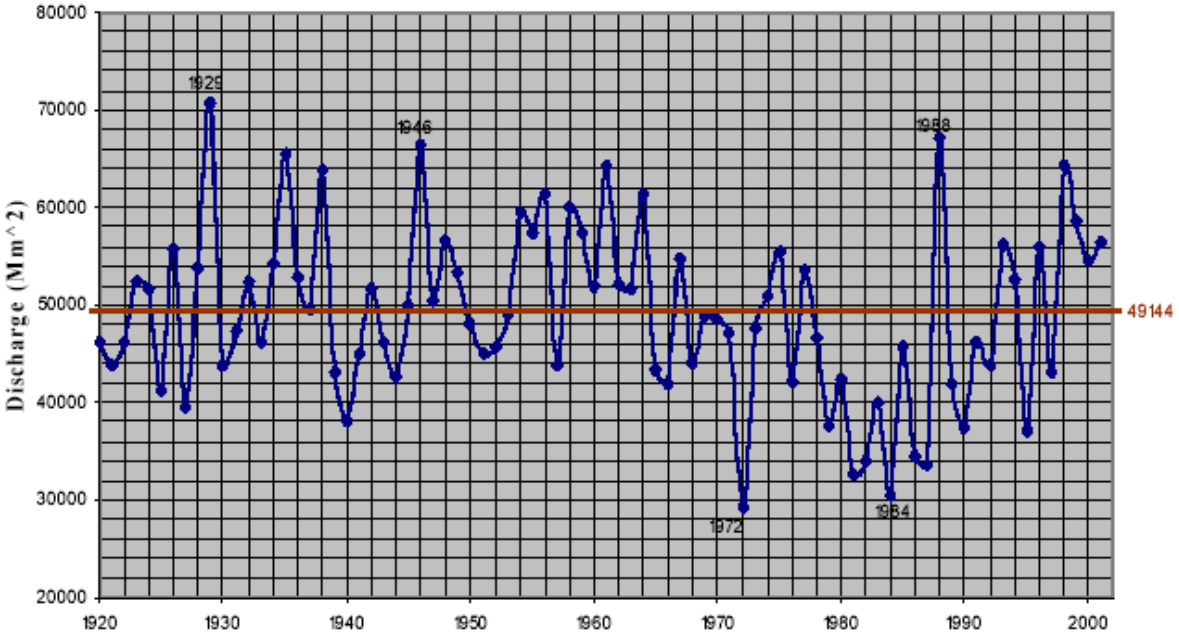

Figure 4.7-4 - Nile Hydrograph (1920 - 2001)

4.7.3.1 Evaporation and sedimentation

The Consultant will use the monthly evaporation losses data available in previous studies (Sudan Long Term Power Plan Study, NEC reports, feasibility studies of new projects and JMP study).

Information concerning the sediment load of the Nile is limited compared with the available water discharge data. The sediment monitoring stations are the following:

- El Deim,
- Wad Alais and Sennar on Blue Nile,
- Gawisi and Hawata on rivers Dinder and Rahad.

Due to the limited measurements, the estimates of sediment load may be subject to a wide range of error.

The sedimentation issue concerns mainly the Blue Nile, the Atbara river and the Main Nile. The reservoir capacity reduction (due to sedimentation) are very well known for Roseires, Sennar and Girba dams.

The Consultant will use the sedimentation data available in previous studies (Sudan Long Term Power Plan Study, NEC reports, feasibility studies of new projects and JMP study).

4.8 OVERVIEW OF THE EXISTING AND COMITTED GENERATION MIX IN THE ISOLATED GRIDS

4.8.1 OVERVIEW

The extent of the existing and committed transmission network which will dictate the extent of the National Grid in Sudan was summarised in the Demand Forecast Report and is discussed in much greater detail in the Transmission Plan report (LTPSPS 2006).

Following the connection of Atbara and Shendi to the National Grid in 2005, there are at the time being 10 states across Sudan that remain isolated from the grid. In these areas the only form of supply is from a handful of isolated diesel generators connected to local networks using distribution voltages (33 kV, 11 kV). The existing and committed generation capacity in each of the 10 isolated states are summarised in the sub-sections below.

