ENTRO

EASTERN NILE POWER TRADE PROGRAM STUDY

AfDB

MARKET AND POWER TRADE ASSESSMENT

VOL 3 - ETHIOPIA

FINAL MAIN REPORT

30 April 2007

EDF – Generation and Engineering Division
73 373
Le Bourget du Lac Cedex
France
Tel: +33-4-79 60 60 60
Fax: +33-4-79 60 62 35
eMail: pierre.brun@edf.fr
http://www.edf.fr

Scott Wilson
Kanthack House, Station Road,
Ashford, Kent TN 23 1 PP
England
Tel: +44 (0) 1233 658200
Fax: +44 (0) 1233 658209
eMail: alan.bates@scottwilson.com
http://www.scottwilson.com

with participation of:

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

TABLE OF CONTENTS

PHYSICAL UNITS AND CONVERSION FACTORS

bbl	barrel	(1t = 7.3 bbl)
cal	calorie	(1 cal = 4.1868 J)
Gcal	Giga calorie	
GWh	Gigawatt-hour	
h	hour	
km	kilometer	
km^2	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
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

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

1. OVERVIEW

Ethiopia located in the Eastern Africa having a population of about 75 million inhabitants. 16% of the people are urban. The growth rate of population is currently 2.8%.

The economy of the country, one of the poorest in the world, is not in line with its endowed natural resources. These resources include natural gas, coal, geothermal, considerable hydroelectric power potential, very large livestock population and extensive irrigation potential.

Ethiopia has one of the lowest levels of energy consumption per capita in the world at 28 kWh. Access to electricity is considered to be 17% of population at present.

1.1 ETHIOPIA UTILITY

Ethiopian Electric Power Corporation (EEPCO) is responsible for generation, transmission and distribution of the interconnected system (ISC) as well as some isolated or self contained system (SCS). The current trend for development of generation using IPP (Independent Power Producers) which entitles EEPCO to buy generated power at negotiated rates is also encouraged.

1.2 CURRENT GENERATION SUPPLY

The ICS has a total installed capacity of 766,9 MW (end of 2006) including 96,3 MW of Diesel plants at Dire Dawa, Awash, and Kaliti, and a Geothermal plant at Aluto-Langano.

The existing thermal plants in the ICS (end of 2006) are as follows:

ICS Diesel and Geothermal Plants	Installed capacity (MW)	Dependable capacity (MW)
Dire Dawa Diesel	38	30
Awash 7 Kilo Diesel	27	12
Kaliti Diesel	12	6
Others	12	0
Aluto Geothermal*	7,3	0
Total Thermal Power Plant (ICS)	**96,3 MW**	**48 MW**

Table 1.2-1 - Existing Thermal Plants in ICS

The existing hydropower plants in the ICS (end of 2006) are as follows:

Plants	Installed capacity (MW)	Dependable capacity (MW)	Average & firm energy capacity (GWh)
Gilgel Gibe I (in 2004)	192 (with 3 units)	184	840 /620
Maleka Wakana (in 1988)	153	153	550 /450
Finchaa (1973-2003)	134 (with 4 units)	128	640 /615
Tis Abay I (in 1964)	11,4	11,4	80 / 65
Tis Abay II (in 2001)	73	68	280 /145
Koka (in 1960)	43,2	38,4	110 /80
Awash II (in 1966)	32	32	165 /125
Awash III (in 1971)	32	32	165 /125
Total Hydro Power Plant (ICS)	**670,6 MW**	**646,8 MW**	**2.8 / 2.2 TWh**

Table 1.2-2 - Existing Hydropower Plants in the ICS

1.3 COMMITTED PROJECTS

Five hydropower projects are committed by EEPCO in 2006 and under construction: Gilgel Gibe II and Gibe III, Tekeze, Upper Beles and Neshe which main characteristic and commissioning dates are shown in the following table:

Hydro Power Plant **(Commissioning date)**	**Installed capacity (MW)**	**Average energy capacity** **(GWh)**
Gigel Gibe II - 2008	420	1,600
Gibe III – (Phase I : 2011 – Phase II :2012)	1870	6,240
Tekeze - 2008	300	960
Beles - 2009 (w/o Tis Abay I & II)	460 (376)	2,000 (1,630)
Neshe HPP - 2010	97	225
Total new capacity (w/o Tis Abay I & II)	3,147 MW **(3 063 MW)**	11,025 GWh **(10,655 GWh)**

Table 1.3-1 - Committed HPP Projects

1.4 TRANSMISSION SYSTEM

The Ethiopian transmission system consists mainly in 230 and 132 kV lines. The 230 kV network extends from Addis Ababa about 400 km eastward to Dire Dawa, about 300 km southward to Shashemene and about 1000 km northward to Tekeze and Gonder.

Three 230 kV substations supply Addis Ababa, that represents 60% of the total demand.

A 400 kV network will be soon erected to evacuate the generation of Gilgel Gibe II HPP until Addis Ababa.

Ethiopia will be interconnected with Sudan with a 230 kV double circuit line between Gonder and Gedaref in Sudan. The commissioning is expected in year 2008.

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 3 presents the Market and Power Trade assessment in Ethiopia.

3. REVIEW OF THE ELECTRICITY SECTOR IN ETHIOPIA

This review covers the following items:

- Energy Sector Background Information.
- Energy Resource Potential and Balances.
- Economic, Financial and Institutional Setting.
- Dynamics of interactions between the energy sector, the economy, and the environment.
- Energy sector sustainability.
- Status of Private Sector Participation in the Energy Sector.

- Energy Efficiency.
- Crosscutting issues (population, gender, poverty, governance, etc).

3.1 ENERGY SECTOR BACKGROUND INFORMATION

3.1.1 INTRODUCTION

Energy consumption in Ethiopia comprises about 5 to 10% of electricity and hydrocarbon fuels, and 90% of traditional biomass fuels. Most petroleum products are consumed in the transport sector and in view of the low availability of electricity[1], household energy is primarily supplied by biomass fuels (charcoal, firewood, and dung); it is estimated that about 40 million tons of wood and 8 million tons of agro-residue and animal waste are used for fuel annually. Fuel wood use has contributed strongly to environmental degradation and deforestation. The use of crop residues and animal waste for fuel is at the expense of soil fertility and contributes to decreasing farm yields. Although the country has a diversity of energy resources (hydro, geothermal, wind, solar, natural gas and coal), it still relies on imported petroleum products.

The Ethiopia's energy sector could be seen into two parts. These are the "Traditional Energy Sector" which is mainly biomass-based (dominated by fuel wood) and the "Modern Energy Sector", including mainly petroleum derived fuels (Kerosene, Diesel, Gasoline), hydropower, diesel, thermal, coal, solar and wind energies.

3.1.2 TRADITIONAL ENERGY SECTOR

The traditional energy in use is biomass based and the main portion is fuel wood followed by dung agricultural residue, charcoal and bio gas. Traditional energy represents more than 94% of the Energy consumption in the country. As reported by the Ministry of Rural Development in 1999, the consumption of traditional energy amounts to 700 PJ of which 581 PJ is woody biomass (83%).

The critical item in the energy consumption profile is household fuel which is associated with deforestation and subsequent land degradation.

3.1.3 MODERN ENERGY SECTOR

The present Ethiopia's modern energy is constituted of fuel (gasoline, diesel oil, kerosene jet fuel) and renewal energy as hydropower, geothermal, wind and solar. As reported by the Ministry of Rural Development in 1999, the consumption of modern energy amounts to 43 PJ of which 38 PJ is fuel (89%) and 11% is electricity. Access to electricity is considered to be 17% at present (EEPCO Master plan).

Taking into account the development of hydropower schemes in the past 8 years it can be stated that the percentage for electricity could be higher. The development and utilization of these sources is important as no other energy sources present a significant development potential for the country as compared to other sources.

[1] Only some 10 to 15% of the population have access to electricity

In recent years interest in the development and utilization of other sources of modern energy has increased which could be witnessed by Nazaret and Mekelle Wind Power Development Studies, which envisages 80 to 120 MW plants, the study has also identified 11 development sites (as per the information from Ministry of Mines and Energy MME). Development of Aluto-Langano Geothermal power plant as well as investigation of Tendaho site with expected power-generating capacity of 30 MW. The development of Natural Gas will also be considered as a source of modern energy of the country. Each type of modern energy sources and status are described briefly as follows.

3.1.3.1 Modern Energy Sources (Generation)

Hydropower

The hydropower potential so far developed and connected into the national grid is in the order of 2.23% (670.6 MW) of the economically exploitable potential of 45,000 MW (as per the Ethiopian Energy Sector Status and Strategic Plan, MME, 2006). As per EEPCO's master plan study, the potential is 30 000 MW and of June 2006 in the next five years the total installed capacity would be expected to be 3 618 MW. This would bring the total percentage of exploited hydro-generation to 8.04% out of the total potential of 45 000 MW and 12% with the 30 000 MW assumption.

Wind and Solar

The development of wind and solar power has not been significant. As part of the first phase of the wind power development project a study has been carried out around Mekelle and Nazaret with generation capacity in the range of 80 to 120 MW, as per the information from Ministry of Mines and Energy MME. The study has also identified 11 development sites.

At national level many studies have suggested that the integration of wind power is not straightforward due to the difficult to limit power surge caused by the wind speed fluctuations with obvious adverse implications for electrical appliances connected to the system.

Furthermore, the studies (chesen) also have pointed out that the cost of development of wind energy may not be as attractive as hydropower or even geothermal power costs.

As the time of the present study no detailled information regarding the national solar energy potential as well as development status could be retrieved.

Geothermal

The potential for substantial geothermal resources was consequently identified in the geological rift of the country and promising potential were located north of Dubti near Tendaho in the Awash basin, and at the Alutu volcanic center near Lake Langano in the Rift Valley lakes basin. Additional potential fields were also identified west and north of Abaya and Corbetii north of Lake Awassa. The total estimated geothermal resources countrywide (Cesen, 1986) is estimated to be of the order of 700 MW which is much lower than the potential presented in the Energy Policy of Ethiopia 1994 which gave an estimated potential for geothermal of 4 000 MW. The figures are very different depending on the sources. The Consultant can not "choose" the right figure (it is not in the scope of the study).

Natural Gas

In Ethiopia exploration for hydrocarbons including natural gas began some 30 years ago. The sources are expected at Kalub and Hilala gas fields. As per the Energy Policy of Ethiopia 1994 the country's potential for natural gas is estimated to be 2.7 TCF or an equivalent of 75 Billion cubic meters, however as per the information from the Ministry of Mines and Energy the potential is currently estimated as 4 TCF or an equivalent of 112 Billion cubic meters. Out of the total estimated the total potential of Kalub is estimated to be 76 Billion cubic meters.

Coal

As per the information from MME it is estimated that 100 million tons of coal and oil shale exist in Ethiopia. To date there are no record that coal has been exploited for the use of energy. However, there are notable activities being carried out to use the resource safely and efficiently.

Rural Electrification Program

As stated in the EEPCO master plan report 2006, generally the overall rural electrification coverage is very low and service is limited mainly to urban areas. Even where the service is available, supply reliability, quality, and problems of connecting additional customers are evident. In order to alleviate this constraint, electrification of the rural communities is planned to be carried out through extension of the ICS or provision of diesel generators. In future it is planned to use other alternative options as well. This could be through developing local mini hydro schemes, solar PVs supply, wind farms, capacitive coupling substations, extensive overhead ground wire supply systems, and other means suitable for lighting, cooking and motive power application for irrigation and agro-industry.

