Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH

Wind Energy Programme TERNA

PN: 97.2019.4-001.09

Information for Project Appraisal: Ethiopia


Candidate Wind Park Site Harena Plateau (Mekelle)

June 2004

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Factor 4 Energy Projects GmbH

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List of Abbreviations

AAU	Addis Ababa University
AGL	above ground level
Birr	Ethiopian currency, 1 € ~ 10 Birr, 1 US$ ~ 8 Birr
BMZ	Bundesministerium für Wirtschaftliche Zusammenarbeit, German Ministry for Economic Co-operation
CFL	Compact Fluorescent Lamps
CPI	Corruption Perception Index
EELPA	Ethiopian Electric Power Authority
EEPCO	Ethiopian Electric Power Corporation
EPLF	Eritrean People's Liberation Front
EPRDF	Ethiopian People's Revolutionary Democratic Front
EREDPC	Ethiopian Rural Energy Development and Promotion Centre
EUR	Euro, European currency €
GoE	Government of Ethiopia
GTZ	Deutsche Gesellschaft für Technische Zusammenarbeit
GW	gigawatt = 1,000,000,000 Watt
HDI	Human Development Indicator
HEP	Hydroelectric Plant
ICS	Interconnected System
IDA	International Development Assistance
IPP	Independent Power Producer
KfW	Kreditanstalt für Wiederaufbau
kgoe	kg oil equivalent
kV	kilovolt = 1,000 Volt
kW	kilowatt = 1,000 Watt
MIDROC	Mohammed International Development Research Organisation & Companies
MVAr	megavoltampere reactive
MRD	Ministry of Rural Development
MW	megawatt = 1,000,000 Watt
NGO	Non Governmental Organisation
NPV	Net Present Value
OECD	Organisation of Economic Co-operation and Development
OLF	Oromo Liberation Front
O/M	Operation and Maintenance
op. cit.	opere citato: in the work cited
p.	page
PSEMP	Power Sector Expansion Master Plan
R&D	Research and Development
RE	renewable energy
RTPC	Rural Technology Promotion Centre
SHS	Solar Home System
TERNA	**T**echnical **E**xpertise in **R**e**N**ewable Energy **A**pplication

Ethiopian Expressions

dergue	Provisional Military Council
injera	Ethiopian staple food, pan-cake like bread
quat	mild stimulant, used as a legal drug in the Horn of Africa and Arabia

Currency Rates

used throughout the study

1 € = 1.24 US$

1 € = 10 Birr

Summary of Findings

After EEPCO – Ethiopian Electric Power Corporation – applied for cooperation within the TERNA wind energy programme, a project appraisal procedure has been agreed upon during a mission of the GTZ representative in December 2003.

A consultancy mission aimed at collecting information for project appraisal mission took place in February 2004 and had the following major findings:

1. Conditions for the **economic operation** of larger grid-connected wind parks in Ethiopia appear favourable, due to the following reasons
   - Indications for reasonable wind regimes in major parts of the country are promising, primarily in the East and in the North. At least one of these sites could be validated through independent measurements (Mekelle) where annual averages of 6.7 m/s in 10 m and more than 8 m/s in 40 m above ground are expected.
   - A preliminary cost estimation put the in-vestment costs for a 50 MW wind park in the range of 52 million €. Based on these estimates, specific energy prices in the range of current hydro, and below thermal and geothermal plants are calculated;
   - Even though EEPCO is both financially and with regard to qualified personnel a rather weak utility company, it can be assumed that EEPCO can be put into position to operate and maintain the wind park. This, however, only under the assumption, that for several years – at least during the warranty period of the turbine equipment – the manufacturer keeps permanent presence in the country and high efforts in capacity building are made.
2. The electric grid of EEPCO is principally suitable for the integration of large wind parks in the multi MW range.
3. The unit size of the turbines, on account of infrastructural limitations in the country, should not exceed 750 kW.

It is proposed that the cooperation between the wind energy programme TERNA and EEPCO aiming at the implementation of a 50 MW wind park goes ahead, according to the proposals outlined in **Section 9** of this report.

Zusammenfassung der Ergebnisse

Nachdem EEPCO - Ethiopian Electric Power Corporation – einen Antrag auf Zusammenarbeit mit der GTZ im Rahmen des TERNA Windenergieprogramms gestellt hatte, wurde die Durchführung einer Prüfmission in Äthiopien abgestimmt, anlässlich des Besuchs des TERNA-Verantwortlichen in Addis Ababa im Dezember 2003.