4.8.2 RED SEA STATE

Port Sudan is the main city within the Red Sea State and is currently the only port for Sudan. The port handles the export of agricultural products and the import of finished products from other parts of the world. There are also some manufacturing activities. The current development in Port Sudan is mostly around the city, with the port being the focal point of economic activities.

The City is currently served by two diesel power stations (B) and (C). Station (A) is now retired.

- Station B comprises two 775 kW CAT gas oil-fired diesel units with a total available capacity of 900 kW, and two 600 kW units with a total available capacity of 1 000 kW. In 2001, two 1 400 kW units were commissioned in Station B with a total available capacity of 2 000 kW.
- Station C comprises three 6.2 MW Sulzer Diesel-fired units with a total available capacity of 17.1 MW. Three further 2.3 MW units, each with an available capacity of 2.0 MW were commissioned in 2002.

Two 1 MW units have been committed to the town of Tokar and are due to be commissioned in 2006/2007.

Owing to the committed connection to the National Grid in 2007 via a single circuit 200 kV line the existing generation plant is deemed to contribute capacity to the National Grid from 2007 onwards.

4.8.3 NORTHERN STATE

Within the Northern State, NEC supplies four isolated networks in the towns of Karima, Dongola, El Dabba and Wadi Halfa.

- The Karima Power Station consists of two 2.3 MW units (4.0 MW total available capacity) which were commissioned in 1999 and two 2.2 MW units (4.0 MW total available capacity) which were installed in 2000.
- The Dongola power station has an installed capacity of 5.6 MW (4.8 MW available capacity) comprising two 0.6 MW (0.5 MW available capacity) CAT gas oil-fired diesel units installed in 1996, a CAT 1.1 MW (1.0 MW available capacity) gas oil-fired diesel unit installed in 1999.
  In addition a 1.25 MW unit and two 1.0 MW units were installed in Dongola power station in 2001 and 2002 respectively.
- The Wadi Halfa power station has an installed/available capacity of 1.8 MW comprising three 0.6 MW CAT gas oil-fired diesel units installed between 1993 and 1997. Two additional 1.0 MW units are due to be commissioned during 2006/2007.
- The El Dabba Power station was commissioned in August 2006 and consists of two 3 MW Scoda diesel engines.

Two additional 1.0 MW units are due to be commissioned in the town of Al Golid during 2006/2007. Once these have been commissioned, the total installed capacity in Northern State will equal 26.4 MW with a total available capacity of 24.6 MW.

Following the commissioning of Merowe in 2008/2009 and the associated 220 kV transmission network, these towns will also receive supply from the National Grid. The existing and committed diesel power plant are assumed to be available to supply the National Grid from 2009.

4.8.4 NORTH AND SOUTH KORDOFAN STATES

Within the two Kordofan States, NEC currently supplies 3 isolated networks in the towns of El Obeid, Um Ruwaba and Kadogli.

- The El Obeid power station has an installed capacity of 9.5 MW (8.2 MW available capacity) comprising two 3.4 MW (3.2 MW available capacity) units installed in 1987, and one 2.7 MW unit (1.8 MW available capacity) installed in 1984.
- The Um Ruwaba power station has an available capacity of 2.8 MW comprising two 600 kW (500 kW available capacity) CAT gas oil-fired diesel units and two 1 000 kW units (900 kW available capacity).

Two 1.0 MW units are committed for installation in the towns of Dilling, Tendalti and Rahad during 2006/2007. Two 2.0 MW units are also committed for installation in Al Fula and Nahood in 2006/2007 and 2007 respectively.

Once these have been commissioned, the total installed capacity in two Kordofan states will equal 27.7 MW with a total available capacity of 26.0 MW.

Following the completion of the committed 220 kV transmission network extensions into these states these and other towns currently without a supply will also receive supply from the National Grid from 2009. The existing and committed diesel power plant are assumed to be available to supply the National Grid from this year onwards.

4.8.5 SOUTH DARFUR STATE

Within the South Darfur State, NEC supplies two isolated network in the towns of Nayala and Ad Dein .

The Nayala power station has an existing installed capacity of 9.40 MW (8 MW available capacity) comprising two 3.5 MW (6.4 MW available capacity) PC2.5 diesel fired units and two PA6L diesel engines 1.2 MW each (1.8 MW total available capacity) installed in 1986.

Two 1 000 kW units were installed in Ad Dein power station in 2006.