It was also expected that community load to accumulate many-fold boosting the economic viability of electrification of the rural community. In this respect, with Universal Electricity Access Program being reorganized at a higher level within EEPCO, identification of potential rural areas of load centers and resettlement communities, and updating of the Rural Electrification Master Plan and enhancing the vast expanse implementation capacity in rural electrification are foreseen in the short term.

3.1.3.2 Transmission

The existing transmission system consists of 6 534 km of transmission lines, of which 1 716 km are at 230 kV level, 2 561 km at 132 kV level, 1 782 km at 66 kV and 476 km at the 45 kV levels respectively. The SOR hydro plant supplies an SCS small system at 66 kV while other such systems are supplied from diesel generation plants. There are a total of 107 substations in the system, of which 11 are at 230 kV, 45 at 132 kV, 26 at 66 kV, and 23 at 45 kV level.

Even though, not reported at present EEPCO is carrying out connection of a number of rural load centres with 33 kV line, which is considered as high voltage distribution line. A 400 kV single circuit transmission line from Gilgel Gibe II to a new sub station near Sebeta of 185 km is under construction.

A 400 kV double circuit transmission line from Beles to a new sub station near Bahar Dar followed by a single circuit transmission to Sululta via Debre Markos, with a total length of 495 km, is planned.

Including the above 400 kV lines, the master plan report shows that between the year 2006-2015 the following will be constructed.

Voltage level	Length
66	305 km
132	1845 km
230	3486 km
400	1210 km
Total	**6846 km**

3.2 ENERGY RESOURCE POTENTIAL AND BALANCES

3.2.1 POTENTIAL

At present the exact information on energy resources potential from solar, wind geothermal, natural gas and coal is not available. It is therefore not possible to include the energy balance of the whole system. However the potential as well as the balance specifically for hydro schemes has a better data. The following paragraphs describe the potential and balances of only hydropower schemes.

Most of the related references of Master Plan Studies of the River Basins in the country give an economically exploitable potential of 30 000 MW for hydropower, which is less than the potential stated in the 2006 Sector Status and Strategic Plan of MME, which is 45 000 MW. The Consultant propose to adapt the value of 30 000 MW (used in EEPCO masterplan).

3.2.2 CONSUMPTION AND DEMAND

The 2006 EEPCO Power System Expansion Master Plan Update has made demand forecast based on different scenarios which includes moderate and target scenarios. The forecasted peak demands for year 2030 are 6 814 MW (moderate) and 14 330 MW (target).

Taking into account the potential of 30 000 MW from hydropower alone in order to analyse the balance the demand of neighboring countries need to be assessed.

3.2.3 BALANCE

As it is normally experienced in most of developing countries the future sustainability of fuel wood production and consumption is very limited, while the potential for electricity (mainly hydro-electricity) production is large. For the long term, development of modern fuels and in particularly electricity supply in the rural parts of the country, which is in line with the country's policies, and development of hydropower seem the only viable alternative to an improbable large increase of fuel wood supply.

However, this is feasible only if present energy demand patterns, conditioned by local tradition (cooking habits, in particular) and cash availability, can be substantially modified.

Taking into account the energy potential and demand for hydropower only, if the potential is implemented as planned, the surplus energy could provide an opportunity for export sales with suitable markets in Sudan, Djibouti, Kenya and Somalia to begin with and ultimately to other countries.

Accordingly, due to the abundance of economically exploitable potential of hydropower and due to the fluctuating output of hydropower plants, there is in most years a surplus generation of energy, which makes hydropower an attractive export commodity. Accordingly, new hydropower could be built primarily for export of power to neighbouring countries. Furthermore, the interconnection at regional level is in conformity with Regional infrastructure development cooperation and with the policy of financing institutions like the WB, AfDB, and others who are supporting the financing of such projects. It is also in conformity with the objectives of the New Partnership for Africa's Development (NePAD) strategy.

3.3 ECONOMIC, FINANCIAL AND INSTITUTIONAL SETTING

3.3.1 INSTITUTIONAL ASPECTS

There is a number of stakeholders in the energy sector, however the mains ones include the Ministry of Water Resources, the Ministry of Energy and Mines and the Ethiopian Electric Power Corporation (EEPCO).

The Ministry of Water Resources is entrusted with broad powers of planning, management, use, administration and protection of water resources. Among MoWR's duties are inventory of water resources, study, design and supervision of medium and large Hydropower projects, allocation of water resources, establishing standards for design and construction of waterworks, issuing guidelines and directives for the prevention of pollution of water resources as well as for water quality and health standards, establishing water users' associations, and settlement of disputes

Ethiopian Electric Power Corporation (EEPCO) is responsible for generation, transmission and distribution of the interconnected system (ISC) as well as some isolated or self contained system (SCS). EEPCO is below the ministerial tutelage of the Ministry of Energy and Mines. The current trend for development of generation using IPP (Independent Power Producers) which entitles EEPCO to buy generated power at negotiated rates is also encouraged.

As per the information from the Ministry of Mines and Energy, the role and responsibility of the ministry is as per the Proclamation No. 4/1995. The powers and duties related to energy are:

- Cause the expansion of mines and energy development of the country;
- Collect and maintain a depository of mineral and energy data prepare reports;
- Undertake studies concerning the development and utilization of energy; and promote the growth and expansion of the country's electric supply;
- In cooperation of with the appropriate organs, ensure the availability of gas, petroleum and by-products necessary of the country;
- In cooperation of with the appropriate organs, determine the volume of energy reserves and ensure that same is maintained;
- Establish, as may be necessary, research and training centers that may assist the enhancement of the development of mining and energy.

Regarding, effective utilization of energy resources as well as others the 1995 Constitution of Ethiopia considers major environmental objectives that promote the full participation of all citizens in the management and protection of the environment. Article 92 of the Constitution sets the following environmental objectives:

- Government shall endeavor to ensure that all Ethiopians live in a clean and healthy environment.
- The design and implementation of programs and projects of development shall not damage or destroy the environment.
- People have the right to full consultation and to the expression of views in the planning and implementation of environmental policy and project that affect them directly.
- Government and citizens shall have the duty to protect the environment.

The Constitution gives the Federal Government power to enact laws for the utilization and conservation of land and other natural resources. It also defines the rights and obligations of the Regional States in administration of land and other natural resources. According to the Rural Land Administration Proclamation (89/1997), each Regional Council shall enact a law on land administration, which is in conformity with the provisions on environmental protection and federal land utilization policies. Therefore, both Federal and Regional governmental bodies, as well as local population, have major stake in all the projects that can potentially significantly affect the environment, and in particular those that might result in major changes to the land availability and use.

Inline with this Environmental Policy of the country has been drafted in 1997. The policy is meant for overall comprehensive formulation of cross sectoral and sectoral issues into a policy framework on natural resources and the environment to harmonize these broad directions and guide the sustainable development, use and management of the natural resources and the environment.

3.3.2 FINANCIAL SETTINGS

As per the master plan of EEPCO 2006, the financial requirements for generation and transmission up to the year 2015 is estimated as 3.4 Billion USD. This does not includes the projects for rural electrification, however the major generation projects with their associated transmission costs include Gilgel Gibe II, Beles, Yayu Coal, Gibe III (Phase 1&2), Halele Worabesa, Chemoga Yeda I&II.

An additional USD 970.9 MUSD is also required for transmission and substation for the same period i.e. up to year 2015.

Even though the financial requirements are not available, the Ethiopian Government, through EEPCO, has launched a rural electrification program. The program aims at increasing the current 17% access rate of electricity to 50%. Accordingly, around 7 000 towns are identified. The planning work is not yet completed, therefore all the necessary information are not available. This program assumed 80% of the plan to be covered through grid extension while the remaining 20% through isolated supply system. Accordingly, that plan envisages access to 24 million people by the end of the project. The project has already been started and some villages have been electrified. The fund for the project for five years has been secured from that of Government of Ethiopia, World Bank and AfDB.

3.3.3 Economic Settings

Ethiopia located in the Eastern Africa having a population of about 75 million inhabitants. The economy of the country was not in line with its endowed natural resources. These resources include natural gas, coal, geothermal, considerable hydroelectric power potential, very large livestock population and extensive irrigation potential.

A federal system of Government has been established since 1991 whereby different regions are empowered for self-administration through regional governments that form the Federal Democratic Republic of Ethiopia. In accordance with proclamation No. 7/1991, national governments shall have political and economic powers to play the vital role in the administration of the economy. This set-up has prompted large-scale development momentum.

After 1991 the Ethiopian economy has undergone a successful growth owing to the adopted new economic policies. Currently the government has undertaken various measures to improve the productivity of the agricultural sector. The on-going economic reform is also essentially aimed at redressing previous economic management problems and encouraging the direct participation of private capital and the involvement of regional governments in the administration of the economy for the eventual transformation to a market based financial system.

The center of the economic reform is the Economic Policy included in the long-term and medium to short-term strategies. The long-term strategy aims at rationalizing the role of the state, mobilizing external resources, enhancing private sector participation in the economy, involving the public in the economic management, laying foundation for Agriculture-Development Led Industrialization (ADLI), and export promotion. The short to medium-term strategy aims at introducing stabilization through capacity building and structural adjustment policy measures.

Fiscal Reform measures introduced to stabilize the economy are summarized under prudent fiscal and monetary policies, which include:

- Rationalization of Government expenditure.
- Enhancement of Revenue generation.
- Adjustment of Interest rate.

- Devaluation of the Birr exchange rate.
- A number of sector and specific policy measures taken by the government.

Structural adjustment also made to bring about growth along with laying the foundation for market-based sustainable development. The introduced measures were structural adjustment of the economy, which included:

- Removal of price distortions and restrictions on private sector activities.
- Revision of tariff rates.
- Commercialization and privatization.
- Fiscal and political decentralization.

In line with the reforms, major emphasis has been exerted at this point on agricultural extension, water harvest and resettlement programs. The impact that such undertakings will have is an improvement on the future economic growth of the nation, with consequent increment on the power sector requirements**.** The recently adopted overall 5 years development program is expected to have tremendous impact on the socio economic development of the country with consequent swift demand growth on the power sector.

3.4 DYNAMICS OF INTERACTIONS BETWEEN THE ENERGY SECTOR, THE ECONOMY, AND THE ENVIRONMENT

As described in the previous sections, Ethiopia's economy sharply contrasts with it natural resources. If the energy is developed it will assist exploitation of the natural resources such as steel industry, and establishment of cement factory, which will in turn assist the construction industry, especially real state and others. Furthermore, availability of energy will enhance the agricultural sector towards modernized farming such as pump irrigation which will lead to the improvement living standard of the rural population. Bringing the rural population into the power market will also assist development of new generating facilities.

The above facts are limited towards local development initiatives, however availability of surplus energy is also expected to attract foreign investment, and capital diversion from other countries.

Notwithstanding the development of thermal generation from Natural Gas and Coal as indicated in the country's Power System Planning, both Mid-Term as well as Long-Term Generation Expansion Plans, will focus on the development of hydropower resources in parallel with complimentary renewable energy resources like geothermal and wind.

In the rural settings, agricultural residues such as dung fuel alternatives consequently denying the land the fertilizing effect that could be obtained from the agricultural residues and resulting in diminishing of soil fertility that will then result in lower agricultural productivity. The availability of renewable and environmental friendly energy will transform the rural population from the use of traditional (woody biomass) use into modern energy usage. This will have a significant and clear environmental benefit to the eco system. Needless to say that this is in line with the environmental development initiative of the Kyoto protocol.