Die Prüfmission wurde im Februar 2004 durchgeführt und kommt zu folgenden wesentlichen Ergebnissen:

1. Die Aussichten auf einen **wirtschaftlichen Betrieb** von größeren Windparks im Netzparallelbetrieb mit dem Verbundnetz sind in Äthiopien aufgrund folgender Umstände günstig:
   - Die Hinweise auf gute Windverhältnisse in verschiedenen Regionen des Landes, vor allem im Osten und Norden, sind vielversprechend. An einem der möglichen Standorte konnten unabgängige Windmessungen mit einem klassifizierenden Messgerät durchgeführt werden. Dort können Jahresmittel von 6,7 m/s in 10 m und mehr als 8 m/s in 40 m über Grund erwartet werden.
   - Eine vorläufige Kostenschätzung ergibt Investitionskosten für einen 50 MW Windpark in der Größenordnung von 52 Millionen €. Mit diesem Investitionsvolumen errechnen sich für den Windpark dynamische Gestehungskosten, die in gleicher Größenordnung wie in den großen Wasserkraftwerken Äthiopiens, und sogar unter denen von thermischen und geothermischen Kraftwerken liegen;
   - Auch wenn EEPCO sowohl finanziell als auch hinsichtlich des Ausbildungsstandes ihrer Mitarbeiter als schwaches Energieversorgungsunternehmen angesehen werden muss, wird davon ausgegangen, dass die Gesellschaft in die Lage versetzt werden kann, einen Windpark zu betreiben und zu warten. Dies wird allerdings nur unter der Voraussetzung erfolgreich sein, wenn EEPCO für mehrere Jahre (mindestens jedoch für die Dauer der Garantiezeit des Anlagenherstellers) intensive Unterstützung vom Hersteller erfährt, und ausführliche Fortbildungsmaßnahmen unternommen werden.
2. Das von EEPCO unterhaltene Übertragungsnetz ist grundsätzlich geeignet, die von größeren Windparks kommende Leistung zu absorbieren.
3. Es sollten in Äthiopien keine Windkraftanlagen größer 750 kW eingesetzt werden: dazu ist die technische Infrastruktur des Landes zu beschränkt.

Es wird empfohlen, dass die beantragte Zusammenarbeit von EEPCO im Rahmen des TERNA-Programms fortgeführt wird, entsprechend den Vorschlägen von **Kapitel 9** dieses Berichtes.

1. Introduction

1.1 The TERNA Wind Energy Programme

Specialised knowledge and experience are needed to determine what wind energy resources a country possesses and to identify suitable locations. Technical and economic analysis is impossible without the acquisition of such information. Such an analysis, in turn, is a pre-requisite for obtaining financing for wind energy projects.

This is, in short, the situation many developing countries with sufficient wind resources face, when intending to go for the environmentally friendly wind power.

Against this background, the Federal German Ministry for Economic Cooperation and Development (BMZ) set up the TERNA wind energy programme (**T**echnical **E**xpertise for **R**e**N**ewable Energy **A**pplication) in 1988.

In order to compensate for the lack of available knowledge, the programme is targeted at providing technical advice and support. It is intended to enable prospective operators of wind farms in developing and more advanced countries to assess the technical and economic potential of wind power projects and to develop promising schemes to the stage where they are ready for implementation.

The programme is being implemented by Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ). The Ministry for Economic Cooperation and Development is financing the measures, but in view of their supra-regional nature it is not using funds from the country quotas that are agreed separately with the various partner countries. From the standpoint of the partner countries, therefore, TERNA provides additional resources which are dedicated specifically to wind energy.

The TERNA wind energy programme promotes wind power projects that operate in grid-parallel operation. To achieve economic operation and sustainable maintenance, an installed capacity of at least 10 MW is regarded necessary. The sites must dispose of suitable wind regimes and have access to an electricity grid. There are no restrictions on the choice of countries, although the emphasis is plainly on states where the framework conditions are adequate to provide for economic operation of the installations. Small-scale individual facilities or isolated wind-diesel systems are not promoted, nor are projects of R&D nature.