Nayala is one of the three towns in the Dafur region that will receive a substantial increase in generation capacity in the next few years.

Five 7 MW units are due to be commissioned between 2006 and 2010, adding 35 MW to the existing capacity.

Two 1.0 MW are also due to be commissioned in the towns of Buram, Adila and Kass in 2006/2007.

Once all the projects are completed the total available off-grid generation capacity in South Darfur State will equal 49 MW.

Following the completion of the committed transmission network extensions into these states these and other towns currently without a supply will also receive supply from the National Grid from 2010. The existing and committed diesel power plant are assumed to be available to supply the National Grid from this year onwards.

4.8.6 NORTHERN DARFUR STATE

In Northern Darfur State the only town to receive an isolated supply from NEC is the town of El Fasher.

The El Fasher power station has an installed capacity of 9.2 MW (6.4 MW available capacity) three 1.6 MW diesel units (with a total available capacity of 3.9 MW) that were relocated from the former Shendi power station in 2006.

Further generating capacity was commissioned in 2000 comprising two 1.2 MW and two 1.0 MW diesel units.

El Fasher will be the second town to receive a significant increase in generation when an additional 18.4 MW of capacity is installed between 2006 and 2010. This will bring the total available capacity to 24.8 MW by 2010. With the committed extension of the National Grid to the Northern Darfur State planned for 2012, these existing and committed units are made available to serve load on the National Grid from that year onwards.

4.8.7 WESTERN DARFUR STATE

In Western Darfur State the only town which receives an NEC supply is the town of El Geneina.

The existing diesel generator plant at the El Geneina power station is summarised and consists of two 400 kW CAT diesel units (200 kW available capacity each) and one 315 kW CAT engine (200 kW available capacity). Two newer 1 000 kW units were installed in the El Geneina Power Station in 2002. The total installed capacity at El Geneina currently stands at 3.1 MW with an available capacity of 2.4 MW.

El Geneina is the third town which will receive a significant increase in generation when an additional 28 MW of diesel plant is installed between 2006 and 2010. These will consist of units between 4 and 7 MW. The second town of Zalinge will also receive a supply from two 1 MW diesel units which are due to be commissioned during 2006.

Upon completion of these projects the total available capacity will increase to 30.4 MW by 2010.

With the committed extension of the National Grid to the Western Darfur State planned for 2014, these existing and committed units are made available to serve load on the National Grid from that year onwards.

4.8.8 EXISTING GENERATION IN THE SOUTHERN STATES OF SUDAN

In the Southern States in Sudan only three towns receive an isolated supply from NEC. The current generating plant are in Juba, Wau and Malakal.

4.8.8.1 Bahr El Jebel State

Within the Bahr El Jebel State the sole NEC supply is located in the town of Juba. The Juba power station had an installed capacity of 5.0 MW (3.8 MW available capacity) comprising three 1.0 MW MAN diesel fired units which were installed in 1985 with a total available capacity of 2.0 MW. Two 1 000 kW units each with an available capacity of 900 kW were installed in 2002.

4.8.8.2 Bahr El Ghazal State

In the State of Bahr El Gazal NEC supplies one isolated network in the town of Waw. The Waw power station has an installed capacity of 3.6 MW (2.4 MW available capacity) comprising two 800 kW BWSC diesel fired units with an available capacity of 600 kW each which were installed in 1983. Two 1 000 kW units each with an available capacity of 900 kW were also installed in 2002.

4.8.8.3 Upper Nile State

In Upper Nile State NEC supplies one isolated network in the town of Malakal. The Malakal power station has a total installed capacity of 2.6 MW (2.2 MW available capacity) which consists of one 600 kW diesel set with an available capacity of 400 kW. Two 1 000 kW units each with an available capacity of 900 kW which were installed in 2002.

4.8.8.4 Committed generation in the Southern States of Sudan

The NEC Development Plan (Medium Term 2006-2011) confirms that NEC are committed to expanding the very limited supply of electricity into towns in the southern states of Sudan.

The plans consist in commissioning a total of 33 MW across 25 towns in pairs of either 1 MW or 0.5 MW diesel generators. NEC have proposed that over time groups of towns will be linked by sub-transmission voltage networks to form the 6 separate regional sub-grids.