3.5 ENERGY SECTOR SUSTAINABILITY

About 94% of Ethiopia's energy supply comes from biomass fuel which is exclusively used for survival. On top of that unsustainable use of the biomass resources has endangered the ecosystem which is manifested in the depletion forest and vegetation reducing agricultural productivity, which in turn induced chronic hunger and poverty in the country. In the past, the energy sector was driven by supply (availability of wood fuel) rather than demand and necessity of development and national welfare.

Recognizing this fact the government has defined an approach of developing and using hydropower to supply people with the energy services that are needed to achieve economic development while ensuring sustainable energy sector growth.

In view of that, the government has put a lot of effort and resources in the electric power sector. As a result the installed capacity of electricity in the country has grown more than twice the amount developed in its past history in last 15 years.

There are still other huge (relatively) pipe line hydropower projects to come in the immediate future. The strategy followed calls for sustainable energy sector development for sustainable development in the nation. Apart from enhancing national growth, the energy sector development focuses on promotion of efficient export market (Energy Sector Strategic Plan, MoME, 2006).

The tools applied to ensure sustainable energy sector development is through using sustainable energy technologies and exploiting renewable resources in particular hydro, solar and other energies as well as indigenous capacity building strategies in all dimensions of the energy sector.

Despite considerable efforts made in the development of modern energy technologies, addressing the traditional energy problem in Ethiopia is inadequate. Still, to date, a great majority of the people rely on traditional sources of energy (wood, agricultural residue, cow dung, etc.) without renewing the resources. Adding to the sustainability issues of resources, the poor pay greater price in terms of monetary, time and labour. Substantial works has been done to improve cooking efficiency of traditional fuel, but lack enforcement and follow up to sustain the effort. The weak point of the efficiency development programme has been in its inability to incorporate other efficiency measures in development, conversion and transport of the resources.

The above trends of supply and demand pattern of the traditional fuel have caused enormous negative consequences on the environment, agricultural productivity and the national economy. Since traditional energy remains to be dominant (in terms of supply magnitude) in the decade to come, sustainability of the sub-sector should be one priority area the government's attention.

Among the things that can guarantee energy sector sustainability more attention is to be devoted to:

1. The development and dissemination of energy technologies by market forces and private initiatives;
2. Improve methodologies of using traditional energy technologies and resources;
3. Devise a strategy to help people to use the energy in parallel with income generating activities;
4. More focus on capacity building and technology transfer;
5. Mobilize national and international private resources for the development of modern energy supply.

3.6 STATUS OF PRIVATE SECTOR PARTICIPATION IN THE ENERGY SECTOR

The Ethiopian government has endorsed rules and regulations allowing development of Hydropower with the private sector. Few investors have shown interest to invest in particular projects. However, to date the participation of the private sector has been minimal. It should be noted that the policy clearly encourage foreign investment.

As per the Ethiopian Energy Sector Status and Strategic Plan, the Investment Code issued in 1996 as proclamation N_O 37/1996 allows the local investors to invest in the production and supply of electrical energy with installed capacity up to 25 MW.

Furthermore, the Sector Status and Strategic Plan also states that the Investment Code issued in 1998 (proclamation No.11/1998) allows foreign investors to invest in the hydro based generation of electricity without capacity limitation.

3.7 ENERGY EFFICIENCY

As per the world energy assessment, at the global level just 37% of primary energy is converted to useful energy meaning that nearly two-thirds is lost. The next 20 years will likely see energy efficiency gains of 23-35% in most industrialized countries and more than 40% in transition economies.

Energy policy has traditionally underestimated the benefits of end-use efficiency for society, the environment, and employment. Achievable levels of economic efficiency depend on a country's industrialization, motorization, electrification, human capital, and policies. But their realization can be slowed by sector and technology specific obstacles including lack of knowledge, legal and administrative obstacles, and the market power of energy industries. Governments and companies should recognize innovations that can lower these obstacles.

To address these and others, the government has initiated an introduction program in using energy efficient house wares, such as baking and cooking stoves. As to the modern energy, no significant step had been taken from all concerned stakeholders.

3.8 CROSSCUTTING ISSUES

3.8.1 POPULATION

The total population of Ethiopia in 2005 is 75 067 000 (CSA, Statistical Abstract, 2006). 84% of the population lives in rural area, engaged in agricultural activities while 16% of the people are urban dwellers (with non-agriculture mainstay). With regard to gender distribution male to female ratio is roughly 1:1.

As per the 1994 CSA, Volume II, Published 1999, the population average growth rate of the country currently is 2.62% per annum. The rural population grows at 2.35% while urban growth rate reaches 4.06% per year.

The average income per capita of the country is estimated to be around 90 USD per year. A large number of people live under persistent poverty.

Due to lack of modern forms of energy and their high cost relative to the low average income per capita, 94% of the country's population rely on biomass energy such as wood, agricultural residue, and animal dung for cooking, heating and (in most cases) for lighting. This high consumption of biomass energy has led to the depletion of forests, shortages of fuel-wood, and degradation of rural ecosystems.

In most parts of the country wood consumption levels have been greater than annual forest resources yields. This, combined with an annual high population growth rate imposes immense pressure on the forest resources.

Ethiopia has one of the lowest levels of energy consumption per capita in the world, which is 28 kWh. Only about 17 % of the population has access to electricity. Electric supply is under the Ethiopian Electric Power Corporation (EEPCo). The state owned company currently provides electricity to over 777 007 customers in approximately 632 towns and communities in Ethiopia, which is only a small proportion of the country's over 75 million inhabitants.

The Ethiopian energy policy puts a great deal of emphasis on prioritising the expansion, development and utilization of hydro power with a strategy of building national capacity in engineering, construction, operation, and maintenance and gradually enhance local manufacturing capability of electrical equipment and appliances.

At the moment the critical and challenging issue in the power sector is low access of the population to electricity, low level of installed national capacity to connect a desired number of commercial and industrial customers and high investment required by the sector.

Even though there are huge challenges in the development of power sector, there are other advantages that warrant favourable electricity market in Ethiopia due to large population size and investment opportunities available in the country.

3.8.2 GENDER

The status of power and water supply in the country is poor and backward requiring substantial time and energy inputs on the part of women. All the tasks of fetching water and collection of fuel wood are the burden of women, which consumes a significant part of the calorie intake. Furthermore, the same women and girls spend considerable amounts of time and effort manually processing-threshing or grinding staple foods before they can be cooked and eaten. Because of these demands on their time, women and young girls are denied opportunities for other more productive activities such as employment and education, not to mention much needed time for rest. They also suffer considerable damage to their health by having to cook indoors on poorly vented stoves and low-quality fuels. In general access to electric power or modern energy to the rural population will alleviate burden of women and will provide an opportunity in having the followings:

- Access to clean water at reasonable fetching distance.
- Access to the media, which defiantly help in awareness creation regarding HIV AIDS and family planning.
- Access to clean air during cooking.
- Sufficient time for child care.
- Access to education .

3.8.3 POVERTY

Poverty is a global challenge and its alleviation is at the heart of MDG 1-Eradicating Extreme Poverty and Hunger. Energy Services are necessary for creating the conditions for economic growth and improving social equality. Modern energy services help to boost the followings:

- Drive economic growth by improving productivity and enabling local income generation through improved agricultural development and non-farm employment.
- Household income by providing lighting that extends livelihood activates beyond daylight hours.
- Additional opportunities for employment to diversify farmer's income sources instead of having a single and risky agricultural livelihood.

In line with poverty reduction program and with the objective of increasing the low level of electricity access and thereby assist the socio-economic development of the rural population, the Ethiopian Government, through EEPCO has launched a rural electrification program. The program aims at increasing the current 17% access rate to 50% which includes an estimated 7 000 towns.

3.8.4 GOVERNANCE

Economic growth and social development in Ethiopia has been constrained by the lack of adequate, efficient supplies of modern energy. The energy sector in the country is characterized by supply and consumption of large quantities of biomass fuel (about 94% of the total consumption) that are meant for survival rather than improvement of the quality of life of the people.

The modern energy sector on the other hand is dominated by the state owned monopoly utility and so far is unable to grip the participation of the private enterprises.

In order to improve governance of the energy sector the government of Ethiopia has already restructured the sector into regulatory and operating entities of the major institutions involved in the energy development. This is intended to create business friendly environment.

Development of local capacities and legal and policy environment has been the concern of the government in the past decades. Hence the Energy Policy and reform of regulatory bodies to ensure good governance of the sector is the first step undertaken by the government in line with the reformation effort made by the country.

In addition to that the government has instituted organizations that will help fight corruption at federal and regional levels. Within each institution in the country a unit has been created to oversee mismanagement and misconduct as part of civil service reform and good governance launched.

The necessary conditions for good governance are in place. However, in order to be able to create the business environment that will attract the investment required for the development and enhance economic growth of the nation, the following points need special attention:

1. Development of manpower and institutional capacities of the energy sector;
2. Adoption of best practices and standards by the institutions of the sector;
3. Legal framework to attract sufficient investment from local and foreign sources;

4. Revisit of the legal, fiscal and regulatory frame work in order to create competitive, free and open market;
5. Mobilization and encouragement of local private sector resources;
6. Creation of public awareness to ensure utilization of the resources efficiently.

4. ASSESSMENT OF THE EXISTING GENERATION MIX OF ETHIOPIA

4.1 INTRODUCTION

This section of the report is based on a review of numerous documents obtained from MoWR and EEPCO concerning the existing, committed and candidate power plants described in the Ethiopian Power System Expansion Master Plan Update (EPSEMPU) of June 2006. It summarizes the status of existing and committed power plants of the generation system as given in the EPSEMPU.

A brief description is given of each existing or committed power plant with the main parameters (cost and performance characteristics), and of liquid fuels available in the country (price projections in 2015) for thermal generation.

In line with the large hydro potential of Ethiopia, the main characteristic of the Ethiopian power generation mix is the large part of hydro generation which account for 90% of the dependable capacity (647 MW out of 726 MW). The 647 MW is dependable system form hydropower plant while 726 MW is total system dependable capacity that is hydropower, diesel and geothermal.

4.2 EXISTING THERMAL PLANTS

4.2.1 EXISTING THERMAL PLANTS

By the end of 2006, the ICS has a total thermal installed capacity of 84 MW composed of:

- Diesel plants at Dire Dawa, Awash, and Kaliti. EEPCO used these plants only in emergency situation.
- A geothermal plant at Aluto-Langano. Currently under refurbishment due to technical problems, the Aluto geothermal plant should be available again in 2007.

The capacities of the existing thermal power plants are shown below. The dependable capacity is reduced due to the de-rating of nominal installed capacities.

ICS Diesel and Geothermal Plants	Installed capacity (MW)	Dependable capacity (MW)
ICS Diesel and Geothermal Plants	**Installed capacity (MW)**	**Dependable capacity (MW)**
Dire Dawa Diesel	38	30
Awash 7 Kilo Diesel	27	12
Kaliti Diesel	12	6
Others	12	0
Aluto Geothermal*	7,3	0
Total Thermal Power Plant (ICS)	**96,3 MW**	**48 MW**

Table 4.2-1 - Existing thermal plants in the ICS (end of 2006)

4.2.2 FUEL PRICES

Petroleum fuels are imported into Ethiopia through the port of Djibouti (or the port of Asab in Eritrea) and transported by road to main centres in the country for electricity production. The nearest source of petroleum fuels available in Ethiopia is the Arabian Gulf. The cost of the fuel delivered to the thermal plants was obtained by adding to the international price, the costs of port handling, local delivery and transport by road in Ethiopia.

At the present time there is no infrastructure in Ethiopia to transport the low cost heavier fuel oil (HFO) and it has therefore been assumed that two types of fuels could be used at present:

- Industrial Diesel Oil (IDO) for Combustion Turbines (CT) and Combined cycles (CC).