TERNA pursues the goal of initiating wind power projects in the megawatt range. In order to achieve this, the programme passes on the necessary knowledge about planning and implementation to potential operators. It is therefore aimed at energy supply companies (public utilities) just as much as at independent investors and private electricity producers (independent power producers, IPPs) as possible operators of wind farms. In the same way, large electricity consumers, needing power plants in the MW range, could be TERNA partners.

The programme offers its partners comprehensive know-how and experience. In order to initiate projects, favourable sites must be identified. Wind measurement and site selection procedures come into play here. This step is followed by practical planning of the installations, in which the design and cost-effectiveness need to be analysed. TERNA also provides advice to project developers on financing matters. The assistance is provided by experts with experience in the relevant fields.

In successful cases, TERNA can thus accompany investment-ready wind farm projects as far as the tendering or contract award stage. The programme does not then become involved in the financing itself. However, TERNA does aim to build bridges to available financing instruments provided by national and international donors.

The services offered by TERNA cover the transfer of know-how relating to siting, planning, implementation and technical and administrative regulatory matters. The partners and GTZ choose the appropriate measures from the set of TERNA instruments to complement the experience already available to them. In particular, the areas of possible cooperation are as follows:

- **Preparation:** Support for wind measurement campaigns, installation of wind measurement instruments, evaluation of data, advice on siting of wind turbines
- **Transfer of know-how:** Running training programmes (workshops) for partner experts; subject matter: wind measurement, assessment of potential wind farm configurations and connection to the grid
- **Planning:** Calculation of investment and project costs, performance of economic feasibility studies and risk assessments
- **Project Implementation:** Provision of advice to public bodies on inviting tenders for wind farm projects; preparation of project documents for project financing ("bankable documents")[1]

1.2 Background to the Ethiopian TERNA-Application

Due to a state-controlled economy from 1975 to 1991 (Provisional Military Council under Colonel Mengistu Haile Mariam, in Amharic *dergue*), combined with practically constant civil conflict with the independency-seeking province of Eritrea, Ethiopia's economy has been stagnant over a long period of time. An annual economic growth of little more than 1 %, in comparison to a population expansion of more than 3 % per year, has resulted in a steady decline in per capita incomes and living standards.

In the same way, the demand for electricity has not risen much during the *dergue* regime, because there were, in the absence of a local industry and due to import restrictions and lack of foreign currency, practically no electric appliances to buy on the market.

In May 1991, dictator Mengistu has been driven out of the country by the forces of the Ethiopian People's Revolutionary Democratic Front (EPRDF), based in Tigray, and the separatist Eritrean People's Liberation Front (EPLF) supported by other groupings, such as the Oromo Liberation Front (OLF). The new Ethiopian Government let Eritrea gain independence (through a referendum in 1992), ended Ethiopia's isolation and adopted a new constitution in 1994, which gave some governmental autonomy to the former provinces of Ethiopia: The Federal Republic of Ethiopia was founded, changed its policiy and saw a relative economic prosperity, never experienced before in history.

In the same way, and with economic growth rates in the range of 5 %, the **electricity demand increased** to a much higher degree, on account of suppressed demand under the *dergue*. The lack of investments in the country's electric generation and distribution system during the *dergue* proved to be a serious constraint: since 1999, regular country-wide load shedding had to be introduced at the end of the dry season, as the reservoirs of the country's hydro power plants were empty. Delays in the completion of new hydro power plants, out-dated distribution equipment and a general low level of operation and maintenance aggravated the lack of generation capacity further.

Proposals to install **large thermal power plants** (diesel) are currently being evaluated at the country's national utility Ethiopian Electric Power Corporation (EEPCO) – to bridge the time until hydro power plants, currently in the planning or construction stages (such as Tekeze and Gojeb), can start to operate.

Under this situation, wind energy came up as a possible alternative to thermal power plants in the plus 10 MW range: The national intercon-

1) Text taken from Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH, Division 44 Environmental Management, Water, Energy, Transport, „Producing Electricity from Renewable Sources: Energy Sector Framework in 15 Countries in Asia, Africa and Latin America", Eschborn 2002, p 6ff. (modified)

nected grid is practical solely supplied by hydro power and thus particularly vulnerable to the high variability and/or lack of precipitation. With wind power plants in parallel, the supplied wind power can serve as a **"water saver"** (rather than as a fuel saver) and – provided the wind resource is sufficient and the plants are correctly dimensioned – help to overcome the critical months at the end of the dry season in Ethiopia (April – May).[2]

Thus, the major advantage of wind power over both hydro power and diesel power generation was seen in the short lead times for planning and erection. Additionally, it was clear that the import of fossil fuel for large diesel plants would strain Ethiopia's budget much more in the long run, than the investment in wind parks, as more favourable loan conditions can be expected for the renewable source 'wind' than for a thermal power plant running on fossil fuel.[3]

Realizing the principal possibility of economic wind plant operation in Ethiopia after the results of new resource assessments were published, EEPCO applied for co-operation within the scope of the TERNA programme in October, 2003.