4.8.9 TECHNICAL CHARACTERISTICS - SUMMARY TABLE

The whole technical and economic characteristics of these here before presented existing and committed thermal power plants in the isolated areas are synthesised in the Appendix (See M2 V4 C1 Sudan tables.xls Sheet “Isolated grid”).

4.9 RENEWAL ENERGY

4.9.1 CONTEXT

Sudan relies on traditional fuels for energy use. Of the 9.9 Million ton oil Equivalent (TOE) consumed in 1999, 80% consists of firewood, charcoal, and biomass residues.

Petroleum products represent 17% of commercial energy consumption needs while electricity represents 2.3% of commercial energy consumption.

The Government in its efforts to preserve its natural resources and to combat desertification by alleviating the burden on the forest resources issued a decree prohibiting the use of fuel wood (brick making and bakeries) in Khartoum state (the largest consumer of the firewood).

Being an essential input for development, the availability of energy and the access to electricity in the rural areas are seen as a key for rural development and thus poverty alleviation in Sudan.

The option of rural electrification by conventional electricity through the extension of the electric grid across the rural areas was put aside due to the substantial capital investment cost required to reach these areas characterized by dispersed human settlement.

The government has started by designing policies to encourage public & private sectors to invest in the field of renewable energy technologies. Accordingly, the Ministry of Electricity decided to favour the development of renewable energy.

To identify those renewable energy technologies and their potential contribution to the energy balance in Sudan, the National Energy affairs (NEA) of the Ministry of Electricity, produced a handbook for renewable Energy in Sudan.

The main objective of promoting solar energy is to reduce dependence PV pumps, and also contribute to the expansion and reliability of the small scale irrigated agriculture, and to supply the services institutions in the rural areas (schools, clubs, health care centres, mosques, churches).

In this Section the potential use of non-petroleum or hydro based energy sources for use in electricity generation for both grid connected and isolated areas is reviewed. The 5 possible energy resources are:

- Mini-Hydro;
- Geothermal energy;
- Biomass;
- Solar;
- Wind.

Each of these resources are discussed in the following sub-sections.

4.9.2 MINI HYDRO GENERATION

The Hydro power potential in Sudan amounts to about 3 200 MW out of which about 6% (Roseires, Sennar, and Khasm El Girba) have so far been developed. Due to the great distances from consumption centres, some potential sites particularly in the South are less attractive than large hydro developments in the North.

Hydropower resources are classified into two categories:

a) Large power stations greater than 10 MW,

b) Mini-Hydro stations of capacity less than 10 MW.

The location of potential Mini-Hydropower in Sudan may be summarized below:

1. Gezira, irrigation canal regulators
2. Jebel Mara
3. Southern Sudan
4. Kinetti River

The main objective is to use the water falls in the South for generating electricity by installing mini-hydro projects, to cover the shortages in power supply.

4.9.3 GEOTHERMAL ENERGY

Geothermal power plants can appear to be economically viable alternatives to conventional thermal power stations.

Previous studies have identified the potential for geothermal generation in several areas of Sudan. In making their own assessment of the geothermal potential, Acres reported the following 3 regions as being those of greatest interest:

JEBAL MARRA: Located north of the town of Kas in the South Darfur/Western Darfur region of Sudan this area is thought to have good geothermal potential, but its distance from any major load centre would mean that development of a large scale geothermal power plant in this area would need careful consideration of the required reinforcements to the transmission system.

• **BAYUDA VOLCANIC FIELD:** Located 200 to 350 km north of Khartoum this area is reported to have some potential for geothermal development. Owing to its proximity to Merowe any geothermal project could be connected into the transmission network once this hydro scheme is implemented.

• **RED SEA COASTAL PLAIN:** Durwara and Suakin, south of Port Sudan, show some signs of geothermal potential and may be the most likely future development site.

However, there is insufficient data from which to accurately define the scale and location of any economically recoverable geothermal energy.

With the limited data available at the present time, according to NEC statement, geothermal energy would not form part of the base case generation plan.

4.9.4 ENERGY FROM BIOMASS

The two principal sources of biomass fuel in Sudan are bagasse (the by-product from sugar cane) and cotton plant stalks.

Bagasse

Sugar processing facilities in Sudan are self-sufficient in electrical power and fully use the bagasse energy resource for electricity production to meet the requirements of the industrial process.