- Light Residual Fuel Oil (LRFO) for medium speed Diesel.

In 2006, the gas-oil price was 5.4Birr/liter delivered by road to Addis Ababa and 5.2Birr/liter to Dire Dawa.

The road distance between the port of Djibouti and Dire Dawa is 310 km (530 km to Awash and 830 km to Addis Ababa).

For EEPCO, the 2006 fuel price delivered to Dire Dawa from Djibouti was:

- AGO: 5.21 Birr/liter
- HFO: 3.88 Birr/liter
- LFO: 3.96 Birr/liter

The price projections for IDO and LRFO to Dire Dawa in 2015 (2006 US dollars) are as follows according to the three average crude oil price scenarios (high, low and medium) given in Module 3 Vol 5 report (identical to the Annual Energy Outlook 2007 projections).

IDO	Crude oil price	Dire Dawa	Awash	Addis Ababa
Low scenario	35 $/bbl	9,4 $/GJ		
Reference	50 $/bbl	12,7 $/GJ	*+0.5 $/GJ*	*+1.2 $/GJ*
High scenario	80 $/bbl	19,1 $/GJ		

Table 4.2-2 - IDO price in 2015 (2006 US dollars)

LRFO	Crude oil price	Dire Dawa	Awash	Addis Ababa
Low scenario	35 $/bbl	6,3 $/GJ		
Reference (medium)	50 $/bbl	8,1 $/GJ	*+0,6 $/GJ*	*+1,5 $/GJ*
High scenario	80 $/bbl	11,9 $/GJ		

Table 4.2-3 - LRFO price in 2015 (2006 US dollars)

4.3 EXISTING AND COMMITED HYDRO GENERATION PLANTS

4.3.1 DEFINITION OF AVERAGE AND FIRM ENERGY

In this section the Consultant uses the same definition for average and firm energy as in the EPSEMPU:

- the average energy of an hydro plant is the average energy generated by the plant over the 37-year hydrological reference period used in the EPSEMPU,

- the firm energy of an hydro plant is the energy generated by the plant with a probability of 36 / 37, i.e. 97.3%.

4.3.2 EXISTING HYDROPOWER PLANTS

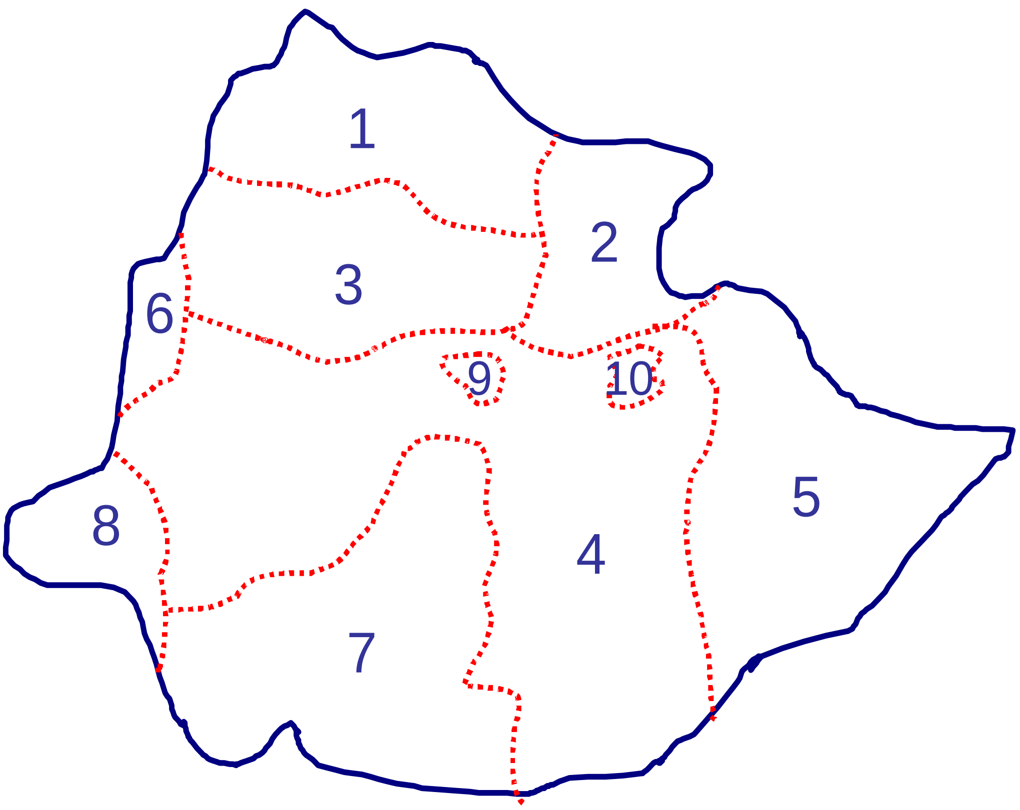
In 2006, the Ethiopian Interconnected System (ICS), consists of:

- three cascade plants on the Awash River: Koka, Awash II and Awash III,
- additional plants at Finchaa on the Finchaa river,
- Maleka Wakana plant on the Wabi river,
- Gilgel Gibe I on the Gibe river,
- the small Tis Abay I and Tis Abay II power plants, both of which are on the Blue Nile River.

Descriptions of the existing hydro power plants are shown below.

Plants	Installed capacity (MW)	Dependable capacity (MW)	Average & firm energy capacity (GWh)
Gilgel Gibe I (in 2004)	192 (with 3 units)	184	840 /620
Maleka Wakana (in 1988)	153	153	550 /450
Finchaa (1973-2003)	134 (with 4 units)	128	640 /615
Tis Abay I (in 1964)	11,4	11,4	80 / 65
Tis Abay II (in 2001)	73	68	280 /145
Koka (in 1960)	43,2	38,4	110 /80
Awash II (in 1966)	32	32	165 /125
Awash III (in 1971)	32	32	165 /125
Total Hydro Power Plant (ICS)	**670,6 MW**	**646,8 MW**	**2.8 / 2.2 TWh**

Table 4.3-1 - Existing hydropower plants in the ICS (end of 2006)



REGIONS:

1. TIGRAY
2. AFAR
3. AMHARA
4. OROMIA
5. SOMALI
6. BENISHANGUL-GUMEZ
7. SOUTH ETHIOPIAN NATIONS & NATIONALITIES
8. GAMBELA
9. ADDIS ABABA
10. HARARI

Table 4.3-2 - Map of Ethiopian regions

4.3.2.1 Koka, Awash II and Awash III (107 MW)

The Koka hydropower plant (in operation since 1960) is located on Awash river approximately 75km south east of Addis Ababa. It was the first major hydroelectric development in the country, as well as the first of three hydro power stations constructed on the Awash river.

The 24 meter high concrete dam originally impounded some 1 680 hm^3 of live storage, slightly more than the mean annual runoff to the reservoir. The dam provides a gross generating head of 42 m for the station, which has three similar units for a total installed capacity of **43.2 MW**. The power station rated flow is 126 m^3/s.

The Awash II and III hydropower plants (in operation since 1966 and 1971) lie in series downstream from Koka and both have installed capacities of **32 MW**, with rated heads of 59.8 m and rated flows of 63 m^3/s. The full supply level (FSL) and low supply level (LSL) for Koka reservoir are 1 590.7m and 1 583.7m, respectively.

A detailed survey of the Koka reservoir was undertaken in 1999 and the updated live storage is 1 033 hm^3.

4.3.2.2 Finchaa/Amerti (134 MW)

The Finchaa/Amerti multi-basin development (in operation since 1973 - 2003) is located in the Blue Nile Basin (Oromia region), some 160 km north west of Addis Ababa, consisting of a storage dam on the Finchaa river with a power plant comprising four 33.5 MW units.

The plant has a gross head of 594 m with a live storage of 788 km^3, which provides the regulation of the inflow. FSL and LSL are 2 219 m and 2 216 m, respectively.

The installed capacity of the plant is **134 MW** and the rated flow is 28.0 m^3/s.

Finchaa–Amerti HPP	**Main Features**
River basin	Abay river
Finchaa Dam	
River	Finchaa
Catchment area	345 km^2
Mean natural inflow	13.6 m^3/s (427 hm^3)
Reservoir FSL	2 219 m
	2 216 m
Total reservoir storage	1 120 hm^3
Active reservoir storage	788 hm^3
Reservoir surface area at FSL	345 km^2
Amerti Dam	
River	Amerti
Catchment area	km^2
Mean natural inflow	4.5 m^3/s (142 hm^3)
Reservoir FSL	2 234 m
	2 232 m
Total reservoir storage	107 hm^3
Active reservoir storage	70 hm^3
Reservoir surface area at FSL	22.8 km^2
Rated head	576 m
Rated total flow	28 m^3/s
Total installed capacity	**134 MW**
Number of units	4
Firm energy	540 GWh/year
Average energy	630 GWh/year

Table 4.3-3 - Finchaa-Amerti HPP - Summary of project characteristics

4.3.2.3 Melka Wakana (153 MW)

The Melka Wakana hydropower plant (in operation since 1988) has a total installed capacity of **153** MW with four identical units of 38,25 MW each. The project is located on the Wabe-Shebelle River, some 150 km south of the Koka-Awash power stations. The 37 m high dam impounds a live storage of 782 hm^3 between FSL of 2 521m and a LSL of 2 508 m. The mean annual inflow is 759 hm^3, indicating a high degree of regulation.

Q max at max head : 14.5m^3/s

Q max at Nominal head :14.73 m^3 /s

Q max at Minimum head : 14.9 m^3 /s

4.3.2.4 Tis Abay I and Tis Abay II (84 MW)

The two Tis Abay hydropower plants are located on the Abay river (also known as Blue Nile river) some 35 km downstream of the Tana Lake (Amhara region).

The Tis Abay I HPP (in operation since 1964) is a small plant currently rehabilitated to a capacity of **11,4 MW** (in operation since 1964). The rated head and flow are 46 m and 29 m^3/s, respectively.

Adjacent to Tis Abay I is Tis Abay II, a two-unit power plant with an installed capacity of **73 MW** (in operation since 2001). The rated head for Tis Abay II is 53 m, and its rated flow is 150 m^3/s. The two plants share a common power canal, although their intakes and tailraces are in different locations.

With the construction of the Chara Chara weir, the level of Lake Tana will be raised by 3 m, increasing the full supply level from 1 784 m to 1 787 m. This yields a live storage (Tana lake) of 9 130 hm^3.

A minimum discharge (about 17 m^3/s) has been allocated to the 45 m-high Tis Isat waterfalls to sustain their visual attraction, so that they continue to be one of the major hubs of development for regional tourism.

After commissioning of the Beles HPP under construction, the two plants would be on standby (or in emergency).

Tis Abay II HPP	Main Features
River basin	Abay
River	Abay
Catchment area	16 300 km^2
Mean natural inflow (annual)	116 m^3/s (3 600 hm^3)
Reservoir FSL	1 787m
Active reservoir storage (Tana lake)	9 130 hm^3
Rated head	53 m
Rated total flow	150 m^3/s
Total installed capacity	**73 MW**
Number of units	2
Firm energy	230 GWh/year
Average energy	280 GWh/year
Plant factor	45%

Table 4.3-4 - Tis Abay II HPP - Summary of project characteristics

4.3.2.5 Gilgel Gibe I (192 MW)

The Gilgel Gibe I hydroelectric project is the largest plant in the system at present.

The Gilgel Gibe river is a tributary of the Omo river or Great Gibe river.