After a short-term visit of GTZ-TERNA manager Dr. Jasper Abramowski in December 2003, the current appraisal procedure was agreed upon between EEPCO and GTZ.

1.3 Contents of this Report

Following the basic structure of the Terms of Reference[4] this report consists of 9 Sections:

1. an introduction to the TERNA programme and the current mission in **Section 1**;
2. an energy sector overview in **Section 2**;
3. a more thorough analysis of the electricity sector in Ethiopia focussing on the existing interconnected system (ICS) in **Section 3**;
4. some basics on the integration of larger wind parks into existing electricity supply systems with an indication of possible feed-in points in Ethiopia in **Section 4**;
5. an analysis of the technical and financial performance of EEPCO, being the intended operator of the wind park in **Section 5**;
6. an overview of wind conditions from meteorological and other sources in **Section 6**;
7. information about possible sites for wind speed measuring stations (and consequently, of large wind parks) in **Section 7**;
8. a summary of findings with a recommendation to go ahead in **Section 8**; and
9. a proposal how to proceed for the site selection of large wind parks (design of measuring campaign) and the further planning steps for project implementation in **Section 9**.

The **Annex** contains background information to the information presented in the main part of this report.

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2) Application of EEPCO for cooperation within the scope of the TERNA Programme in **Annex 1**

3) Therefore, the economic evaluation of the planned wind park project should be calculated in comparison to large diesel power plants, since this would be the alternative for EEPCO within the next 10-year time frame.

4) See **Annex 2** (in German). An excerpt in English has been made by the consultant and handed over to EEPCO during the kick-off meeting of this appraisal mission on February, 12th,2004

2. Energy Sector

2.1 Country Basics

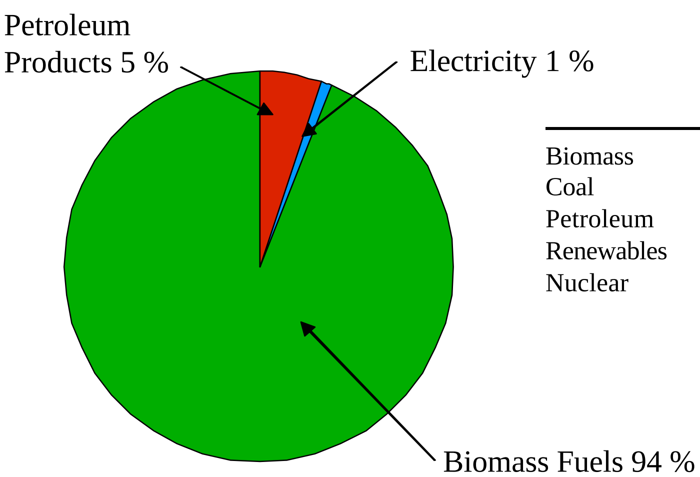
2.1.1 Overview

With 95 % of its primary energy consumption coming from renewable energy sources, Ethiopia, theoretically, could be a country with a principally sustainable energy system so many OECD countries are targeting at.

However, of this large renewable share, 94 % is household fuel (fuel wood, agricultural residues, animal dung) used as non-commercial energy in rural and urban households (**Figure 2-1**). In addition, the over-exploitation of the biomass resource in several regions of the country has already caused serious environmental destruction (soil erosion, top soil losses, reduced soil fertility, desertification).