The outcome of this activity may only have a marginal impact on the demand supplied by the NEC grid. In addition, as the seasonality of both bagasse production and power demand from the sugar processing plants run in parallel there are no significant periods when either these facilities can export to the grid or when a sustained fuel shortage would require long term imports from NEC.

Cotton stalk waste

A review of the Acres 1993 LTPSPS Study indicates that the use of cotton stalks as an energy source for power generation is unlikely to be economic in the foreseeable future. Previous studies indicate that a better, and more economic use of this fuel would be by using it as a domestic heating fuel in substitution for fuel wood.

4.9.5 SOLAR ENERGY

The Acres 1993 LTPSPS Study reports that Sudan is relatively well endowed with solar energy, but that the costs of exploiting the resource for direct electrical energy production using photovoltaic technology is prohibitive (circa 40 cents per kWh). Alternative uses of solar energy, such as for domestic and industrial water heating, were assumed to be substitutes for primary fuels (oil and gas) as opposed to electricity. Acres concluded that the impact of the exploitation of solar energy on the NEC generation development plan were deemed negligible.

Sudan's average annual intensity of 2 300 kWh/m² offers a potential market for the development of this technology particularly in the off-grid areas. However, until such time as capital costs reduce to a level where they can compete with more conventional power supply options and plants are proven to be commercially viable they have not been considered in the Sudanese Long Term Power Planning Study.

4.9.6 WIND ENERGY

Wind energy exploitation is currently receiving significant global interest as governments and utilities strive to reduce greenhouse gas emissions and reduce reliance on conventional carbon fuels. Wind turbines can be used in remote locations to power water pumps for irrigation, charge batteries for energy storage and can provide a direct source of power to local communities.

The main problem with wind generation is the intermittent nature of supply. Even in relatively 'windy' locations the fluctuations of wind speed and hence power output can vary significantly with time. A report in 2002 by Lahmeyer studied the use of wind energy in four areas of Southern Darfur State. Whilst it concluded that in certain circumstances wind power can provide an alternative to the installation of new isolated diesel units in remote locations, it is not necessarily suitable as the sole provider of electrical power, even in the most favourable wind resource locations.

5. ASSESSMENT OF EXISTING TRANSMISSION SYSTEM

See Long-Term Power System Planning Study – 5 November 2006: Chapter 2 – Existing and Committed Transmission System

This task reviews the existing transmission network in the three countries, focussing on the possible constraints created to the integration of the three power systems.

Existing Transmission System (see Map of Sudanese Grid)

The existing transmission voltage level in Sudan are 66, 110 and 220 kV.

The present system is based on a 830 km double 220 kV circuit backbone from Roseires Dam in the south to Atbara in the north, via Khartoum, along the Nile river. The main load centre (half of the system load), Khartoum, is supplied by a 110 kV double circuit ring, with two 220/110 kV injections (Eid Babiker and Kilo X). A 110 kV single circuit is following the 220 kV backbone from Khartoum to Sennar (with four 220/110 kV injections), with single antennas towards east or west to the major load centres. The 66 kV extends the 110 kV single antenna to the north east of Gedaref (eastern states of Kassala and Gedaref).

There are a total of 32 substations in the system, of which 9 are at 220 kV (2 around Khartoum, Eid Babiker and Kilo X), 22 are at 110 kV (9 around Khartoum), 7 are at 66 kV level. Substation layouts are based on double bus system at the 220 kV and most of the 110 kV stations, while a single bus arrangement in all other stations.

The distribution is equipped with 11 and 33 kV feeders.

The other isolated networks in Sudan, on a distribution level (11 or 33 kV), supplied by local generation, mainly diesel generators.

Committed Transmission Installations

A new voltage level - 500 kV - should be commissioned in 2007-2008, with the first MW turbined in Merowe Dam (1 250 MW). Three 500 kV circuits (one single and one double) will inject Merowe generation on the 220 kV, the first one in Atbara (north extremity of the present 220 kV backbone), the second one on the 220 kV ring around Khartoum (Markhiat and Kabashi).

NEC has a considerable transmission planning over the next couple of years, with over 2 000 km new 220 kV circuits, and the completion of a 220 kV ring around Khartoum.

6. ASSESSMENT OF EXISTING POWER TRADE

At present there is no international power trade in the Eastern Nile region comprising Ethiopia, Eritrea, Sudan and Egypt. This is partly because until today there was no transmission facilities to enable such trade.