The powerhouse on the Great Gibe River comprises three units (Francis turbine) with an installed capacity of **192 MW** and a rated flow of 101.5 m^3/s. The associated reservoir has a live storage of 657 hm^3 between the minimum and maximum operating levels of 1 653 m and 1671 m respectively. The reservoir was created by the construction of a 40 m high rock-fill dam with asphalt facing.

The average production for the Gilgel Gibe I HPP with a total installed capacity of **420 MW** is estimated at about **700 GWh/year.**

Gilgel Gibe I HPP	Main Features
River basin	Omo Gibe
River	Gilgel Gibe
Catchment area	4,225 km^2
Mean natural inflow (annual)	50.4m^3/s (1 590 hm^3)
Reservoir FSL	1 671 m
Reservoir MOL	1 653 m
Total reservoir storage	839 hm^3
Active reservoir storage	657 hm^3
Reservoir surface area at FSL	- km^2
Rated head	223 m
Rated total flow	101.5 m^3/s
Total installed capacity	**192 MW**
Number of units	3
Firm energy	635 GWh/year
Average energy	725 GWh/year
Plant factor	45%

Table 4.3-5 - Gilgel Gibe I HPP - Summary of project characteristics

4.3.3 COMMITTED AND UNDER CONSTRUCTION HYDROPOWER PROJECTS IN 2006

Five hydropower projects are committed by EEPCO in 2006 (under construction or financed): Gilgel Gibe II and Gibe III, Tekeze, Upper Beles and Neshe.

Hydro Power Plant (Commissioning date)	Installed capacity (MW)	Average energy capacity (GWh)
Gigel Gibe II - 2008	420	1,600
Gibe III - 2012	1870	6,240
Tekeze - 2008	300	960
Beles - 2009 (w/o Tis Abay I & II)	460 (376)	2,000 (1,630)
Neshe HPP - 2010	97	225
Total new capacity (w/o Tis Abay I & II)	3,147 MW **(3 063 MW)**	11,025 GWh **(10,655 GWh)**

Table 4.3-6 - Hydro Power Plants under construction in the ICS (end of 2006)

In 2009, the total installed capacity of the Ethiopian ICS will be about **1 770 MW** in hydro generation.

It could be noted that Halele-Worabesa and Chemoga-Yeda HPP are identified in the "medium term requirement" of the EPSMEPU for the period 2009-2015.

4.3.3.1 Tekeze hydropower (300 MW)

The river Tekeze is situated in the north west of Ethiopia and the main tributary of the river Atbara (tributary of the Nile). The Tekeze HPP project is located in the Tekeze gorge (Simeous Mountains) and in the Tigray region.

The Tekeze HPP, studied to feasibility level in 1997 (Howard Humphreys & Partners) is designed to contain four units, each with a 75 MW capacity, giving an installed capacity of **300 MW** for the plant.

A 175 m-high concrete arch dam will provide some 5 300 hm^3 of live storage operating between LSL and FSL of 1 096 m and 1140 m respectively. As the annual average inflow is about 3 790 hm^3, the degree of regulation is high (inter-annual storage). The design net head is 155 m, and the rated flow is 165 m^3/s.

The project, which is now under construction, is scheduled for operation in **2008.** The reservoir inflows were estimated in the project's feasibility study using a variety of sources of information.

Tekeze HPP	Main Features
River basin	Tekeze
River	Tekeze
Catchment area	30 390 km^2
Mean natural inflow	119 m^3/s (3 750 hm^3)
Reservoir FSL	1140 m
Reservoir MOL	1,096 m
Total reservoir storage	9 293 hm^3
Active reservoir storage	5 293 hm^3
Reservoir surface area at FSL	147 hm^2
Rated head (max)	154 m
Rated total flow	116 m^3/s
Total installed capacity	**300 MW**
Dependable Capacity	186 MW
Number of units	4
Firm energy	981 GWh/year
Average energy	1 200 GWh/year
Plant factor	40 %
Project costs (2004)	**$447 M**
including Transmission	($42.3 M)
Construction period	5 years
Commissioning date	2008
Generation cost (Economic)	$60 /MWh

Table 4.3-7 - Tekeze HPP characteristics

The firm production for the Tekeze HPP with a total installed capacity of **300 MW** is estimated at about **981 GWh/year** for a total cost of **$447 M** (**$1,500 per kW** of installed capacity).

Note: the filling time of the reservoir is expected to be between 3 and 4 years.

4.3.3.2 Gilgel Gibe II (420 MW)

The Gilgel Gibe II hydropower project will comprise four units (Pelton turbine) with a total installed capacity of **420 MW**. The rated flow is 101.5 m^3/s with a 470 m design head.

The Gilgel Gibe is a tributary of the Omo River (Great Gibe river).

It lies in series downstream from Gilgel Gibe I under completion. This high capacity plant collects its flow to the powerhouse via a 25 km tunnel, which is now under construction (Salini Costruttori Spa).

The project is scheduled for operation in **2008.**

The average production for the Gilgel Gibe II HPP with a total installed capacity of **420 MW** will be **1,625 GWh/year** for a total cost of **$380 M** (**$900 per kW** of installed capacity).

Gilgel Gibe II HPP	Main Features
River basin	Omo Gibe
River	Gilgel Gibe
Catchment area	4304 km^2
Mean natural inflow	50.5 m^3/s (1590 hm^3)
Reservoir FSL	1431m
Total reservoir storage	0 hm^3
Active reservoir storage	0 hm^3
Reservoir surface area at FSL	0 km^2
Rated head	470m
Rated total flow	101.5 m^3/s
Total installed capacity	**420 MW**
Number of units	4
Firm energy	1 430 GWh/year
Average energy	1 625 GWh/year
Plant factor	44%
Project costs (2004)	**$500 M**
Including "Transmission"	$50 M
Construction period	4 years
Commissioning date	2008
Generation cost (Economic)	$50 /MWh

Table 4.3-8 - Gilgel Gibe II HPP - Summary of project characteristics

4.3.3.3 Gibe III (1870 MW)

The Gibe III hydropower project will comprise ten units with an installed capacity of **1,870 MW** and a rated flow of 950 m^3/s. A 240 m high double curvature arch dam will provide some 10 km^3 of live storage with a gross head of 207 m. The minimum and maximum operating levels are 800 m and 892 m respectively.

Gibe III HPP is currently under construction after a feasibility study and design preparation by Salini. Gibe III phase 1 is expected to be commissioned by 2011, while phase 2 is expected for 2012.

Gilgel Gibe III HPP	**Main Features**
River basin	Omo Gibe
River	Omo
Catchment area	34,159 km^2
Mean natural inflow	438.2 m^3/s (13,800 hm^3)
Reservoir FSL	889 m
Reservoir MOL	853 m
Total reservoir storage	17,000 hm^3
Active reservoir storage	10,000 hm^3
Reservoir surface area at FSL	- km^2
Rated head (Design)	211 m
Rated total flow (Design)	950 m^3/s
Total installed capacity	**1,870 MW**
Number of units	
Firm energy	5,300 GWh/year (1,320 MW)
Average energy (Basic design)	6,240 GWh/year
Plant factor	39%
Project costs (2006)	**€1,435 M** ($1,850 M)
w/o Transmission	
Construction period	6/7 years
Commissioning date	Phase I : 2011- Phase II : 2012
Generation cost (Economic)	$55 /MWh

Table 4.3-9 - Gibe III HPP - Summary of project characteristics

4.3.3.4 Beles HPP (460 MW)

The Beles hydropower project is located southwest of Lake Tana.

The Beles HPP project was studied to feasibility level by the consultant Lahmeyer International in August 2000, for an installed capacity of 220 MW. The project would divert flow from Lake Tana to the upper reaches of the Beles river and the diverted flow would serve for irrigation purposes as well as for power generation. The project reduces flows to the existing Tis Abay plants.

In January 2006, Salini Costruttori Spa proposed a new design with an underground powerhouse of four units (40 m^3/s) and a total installed capacity of **460 MW.** The project is now under construction by Salini since September 2006 (it is scheduled for operation in March 2009).

The average diversion flow is 85 m^3/s to the Upper Beles river, with a minimum compensation flow of 17 m^3/s and periodic excess flow releases to the Isat waterfalls and the Abay river "Blue Nile river". The net average production for the Beles HPP with a net total installed capacity of 376 MW will be 1,630 GWh/year for a total cost of $500 M ($1,300 per kW of installed capacity).

Beles HPP - Summary of project characteristics:

Beles HPP	**Main features**
River basin	Abay
River	Upper Beles
Catchment area	15,320 km^2
Mean natural inflow	175 m^3/s
Reservoir FSL	1,787 m
Reservoir MOL	1,784 m
Total reservoir storage	32,273 hm^3
Active reservoir storage	9,126 hm^3
Reservoir surface area at FSL	3,130 km^2
Rated head	315 m
Rated total flow	160 m^3/s
Total installed capacity / (Tis Abay I & II)	**460 MW /** (- 84 MW)
Number of units	4
Average energy	2,000 GWh/year
(Tis Abay I & II)	(- 370 GWh/year)
Plant factor	50%
Project costs (2004)	**$500 M**
Excluding Transmission line	
Construction period	From 3 to 4 years
Commissioning date	2009
Generation cost (Economic)	$50 /MWh

Table 4.3-9 - Beles HPP - Summary of project characteristics

4.3.3.5 Neshe (97 MW)

The proposed Finchaa-Amerti-Neshe multipurpose project is located about 250 km northwest of Addis Ababa in the Blue Nile river basin situated on the Neshe River near the Amerti dam.

MWH HARZA studied the project to feasibility stage in September 2005.

The plant will have two units (Pelton) with an installed capacity of **97 MW** and an average flow of 5.8 m^3/s. The reservoir would have an active storage of 363 hm^3 between the FSL of 2,230 m and the MOL of 2,214 m. The reservoir would contain a total storage of 448 hm^3 and the reservoir surface area at the FSL would be 29.2 km^2.

Neshe HPP	**Main Features**
River basin	Abay river
River	Neshe
Catchment area	330 km^2
Mean natural inflow	5.8 m^3/s (183 hm^3)
Reservoir FSL	2,230 m
Reservoir MOL	2214 m
Total reservoir storage	448 hm^3
Active reservoir storage	363 hm^3
Reservoir surface area at FSL	29.2 km^2
Rated head (Design)	614 m
Rated total flow (Design)	9.36 m^3/s
Total installed capacity	**97 MW**
Number of units	2 (Pelton)
Firm energy	215 GWh/year
Average energy	225 GWh/year
Plant factor	26%
Project costs (2006)	**$ 133 M**
w/o Transmission	
Construction period	3 years
Commissioning date	2010
Filling time	2 years (75 % after 1 wet season)
Generation cost (Economic)	$85/90 /MWh

Table 4.3-10 - Neshe HPP characteristics

Note: In 2005 a pre-feasibility study was carried out on a project for water transfer by a pumping station between the Neshe and the Amerti reservoirs.

As per Finchaa-Amerti-Neshe Multipurpose Project, Pre-Feasibility Report (Draft Version), December 2003, point out the followings regarding environments:

- Continuous biological compensation flow of 185 l/s is recommended for the release downstream of Neshe Dam.
- Loss of lowland habitat, which planned to be mitigated.
- Resettlement of 700-1300 households.

4.3.4 SCHEMATIC CONFIGURATION OF RIVER SYSTEM

A schematic representation of each river system with existing, committed and candidate hydro power projects is given in Module 3 Vol 3.

4.3.5 HYDROLOGY

Ethiopia is divided into twelve hydrological basins.