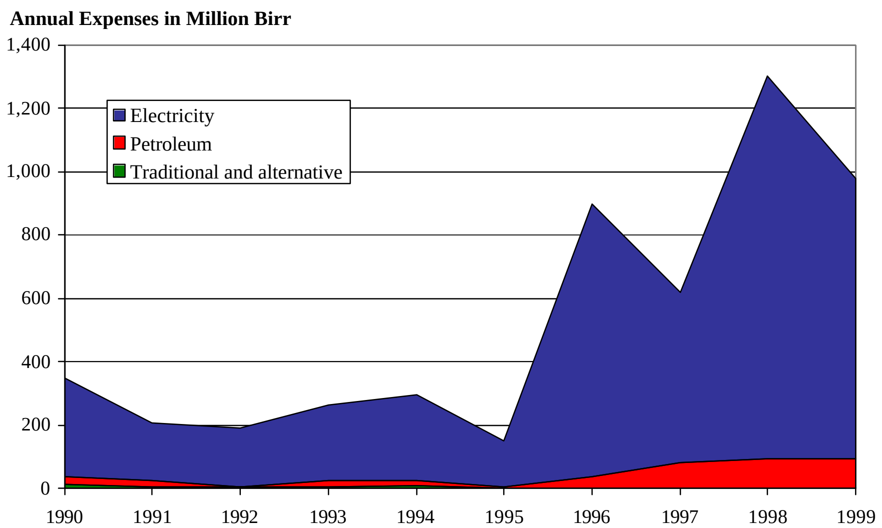
Under this situation the Government of Ethiopia, does not place the major emphasis on the **protection of natural resources** and the development of the traditional biomass sector, but – as do most other African governments – on the strengthening of the commercial energy sector, primarily the electricity sector (**Figure 2-2**). In the view of the consultant, this policy has lead to a widening gap between the energy situation of the urban and rural population and has aggravated the biomass crisis in the country further.

Figure 2-1:
Primary Energy Consumption in Ethiopia



	Ethiopia	World
Biomass	94 %	12 %
Coal	0 %	23 %
Petroleum	5 %	52 %
Renewables	1 %	3 %
Nuclear	0 %	10 %

Figure 2-2:
Government Spending in the Energy Sector



Source: Wolde-Giorgis, "Renewable Energy for Rural Development in Ethiopia. The case for New Energy Policies and Institutional Reform" in: Energy Policy, Vol. 30, Taking the total government spending over the 10 year period from 1990 to 1999, of 5,260 million Birr (= 492 million €) only 41 million Birr or **0,7 % was directed to the development of traditional energy resources**.

Close to 92 % went into the electricity sector, practically all of it for infrastructure works for the state-owned Ethiopian Electrical Power Corporation (EEPCO). This money was invested into the expansion of the electricity generation base and the transmission and distribution network, a major part of which benefited the urban centres.[5]

With 43.8 kg oil equivalent (kgoe) **per capita consumption** of commercial energy and only 22 kWh per capita electricity consumption Ethiopia has one of the lowest specific energy consumption in the world and stands out even in the sub-Saharan context (~ 800 kgoe/cap).[6] However, the equally under-average economic figures of the country – 100 US $ per capita GNP, for instance – agree with this low energy consumption.

2.1.2 Other Country Indicators

Ethiopia is Africa's second populous country with 69 million inhabitants estimated for 2003 and a population growth rate of 2.3 % pa. With 84 % rural population, it is also the country with one of the lowest percentages of urban population in Africa. As such, 45 % of gross national product (GNP) is derived from agriculture, with coffee, hides, and – more recently – *quat* (a mild stimulant being chewed in the Middle East) as the principal foreign export earner. In total, 90 % of foreign currency comes from the agricultural sector.

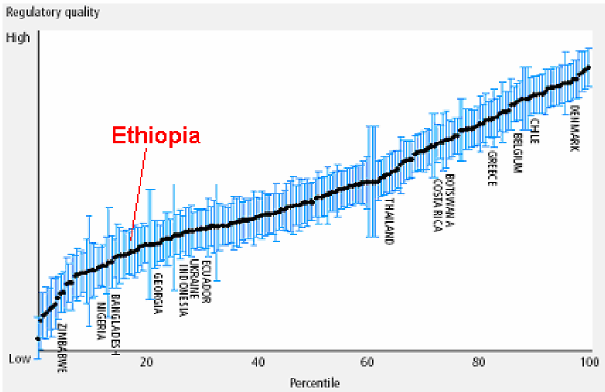
Thus, with 92 % of the energy budget being spent in the electricity sector predominantly in the urban areas, a net resource transfer takes place from the country-side to the cities.

With regard to other country statistics, Ethiopia is faring equally critically: the **Human Development Index** (HDI), being a figure taking into account education, health service, access to clean water etc. lists Ethiopia as country 172 of 176.