The situation will be changing soon with the three interconnection projects (characterized by different stages of development): Ethiopia – Sudan, Ethiopia – Djibouti and Ethiopia – Kenya (see M3 report).

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EASTERN NILE POWER TRADE PROGRAM STUDY

AfDB

MARKET AND POWER TRADE ASSESSMENT

VOL 4 - SUDAN

APPENDIX

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LIST OF APPENDICES

Plant Name	Plant type	Fuel Type	Heat rate	Efficiency (%)	Variable O&M	Intalled capacity (MW)	Net Capacity	F.O.R	P.O.R.	Total availability	Comissioning date	Retirement (*)
			(kJ/kWh)	(%)	($/MWh)	(MW)	(MW)	(%)	days/year	(%)		
Kathoum North ST U1	Steam	HFO	12860	28.0%	0.98	30.0	27.7	5.0%	30	87.2%	1984	2015
Kathoum North ST U2	Steam	HFO	12860	28.0%	0.98	30.0	27.7	5.0%	30	87.2%	1986	2015
Kathoum North ST U3	Steam	HFO	11249	32.0%	0.98	60.0	50.8	5.0%	30	87.2%	1993	2023
Kathoum North ST U4	Steam	HFO	11249	32.0%	0.98	60.0	50.8	5.0%	30	87.2%	1993	2023
Kathoum North GT U1	GT	Gas Oil	15840	22.7%	3.31	20.0	16.8	8.0%	42	81.4%	1992	2010
Kathoum North GT U2	GT	-	-	-	-	-	-	-		-	-	Retired
Kathoum North GT U3	GT	Gas Oil	15840	22.7%	3.31	25.0	16.8	8.0%	42	81.4%	2001	2015
Kathoum North GT U4	GT	Gas Oil	15840	27.3%	3.31	25.0	16.8	8.0%	42	81.4%	2001	2015
Garri 1 CCGT	CCGT	Gas Oil	8800	41.0%	2.21	220.0	164.0	4.7%	30	87.5%	2003	2028
Garri 2 OCGT U5	OCGT	Gas Oil	12000	30.0%	3.31	40.0	28.0	5.0%	25	88.5%	2003	BS(**)
Garri 2 OCGT U6	OCGT	Gas Oil	12000	30.0%	3.31	40.0	28.0	5.0%	25	88.5%	2003	BSP
Garri 2 OCGT U7	OCGT	Gas Oil	12000	30.0%	3.31	40.0	28.0	5.0%	25	88.5%	2003	BSP
El Fau U1	Diesel	HFO	9600	37.5%	2.76	6.6	5.0	7.6%	45	81.0%	2003	2010
El Fau U2	Diesel	HFO	9600	37.5%	2.76	6.6	5.0	7.6%	45	81.0%	2003	2010
Kassala Diesel U1	Diesel	Gas Oil	13200	27.3%	0.18	1.0	0.5	15.0%	15	81.5%	-	2011
Kassala Diesel U2	Diesel	Gas Oil	10120	35.6%	0.18	1.0	0.5	15.0%	15	81.5%	-	2011
Kassala Diesel U3	Diesel	Gas Oil	12496	28.8%	0.18	1.0	0.5	15.0%	15	81.5%	-	2011
Kassala Diesel U4	Diesel	Gas Oil	12936	27.8%	0.18	1.0	0.5	15.0%	15	81.5%	-	2011
Kassala Diesel U5	Diesel	Gas Oil	13200	27.3%	0.15	3.7	2.0	15.0%	21	80.1%	-	2011
Kassala Diesel U6	Diesel	Gas Oil	15730	22.9%	0.24	1.6	1.3	18.0%	15	78.6%	-	2011
Kassala Diesel U7	Diesel	Gas Oil	10120	35.6%	0.24	1.6	1.3	18.0%	15	78.6%	-	2011
Kassala Diesel U8	Diesel	Gas Oil	11088	32.5%	0.24	1.6	1.3	18.0%	15	78.6%	-	2011
Khashm Girba Diesel U1	Diesel	Diesel Oil	10200	35.3%	3.31	2.9	2.0	15.0%	21	80.1%	1984	2010
Khashm Girba Diesel U2	Diesel	Diesel Oil	10200	35.3%	3.31	3.5	2.0	15.0%	21	80.1%	1990	2010
Kuku GT U1	GT	Gas Oil	15300	23.5%	3.31	10.0	9.0	10.0%	28	83.1%	-	2007
Kuku GT U2	GT	Gas Oil	15300	23.5%	3.31	13.4	10.0	10.0%	28	83.1%	-	2008