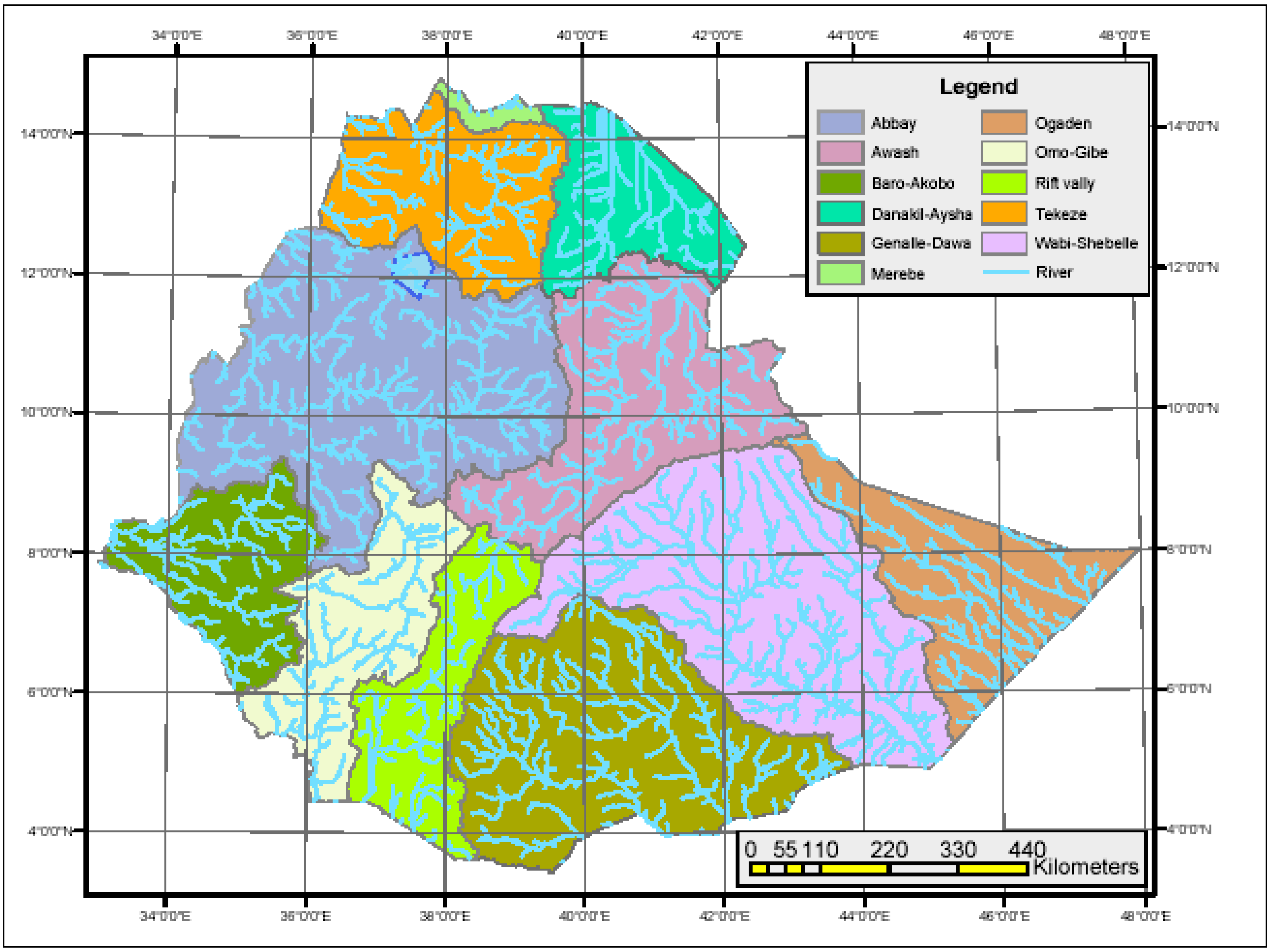


Figure 4-1 - Ethiopian major river basins

Among these basins, three basins, namely Baro-Akobo, Abay (the Blue Nile) and Tekeze cover one third of the total area of Ethiopia and account for 65% of the country's estimated annual water resource.

Abay (Blue Nile) sub-basin

The Blue Nile flows from Lake Tana and crosses the border Ethiopia/Sudan at Deim.

The Lake Tana is a natural reservoir of 3 060 km^2. Its outflow is regulated since 1996 using the Chara Chara regulating weir.

The main tributaries in Ethiopia are the Dedessa, Dabus and Angar rivers, confluencing with the Blue Nile at the Kessie station and the Beles river.

Except one dam on the Finchaa river (one of the tributaries of the Blue Nile in its upper course), and two run-of-river plants (Tis Abay I & II) on the Abay, there is no other dam in the sub basin of the Blue Nile in Ethiopia.

Flows on the Blue Nile and its tributaries have been measured monthly for long periods. On the Blue Nile, data are available at the following gauging stations:

- Bahir Dar (at the out let of Tana lake),
- Kessie (covering 40% of the Ethiopian sub basin of the river),
- at the Ethio-sudan border.

Data are also available on the following tributaries: Wenchit, Jemma, Debis, Angar, Didessa, Dabana, Aleltu and Dabus.

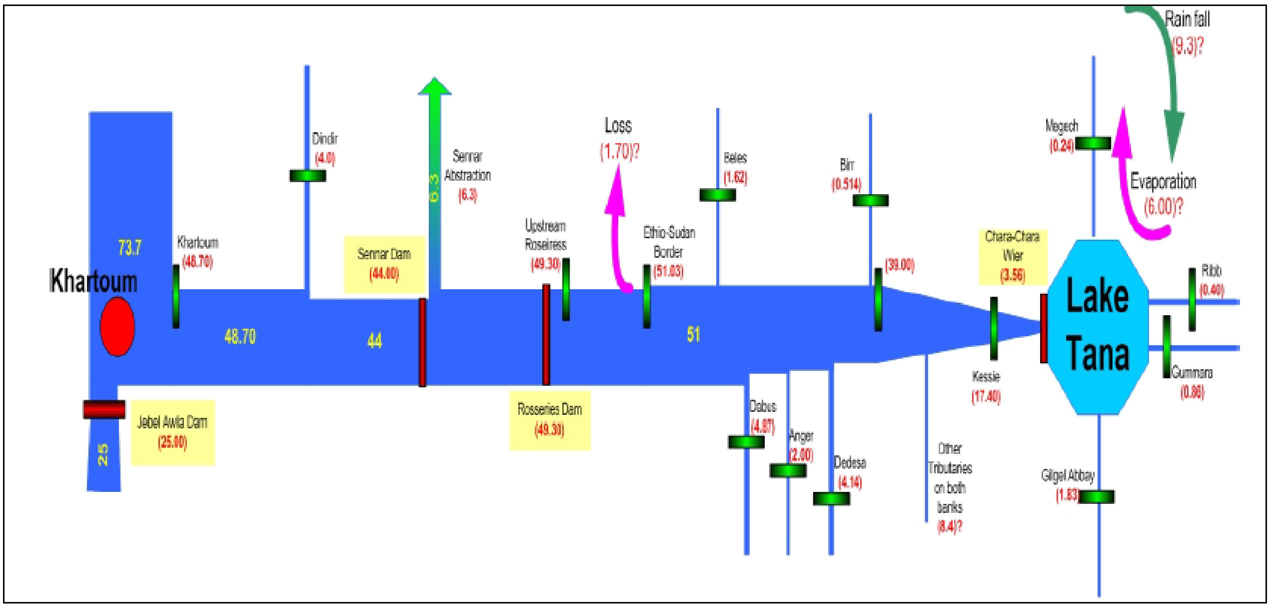


Figure 4-2 - Schematic flows of The Nile Blue

Tekeze sub-basin

The Tekeze (also named Setite river in Sudan) flows from central north plateaus of Ethiopia and rejoins the main Nile at Atbara (Sudan).

Flows of the Tekeze river have been measured at the gauging stations of Embamadrie and Humera.

The basin of Tekeze also includes the sub basins of the Angeren and the Guang rivers.

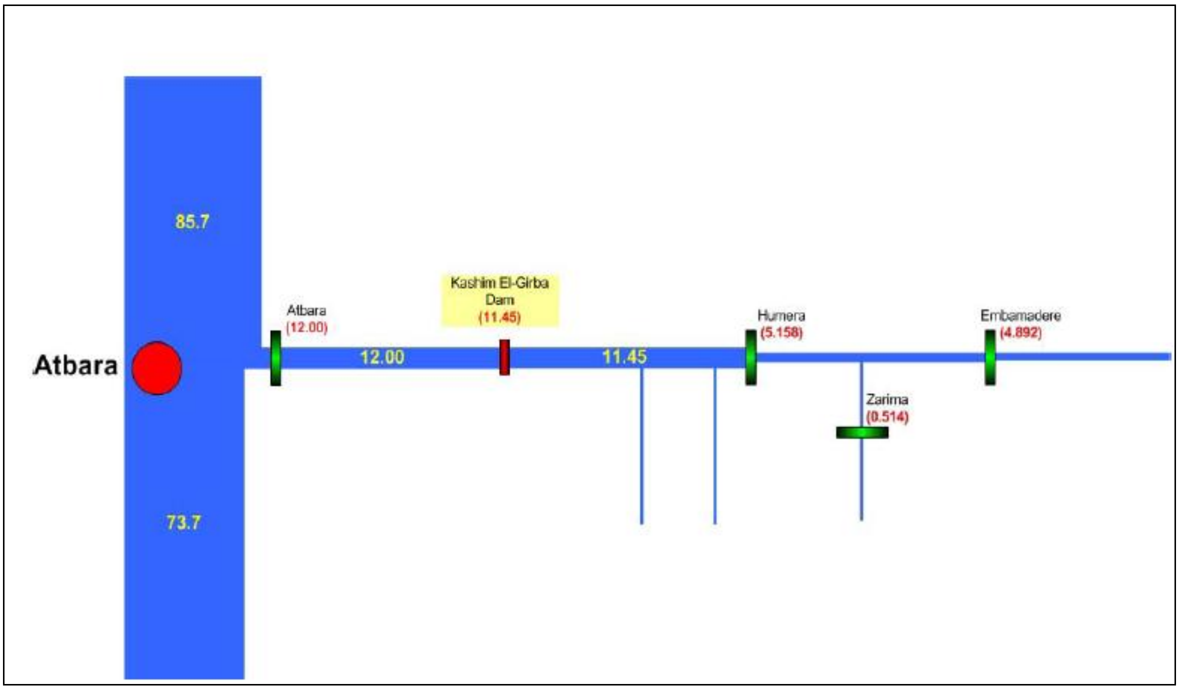


Figure 4-3 - Schematic flows of The Tekeze River

Akobo sub-basin

The Akobo river is a tributary of the Pibor (confluence is located in Sudan) and both the Baro and the Pibor form the Sobat at their confluence beyond the Ethiopia/Sudan border, which rejoins the White Nile at Malakal (Sudan). The Akobo and Baro rivers both flow from south western highland plateau of Ethiopia.

Flows on the Baro river have been measured monthly since 1976 at the gauging station of Gambela, and all the major rivers of the sub basin are gauged.

Omo-Gibe sub-basin

The Omo-Gibe (or Great Gibe) river flows from south east of Ethiopia and drains into the lake Turkana in Kenya.

Flows of the Ome-Gibe and its tributaries have been measured at the following gauging stations:

- Gilgel Gibe at Asendabo, Caro Dos (only 5 recorded years) and at the damsite (since 1998);
- Omo Gibe near Abelti and at Tollay Road bridge (since 1998);
- Wabi river at Wolkite;

- Gojeb river at Shebe.

The longest record is that of the Abelti station starting in 1963 with a monitoring period of 38 years.