The **Corruption Perceptions Index** (CPI) of Transparency International puts Ethiopia at place 92 of 133 surveyed countries in 2003,[7] showing, with a score of 2.5, a worsening trend as compared to 3.5 the previous year.[8]

In spite of a vibrant independent private press sector in the country, Ethiopia's record on **press freedom** is relatively poor. According to the French non-governmental organisation (NGO) "Reporteurs Sans Frontiers" the country ranked as number 124 out of 166.

Figure 2-3:
Regulatory Quality Ratings[9]



Ethiopia's **telecommunication system** is one of the least developed in the world: only 0.6 telephones per 100 inhabitants are connected to fixed lines, compared to 7.2 telephones for Africa as a whole. A mobile telephone system,

5) These figures are derived from published government documents as indicated in the official budget. As such they might not represent in full the amount of money spent on the biomass sector within the scope of bi- or multilateral cooperation projects.

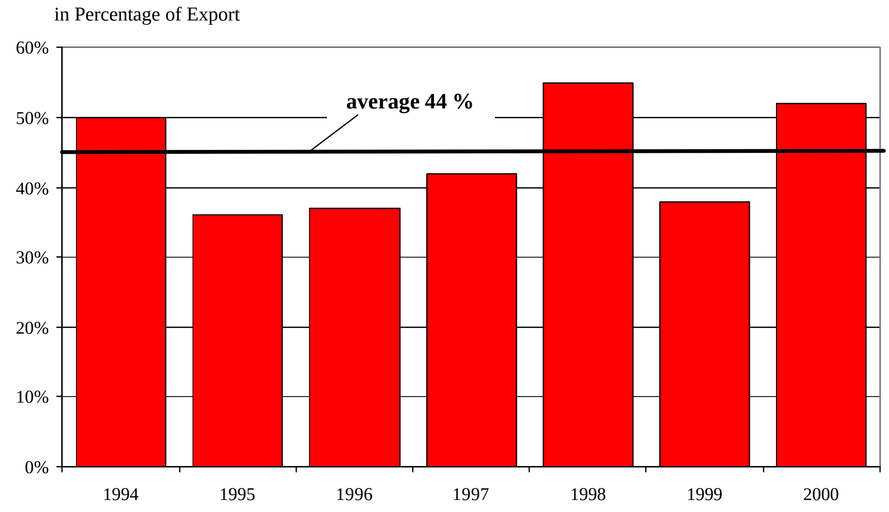
6) European Union Energy Initiative for Poverty Eradication and Sustainable Development, Desk Study Ethiopia, November 2003

7) The Economist Intelligence Unit (ed), "Country Profile Ethiopia 2004", London 2004, p. 39

8) This score is on a scale from 0 to 10, with zero being the most corrupt and 10 the least.

9) World Bank, International Finance Corporation, Oxford University Press, "Doing Business in 2004 – Understanding Regulation", Washington 2004, p.14

Figure 2-3:
Fuel Imports as Percentage of Export Earnings



Source: Bekele Bayissa, "The Prevailing Fuel Crisis and Mitigating Measures", in: Professional Associations' Joint Secretariat (eds.), Proceedings of Energy Conference 2002, p. 321, modified

limited to Addis Ababa and its neighbourhood, was launched in 1999 and has ca. 50,000 users, while the waiting list has grown to more than 100,000 at the end of 2003.

Another indicator concerns the **economic freedom** and gauges policy conditions for doing business in more than 130 countries. In an analysis of World Bank and International Finance Corporation,[10] Ethiopia ranks as a highly regulated country, however, with a relative low quality of regulation.[11] As such, it is prone to inefficiency and corruption linked to a low degree of economic freedom.

2.2 Energy Provision

2.2.1 Electricity

Approximately 90% of Ethiopia's electric power is generated from hydroelectric sources, and there is considerable untapped potential along the Nile and Awash valleys. Reliance on hydroelectric power (HEP) has left the country vulnerable to drought, however, and extensive power cuts has occurred regularly at the end of the dry season since 1999.

Electric power supply falls under the jurisdiction of the Ethiopian Electric Power Company. EEPCO is the sole utility in the country, is state-owned and works under the Ministry of Infrastructure.