Note : * reflects the first year that the unit is not available
BSP : beyond the end of the sutudy period (2030)

COMMITTED TPP

Plant Name	Plant type	Fuel Type	Heat rate	Efficiency (%)	Variable O&M	Intalled capacity (MW)	Net Capacity	F.O.R	P.O.R.	Total availability	Comissioning date
Khartoum North ST U5	Steam	HFO	8,400	42.90%	4.28	100	95	5%	40	84.6%	2008
Khartoum North ST U6	Steam	HFO	8,400	42.90%	4.28	100	95	5%	40	84.6%	2008
Garri 2 CCGT M1	CCGT	Gas oil	12,040	29.90%	1.18	-	94.8	3%	30	89.0%	2008
Garri 2 CCGT M2	CCGT	Gas oil	12,040	29.90%	1.18	-	105.6	3%	30	89.0%	2008
Port Sudan ST U1	Steam	Coal	9,500	37.90%	6.59	135	128.5	6%	40	83.7%	2009
Port Sudan ST U2	Steam	Coal	9,500	37.90%	6.59	135	128.5	6%	40	83.7%	2009
Port Sudan ST U3	Steam	Coal	9,500	37.90%	6.59	135	128.5	6%	40	83.7%	2009
Kosti ST U1	Steam	Crude	10,200	35.30%	4.33	125	118.8	5%	40	84.6%	2009
Kosti ST U2	Steam	Crude	10,200	35.30%	4.33	125	118.8	5%	40	84.6%	2009
Kosti ST U3	Steam	Crude	10,200	35.30%	4.33	125	118.8	5%	40	84.6%	2010
Kosti ST U4	Steam	Crude	10,200	35.30%	4.33	125	118.8	5%	40	84.6%	2010
Garri 3 ST U1	Steam	Crude	10,200	35.30%	4.28	135	128.3	5%	40	84.6%	2010
Garri 3 ST U2	Steam	Crude	10,200	35.30%	4.28	135	128.3	5%	40	84.6%	2010
Garri 3 ST U3	Steam	Crude	10,200	35.30%	4.28	135	128.3	5%	40	84.6%	2010
Garri 3 ST U4	Steam	Crude	10,200	35.30%	4.28	135	128.3	5%	40	84.6%	2011
Garri 4 ST U1	Steam	Sponge coal	9,500	37.90%	6.24	50	47.5	6%	50	81.1%	2007
Garri 4 ST U2	Steam	Sponge coal	9,500	37.90%	6.24	50	47.5	6%	50	81.1%	2007
El Bagair ST U1	Steam	Crude	10,200	35.30%	4.28	135	128.3	5%	40	84.6%	2009
El Bagair ST U2	Steam	Crude	10,200	35.30%	4.28	135	128.3	5%	40	84.6%	2009
El Bagair ST U3	Steam	Crude	10,200	35.30%	4.28	135	128.3	5%	40	84.6%	2010
El Bagair ST U4	Steam	Crude	10,200	35.30%	4.28	135	128.3	5%	40	84.6%	2010
Kassala Diesel U1	Diesel	HFO	9,000	40%	3	10	9.6	5%	53	81.2%	2007
Kassala Diesel U2	Diesel	HFO	9,000	40%	3	10	9.6	5%	53	81.2%	2007
Kassala Diesel U3	Diesel	HFO	9,000	40%	3	10	9.6	5%	53	81.2%	2007
Kassala Diesel U4	Diesel	HFO	9,000	40%	3	10	9.6	5%	53	81.2%	2007
Kassala Diesel U5	Diesel	HFO	9,000	40%	3	10	9.6	5%	53	81.2%	2007
Kilo X GT U1	OCGT	Gas oil	12,040	29.9%	1.18	41.2	32.7	2.0%	25	91.3%	2007
Kilo X GT U2	OCGT	Gas oil	12,040	29.9%	1.18	41.2	32.7	2.0%	25	91.3%	2007
Al fula ST U1	Steam	Crude	10,500	34%	4.28	135	128.3	5%	40	84.6%	2009
Al fula ST U2	Steam	Crude	10,500	34%	4.28	135	128.3	5%	40	84.6%	2009
Al fula ST U3	Steam	Crude	10,500	34%	4.28	135	128.3	5%	40	84.6%	2010
Al fula ST U4	Steam	Crude	10,500	34%	4.28	135	128.3	5%	40	84.6%	2010