Awash sub basin

The Awash rises on the Ethiopian plateau to the west of Addis Ababa, flowing eastwards to Koka reservoir (operational since 1960) and used for hydropower and irrigation. Downstream, water is abstracted from the awash for irrigation and it eventually disappears in the saline lakes near the border with Djibouti.

Daily flow records are available for the following gauging stations:

- Awash at Koka 1 (downstream of Koka dam), Wonji, Nurahera and Metahara,
- Kelata at Sire.

Most existing and planned hydro power plants are located on the 5 sub basins described before (excepted projects in the Genale-Dawa and Wabe-Shebelle sub-basins). For the other sub basins, no data has been found.

4.3.5.1 Data Base

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

A previous work of data compiling has been made by various Consultancy companies on these three following basins: Abay, Tekeze and Akoba.

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

Station	Location		No. Years	Period	Remarks
	Lat	Lon			
BARO-AKOBO					
Baro nr Gambella	8.15	34.34	21	1976-1985, 1990-200	Incomplete for years 1976,1985,1990,1991,1992,1993,1996,1998,1999
Gilo nr Pignudo	7.37	34.14	20	1977-1990,1994-1996	Incomplete for years 1980, 1984, 1985, 1986.1988.1989, 1990,1995,1996,1999.
Alwero nr Abobo	7.84	34.55		X	X
Sor nr Metu	8.19	35.36	21	1980-2000	incomplete for years 1992-1993
Gebba nr Suppe	8.29	35.39	25	1976-1977,1979-1983, 1986-1991,1993-2000	incomplete for years 1976,1977,1979,1980,1981,1982,1983,1988,1991,1993,1994,1996,1997, 1998,2001,2002,2003
ABBAY					
Abbay nr Bahidar	11.36	37.25	21	1980-2000	incomplete for year 1991
Abbay nr kessie	11.04	38.11	21	1980-2000	incomplete for years 1981,1985,1986,1991
Wechit nr Alem Ketema	10.05	38.47		X	X
Jemma nr Lemi	9.55	38.54	2	1996-1997	
Debis nr Guder	9.01	37.46	4	1997-2000	
Didessa nr Arjo	8.41	36.25	22	1981-1997,2000-2004	incomplete for years 1981,1984,1986,1987,1988,1989,1990,1991,1992,1996,1997,2003,2004
Dabana nr Abasina	9.02	36.03	24	1961-1984	incomplete for years 1961,1962,1964,1966,1970,1973,1975,1977,1978,1980,1981,1982,1983,1984
Anger nr Nekemet	9.26	36.31	12	1980-1985,1994-1999	incomplete for years 1985,1994,1995,1996,1999
Bogena nr Lumame	10.15	37.57	8	1996-2003	incomplete for years 1998,1999,2000,2001,2002,2003
Alellu nr Muka	9.39	38.57	19	1980-1991,1194-	incomplete for years 1980,1989,1991,1996

				2000	
Birr nr Jiga	10.39	37.23	16	1985-2000	incomplete for years 1985,1887
Dura nr Metekel	10.59	36.29		X	X
Dabus nr Assosa	9.52	34.54	24	1963,1968-1980	incomplete for years 1963,1976,1977,1978,1979,1980
Muger nr Chancho	9.18	38.44	20	1980-2000	incomplete for years 1985,1986
Abbay nr border	11.14	34.59		X	X
TEKEZE					
Tekezze nr Yechi	13.21	38.45	8	1996-2003	incomplete for years 1996,1997
Tekezze nr Humera	14.17	36.37	4	1981-1984	
Tekezze nr Embamaderre	13.44	38.12	17	1967-1976, 1995-2000	incomplete for years 1970,1994,1998,1999
Zerem at Zerem	12.25	38.02	4	1973-1976	incomplete for year 1973

Table 4.3-11 - Hydrologic Data Base

4.3.5.2 Variability of inflows

Basic climatic features of these basins are near equatorial location and high altitude. The largest source of moisture is the tropical Atlantic, which results in the main July September rainy season.

The following hydrographs are representations of Blue Nile variability: at Kessie, more than 85% of the runoff is concentrated between the months of June to October with a peak in August.

The annual flow exhibit a very strong variability and an annual trend since the middle of the nineties, which might be attributed to the regulating effect of the Chara Chara reservoir.

Table 4.3-12 - Seasonal distribution of Runoff. Abay at Kessie

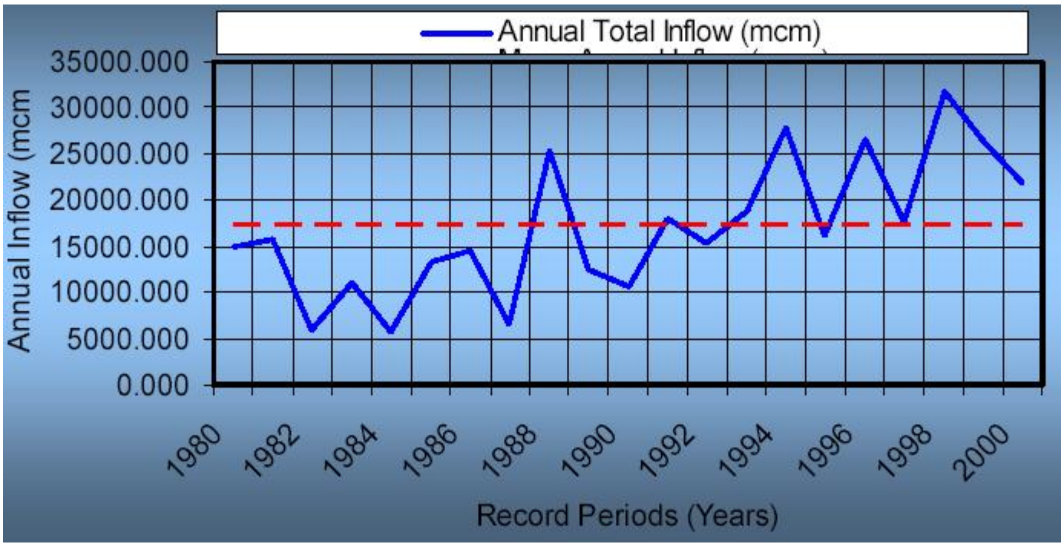


Table 4.3-13 - Annual inflow time series. Abay at Kessie

The Baro, Akabo and Tekeze rivers exhibit the same monthly variability but with less annual variability.

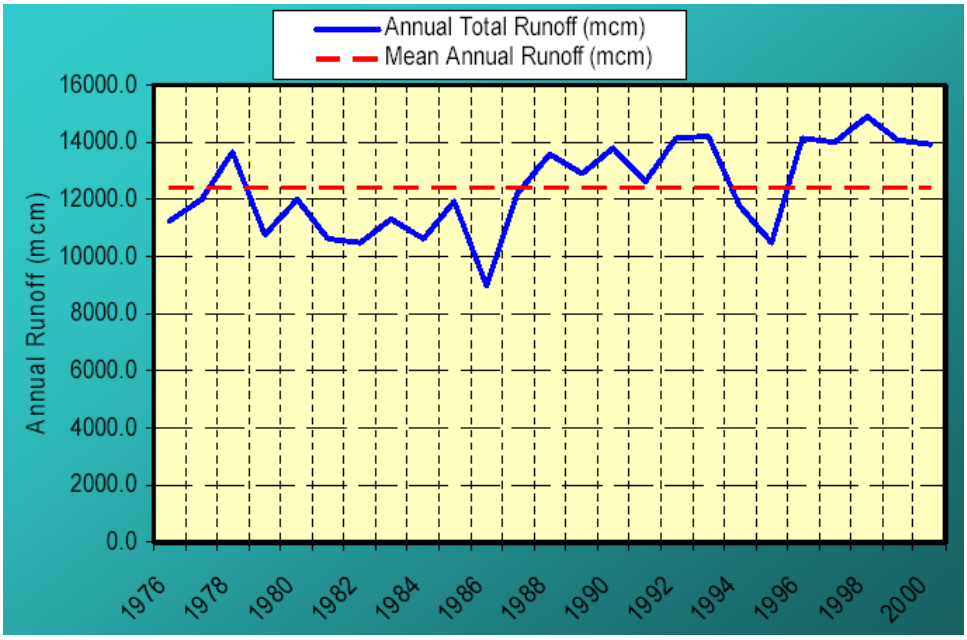


Figure 4-4 - Annual inflow time series. Baro River near Gambella

On the Awash river, the natural regime is the same as that of the Blue Nile, but downstream of the Koka reservoir, the runoff is significantly modified by the reservoir operation. Wet season flows immediately downstream are reduced from 84% of annual total to about 34%.

4.3.5.3 Evaporation and sedimentation

The Consultant will use the monthly evaporation losses and sedimentation data collected in consultant's study for the Baro-Akobo, Abay and Tekeze rivers.

For the Blue Nile basin, evaporation and sedimentation data are available at different gauging station. One of the major source of sediments is erosion of the intensively farmed areas.

For the two other basins, only few data are available.

4.3.6 RENEWAL ENERGY

In 2007, the only existing significant renewable source of energy consist of geothermal.

The **Aluto-Langano** geothermal site is located in the "Aluto Volcanic Complex " about 200 km south of Addis Ababa between the lakes of Ziway and Langano.

A 7.3 MW pilot geothermal power plant was installed and completed in 1999 but today the plant is out of service due to technical limitations and energy generation is not expected by EEPCO before 2007.

The site could be further developed in two stages for an additional 30 MW of new capacity based on an "Electroconsult" assessment (feasibility study in 1986).

5. ASSESSMENT OF THE EXISTING TRANSMISSION NETWORK OF ETHIOPIA

See Ethiopian Power System Expansion Master Plan update – June 2006: Chapter 3 – Status of the Existing System

Existing Transmission System (see Appendix M2_V3_A3 Existing and Committed HPP and Appendix M2_V3_A3 Addis Ababa Transmission System)

The existing transmission system consists of 6 534 km of transmission lines:

Voltage (kV)	Length (km)
230	1 716
132	2 561
66	1 782
45	476

Table 4.3-1 - km of lines per voltage in the existing transmission system

The 230 kV system extends from Addis Ababa about 400 km eastward to Dire Dawa, south of Maleka-Wakana and about 1 000 km toward the west and north. The 45 kV system is not extending further, it is being phased out. Some sections of the 66 kV and 45 kV system are no longer in use, as they are being replaced by higher voltage lines. Some areas of the above system are operated as Self Contained System (SCS) being remote from the Interconnected System (ICS). The SOR hydro plant supplies an SCS small system at 66 kV while other such systems are supplied from Diesel generation plants.

There are a total of 107 substations in the system, of which 11 are at 230 kV, 45 are at 132 kV, 26 are at 66 kV, and 23 stations at 45 kV level. Substation layouts are based on double bus system at the major generating stations while a single bus arrangement is in use at almost all other stations. About 226 MVar of switched reactors are used to control the voltage levels on the system, particularly at light load conditions. Among these reactors, 10 are connected in 230 kV, 5 in 132 kV and 6 in 15 kV. Over voltages on the 230 kV system are experienced in the north during low loads, but can be corrected by having sufficient reactive generation absorption in the area or making switched shunt reactors available.

Addis Ababa represents 60% of the total demand. The other major load centres are located in: Nazareth, Dire Dawa, Harar and Bahar Dar.