Currently, EEPCO has about 650 MW of installed capacity (of which about 400 MW must be regarded as firm capacity), but less than half of Ethiopia's towns are connected to the grid, despite the electrification of more than 80 urban centres during 2001-03. EEPC0 embarked on a 25-year master plan in 2001, which calls for investment of 18 billion Birr (US$2.1 billion) in order to double capacity to 1,330 MW.[12] Several projects are underway or in the pipeline, although most have experienced delays because of technical and regulatory difficulties on the ground, or owing to shortages of finance.

At present, the two biggest projects are the 300 MW Tekeze HEP plant, to be built by a Chinese-led consortium in the north, and the 180 MW Gilgel Gibe HEP facility on the Omo River in the south-west. Gilgel Gibe HEP has

10) World Bank, International Finance Corporation, Oxford University Press, "Doing business in 2004 – Understanding Regulation", Washington 2004

11) See **Section 3.5.2** Legal Framework in Practice

12) EEPCO and ACRES International, "Ethiopian Power System Expansion Master Plan", Final Report, Addis Ababa, January 2003, cited in the following as EEPCO/ACRES 2003

been in the planning now for more than 15 years. It started first with North Korean consultancy under the *dergue*, but encountered geological problems which brought the project to a halt.

After 1993, a re-planning set in financed by the World Bank. The first two of three 60 MW turbines started regular operation in February 2004, being 12 months behind schedule.

Construction of Ethiopia's first **independent power project (IPP)**, the 150 MW Gojeb HEP plant, commenced in 2002. Gojeb is being developed by the Saudi-based Mohammed International Development Research Organisation & Companies (MIDROC), one of Ethiopia's largest foreign investors. When the plant has been completed, MIDROC will sell the output to EEPCO.

However, since the large World Bank programmes have started in the early 90s, a gradual increase of electricity tariffs has been agreed upon, several steps of which have been enforced already.

Whether this is a wise strategy, as long as no sufficient and regular electricity services can be delivered by EEPCO, is questionable.

2.2.2 Fossil Fuel Sector

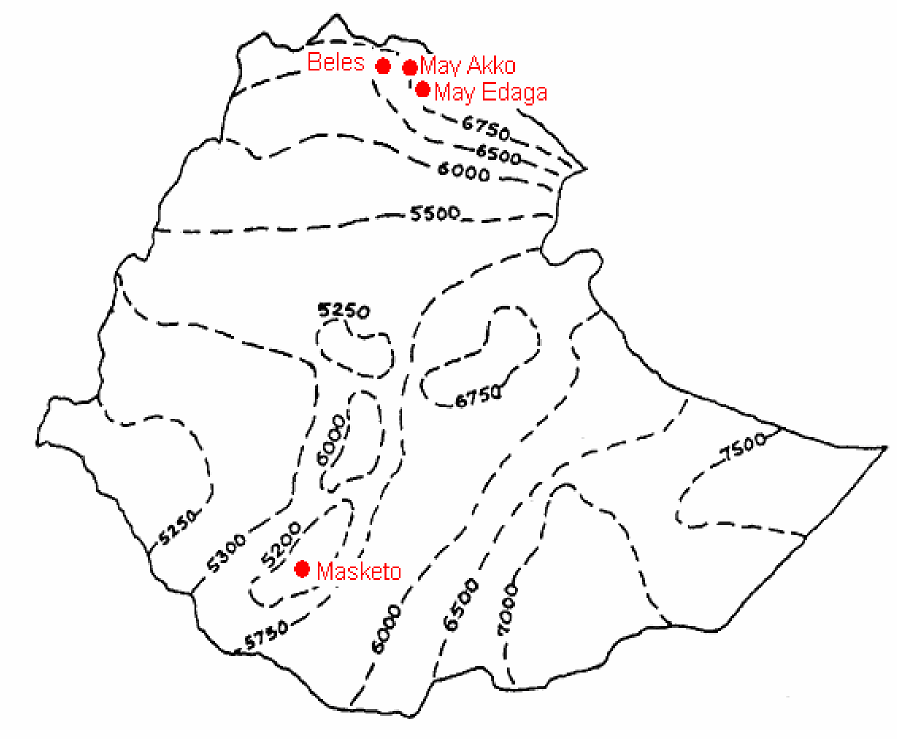
In the early 1970s, **gas fields** were discovered in the Eastern part of Ethiopia, contributing, among others, to the armed conflict with neighbouring Somalia. Being some 500 km away from the populated areas of Ethiopia in a desert with practically no infrastructure whatsoever, the Calub gas fields are difficult to exploit.