EXISTING & COMMITTED HPP

	Reservoir	River	Dam completion	live storage hm3	Maximum O.W.L masl	minimum O.W.L masl	Historical data years	Installed capacity MW
Existing	Jebel Aulia	White Nile	1937	3.89	377.4	372.5	1938 - 2005	30.8
	Roseires	Blue Nile	1966	2.12	481.0	467.6	1967 - 2006	280
	Sennar	Blue Nile	1925	0.48	421.7	417.2	1926 - 2006	15
	El Girga Kaplan T	Atbara	1964	0.617	474.0	463.5	1965 - 2006	10.6
	El Girba Pump T	Atbara	1964				1965 - 2006	6.6
Committed	Merowe	Nile	2008					1250

	Hydro Power Plant	River	Unit	Total installed capacity MW	Total net capacity MW	Total maximum discharge m^3/s	Head m	Average energetic rate kWh/m3	Commisioned year years
Existing	Jebel Aulia	White Nile	80	30.8	28	692	1.88 - 5.4	110	2003-2005
	Roseires	Blue Nile	7	280	276.5	1032	33 - 38	130	1971-1989
	Sennar	Blue Nile	2	15	14.3	117	10	26	1962
	El Girba Kaplan T	Atbara	2	10.6	7	14	30	10	2003-2004
	El Girba Pump T	Atbara	3	6.6	4	34	5	36	2003-2004
Committed	Merowe	Main Nile	10	1250		3100			2009
	Sennar extension	Blue Nile	4	65		524			2011
	Roseires heightening with Dinder	Blue Nile	3	415		1538			2012

EXISTING AND COMMITED TPP IN THE ISOLATED GRID

State	Date of interconnection to the main grid	Existing & comitted cities' plants	Installed capacity MW	Available capacity MW	Comissionnig date
Red sea	2007				
		Port Sudan station (B)	5.55	3.9	1998/2001
		Port Sudan station (C)	25.5	23.1	1985/2002
		Tokar	2	2	2006/2007
		Total	**33.05**	**29**	
Northern State	2009				
		Karima	9	8	1999/2000
		Dongola	5.6	4.8	1996/2002
		Wadi Halfa	1.8	1.8	1993/1997
		El dabba	6	6	2006
		Wadi Halfa	2	2	2006/2007
		Al Golid	2	2	2006/2007
		Total	**26.4**	**24.6**	
North & South Kordofan States	2009				
		El Obeid	9.5	8.2	1984/1987
		Um Ruwaba	3.2	2.8	1994/2004
		Kadogli	2	2	2004
		Dilling	2	2	2007
		Tendalti	2	2	2007
		Rahad	2	2	2007
		Al Fula	3	3	2007
		Nahood	4	4	2007
		Total	**27.7**	**26**	
South Darfur State	2010				
		Nayala	9.4	8	1985
		Ad Dein	2	2	2006
		Buram	2	2	2007
		Adila	2	2	2007
		Kass	2	2	2007
		Nayala	35	35	2007/2010
		Total	**52.4**	**51**	
Northern Darfur State	2012				
		El Fasher	9.2	6.4	2000
		El Fasher	18.4	18.4	2006/2010
		Total	**27.6**	**24.8**	
Western Darfur State	2014				
		El Geneina	3.1	2.4	1994/2002
		Zalinge	2	2	2006
		El Geneina	26	26	2006/2010
		Total	**31.1**	**30.4**	
Southern States	???				
- Bahr El Jebel State		Juba	5	3.8	1985/2002
		Juba	7	7	2007
- Bahr el Gazal State		Waw	3.6	2.4	1983/2002
		Waw	9	9	2007
- Upper Nile State		Malakal	2.6	2.2	1995/2002
		Malakal	6	6	2007
- Other southern subgrids		Maribi	6	6	2007
		Kangor	2	2	2007
		Nasir	3	3	2007
		Total	**44.2**	**41.4**	

Map of Sudanese Grid