There are presently three 230 kV substations supplying Addis Ababa: Gefersa, Kaliti I and Sebeta, and a fourth substation Cotobie under construction. These 3 substations are connected through one single 230 kV transmission circuit and two 132 kV transmission lines. A 132 kV transmission line connects Gefersa substation with Addis North and Cotobie 132 kV substations and from there to Kaliti I 230 kV substation to complete the ring around Addis Ababa. It will be reinforced by the commissioning of the 230 kV circuit from Cotobie to Kaliti I. The tripping of one of these 230 kV lines leaves the 230 kV system unmeshed. Three 30 kV, eight 132 kV and six 45 kV substations feed the load in and around the Addis Ababa region.

Committed Transmission Installations

The highest voltage level in the system presently is 230 kV. The new highest voltage level will soon be 400 kV as the contract for the construction of the 400 kV transmission lines from Gilgel Gibe II to Gilgel Gibe I and Sebeta has been already signed. With regard to 230 kV lines, a double-circuit 230 kV transmission line from Tekeze to Mekele and a single circuit line from Gonder to Metama are under construction. The Finchaa - Ghedo – Gefersa, the Alamata - Kombolcha - Kality I and the Kombolcha - Samera - Dichato lines are in procurement stages. The 132 kV lines from Dire Dawa to Jijiga, Yirga Alem to Hagere Mariam, Ghimbi to Assosa, and Wolayita Sodo to Sawla are completed or are at the final stage of the construction phase.

See the following tables.

Connection Point	Voltage Level	km	Status	Remark
Gilgel Gibe II - Gilgel Gibe I	400	30	Design	Contract signing
Gilgel Gibe II - Sabata II	400	185	Design	Contract signing
Finchaa - Ghedo	230	93.6	U.C	Procurement
Ghedo - Gefersa	230	134	U.C	Procurement
Tekeze - Mekele	2x230	90	U.C	
Combolcha – Samara - Ditchato	230	243	U.C	Procurement
Gonder-Metema	230	165	U.C	
Alamata-Combolcha-Cotebe-Kality	230	462	U.C	Procurement

Table 4.3-2 - Under construction and committed 400 kV and 220 kV Transmission Lines

Connection Point	Voltage Level	Status
Mota	230/33	U.C
Sebeta II	400/230	Design
Samara	230/132/33	U.C
Dichato	230/132/33	U.C
Metema	230/33	U.C
Nifas Mewcha	230/33	U.C
Gashena	230/33	U.C

Table 4.3-3 - Under Construction and Committed 400 kV and 220 kV New Substations

6. ASSESSMENT OF EXISTING POWER TRADE FROM ETHIOPIA

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).

ENTRO

EASTERN NILE POWER TRADE PROGRAM STUDY

AfDB

MARKET AND POWER TRADE ASSESSMENT

VOL 3 - ETHIOPIA

APPENDIX

30 APRIL 2007

EDF – Generation and Engineering Division
73 373
Le Bourget du Lac Cedex
France
Tel: +33-4-79 60 60 60
Fax: +33-4-79 60 62 35
eMail: pierre.brun@edf.fr
http://www.edf.fr

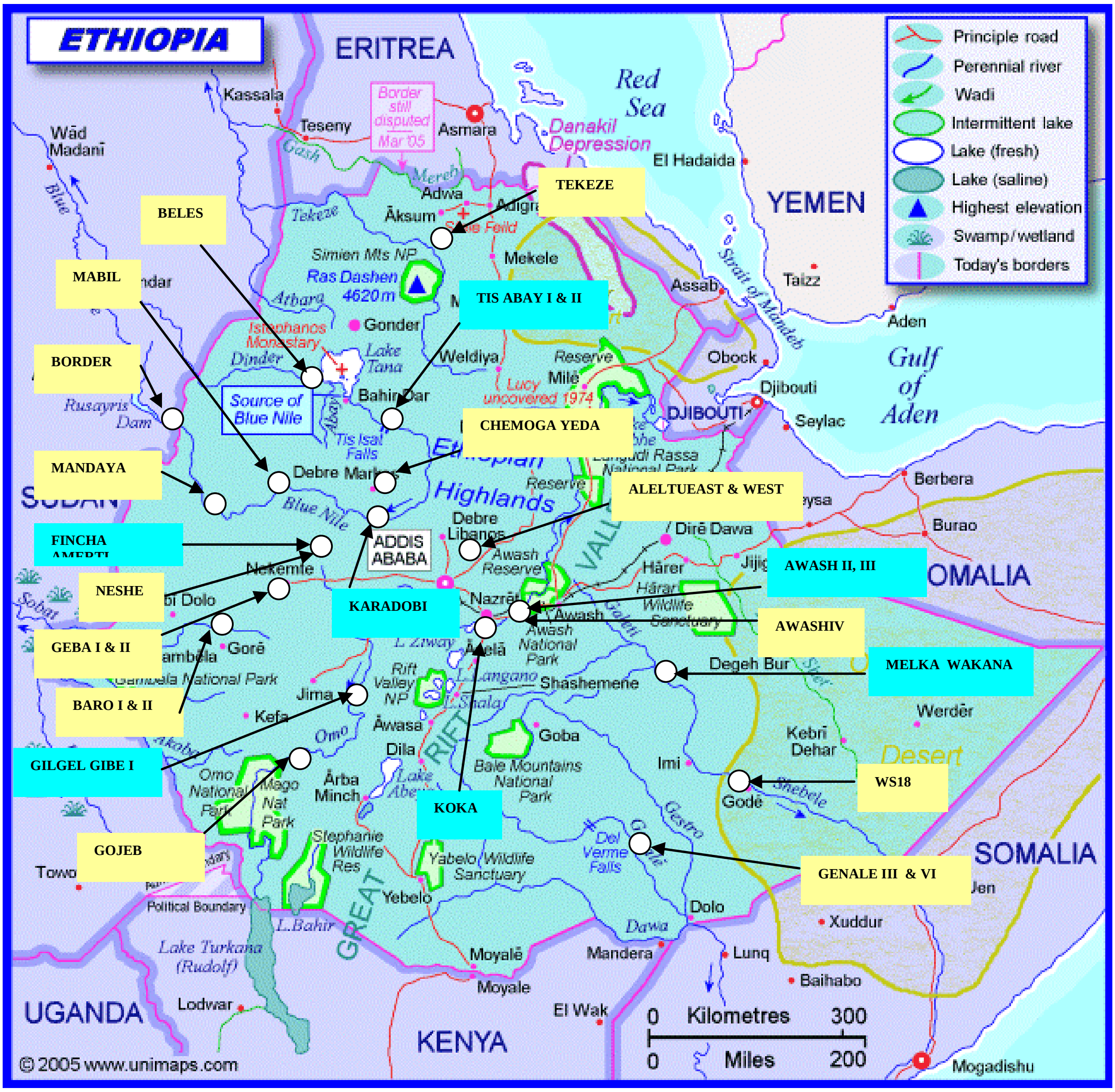
Scott Wilson
Kanthack House, Station Road,
Ashford, Kent TN 23 1 PP
England
Tel: +44 (0) 1233 658200
Fax: +44 (0) 1233 658209
eMail: alan.bates@scottwilson.com
http://www.scottwilson.com

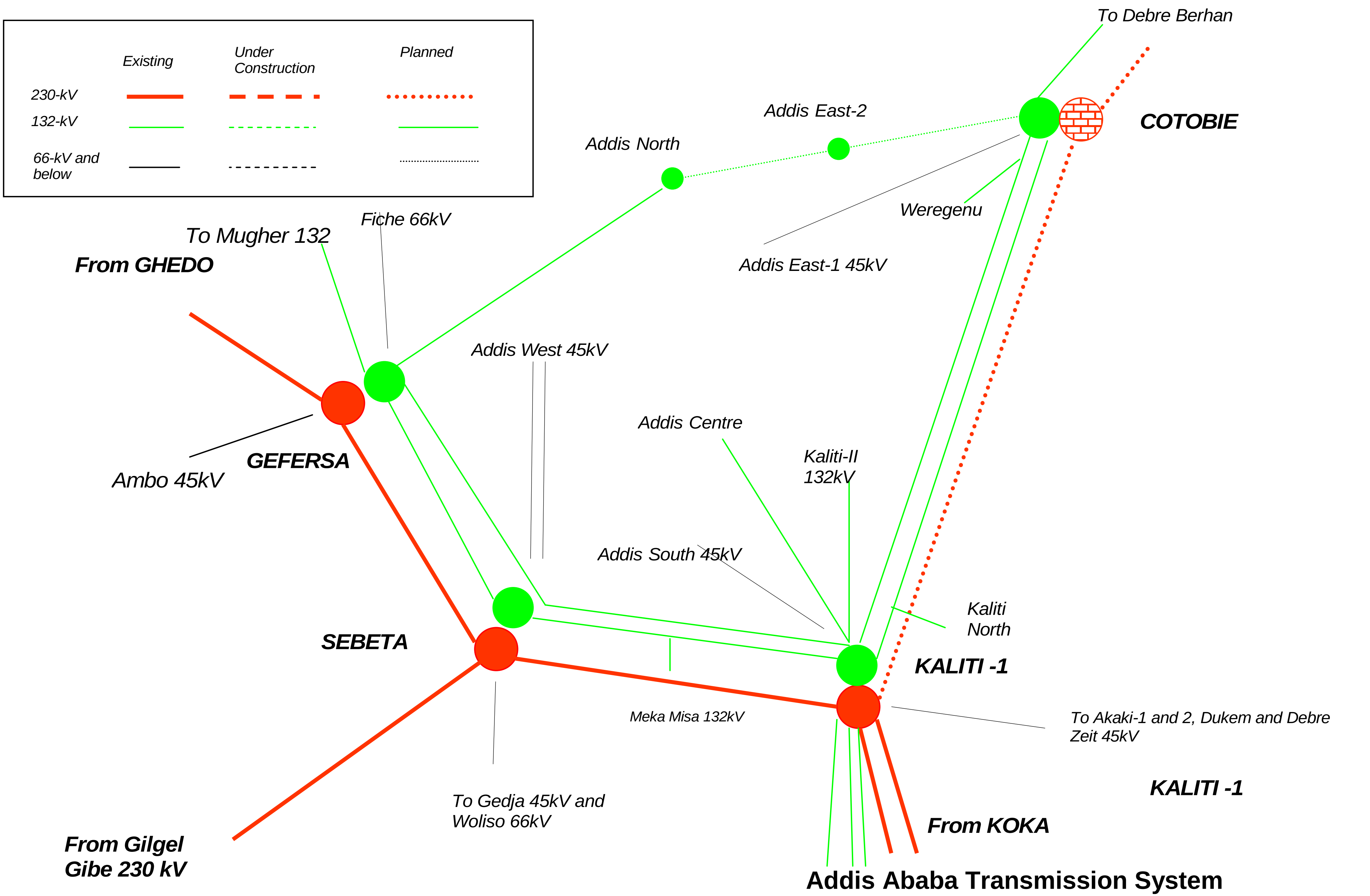
with participation of :

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

LIST OF APPENDICES

EXISTING AND COMMITTED HYDROPOWER PLANT IN ETHIOPIA




Existing
Under Construction
Planned
230-kV
132-kV
66-kV and below
To Debre Berhan
COTOBIE
Addis East-2
Addis North
Weregenu
Addis East-1 45kV
Fiche 66kV
To Mugher 132
From GHEDO
Addis West 45kV
Addis Centre
Kaliti-II 132kV
GEFERSA
Ambo 45kV
Addis South 45kV
Kaliti North
SEBETA
KALITI -1
Meka Misa 132kV
To Akaki-1 and 2, Dukem and Debre Zeit 45kV
KALITI -1
To Gedja 45kV and Woliso 66kV
From KOKA
From Gilgel Gibe 230 kV
Addis Ababa Transmission System