A contract for a second IPP, the 162 MW Genale HEP facility, was agreed with Enerco of the US in mid-2001.

To help speed expansion and improve efficiency in the sector, the government is considering a proposal to hand over EEPCO to private management for an initial period of between two and three years, although outright privatisation of what is viewed as a "strategic asset" is not in prospect.[13]

The company would not be viable without subsidies, as it makes a loss of around 35 % on the power that it sells.[14]

Figure 2-4:
Annual Solar Radiation in W/m² - Ethiopia



Source: Addis Ababa University (AAU), Faculty of Technology, Electrical Engineering Department, Study of Feasible Options for Rural Electrification in Ethiopia, Final Report Vol. II "Renewable Energy Resources an Technology", Addis Ababa August 2001

Of several development proposals over the years – the last one from the US firm Sicor in 1999 – none has been implemented. In late 2003, however, an agreement was signed with SIL of Jordan for the development of the Calub

13) personal information, Ato Engedasew Negash, Director of Corporate Planning, EEPCO, at present talks are held with the Austrian Technical Cooperation

14) The Economist Intelligence Unit (ed), "Country Profile Ethiopia 2004", London 2004, p. 27

gas reserves. SIL has signed a 25-year contract to invest 1.5 billion US$ for the construction of a gas-to-liquids plant at Dire Dawa with a capacity of **34,000 barrels per day** of petroleum products.

Given that current petroleum consumption is estimated at 23,000 b/d, the new plant would more than cover Ethiopia's requirements in the short term and would give a significant boost to the economy. However, given the record of failed developments at Calub, there is no certainty that the project will go ahead as planned.

In a separate development, Petronas (Malaysia) signed an agreement with the government in mid-2003 to **explore for hydrocarbons** in the western Gambella region, which is geologically related to oilfields in neighbouring Sudan.

Coal has been found in several parts of the country, among them in the North (Wuchale, Wello) and in the Southwest (Dilbi, Jimma and Illubabor). Its total capacity is estimated at more than 200 million tonnes.[15] Under consultancy from China, plans are evaluated to establish a fertilizer plant in combination with a coal-fired power generation plant in the range of 24 MW. Due to the poor quality of the coal, however, no soon progress on the project implementation can be expected.

All of Ethiopia's **fossil fuel requirements** are imported, entirely in form of refined petroleum products since the closure of the refinery in Assab in 1997, being formerly operated jointly by both countries.

15) Bekele Bayissa, "The Prevailing Fuel Crisis and Mitigating Measures", in: Professional Associations' Joint Secretariat (eds), Proceedings of Energy Conference 2002

2.2.3 New Renewables

Following the classification, where old renewables mean (large) hydro power and traditional biomass energy, the utilisation of new renewables in Ethiopia is, despite a considerable potential, at present practically nil.

The annual **solar irradiation** in Ethiopia varies, according to region, between 5,000 and 7,500 Wh/m^2 (for comparison Germany: ~ 1,700 Wh/m^2).

To use this considerable solar power of Ethiopia (slogan of the Ethiopian tourist bureau: "13 Months of Sunshine"), at present, only 450 kW of photovoltaic panels are installed – half of it for telecommunication purposes. Other applications, especially solar home systems are far less common in Ethiopia than in neighbouring Kenya; they are, in effect, solely disseminated through NGO or other donor funded projects.

Even though PV applications and particular **solar home systems** (SHS) must be regarded as a viable alternative to grid-based rural electrification, Ethiopia has not engaged to a wider extent to such programmes.

Figure 2-5:
Village Grid System by Photovoltaics – Mita with 31.5 kW

Source: EREDPC

Solar water heaters could meet a considerable demand in a country where, on account of altitude, only moderate ambient temperatures prevail where the majority of people live.

Wind energy, so far has only been used in wind pumping applications in the Rift Valley south of Addis. Of more than 100 units having been installed in the 1960s, about 70 wind mills are still operable and pump drinking water for a population of 120,000.[16]

A wind turbine with 2.5 kW installed capacity for an autonomous energy supply system at the EREDPC test and demonstration site (**Figure 2-7**). This unit had been installed within the Energy I Project of World Bank to demonstrate a small grid system, suitable for a village electrification based on batteries.

At the same site, a modern wind pumping system (Kijito from Kenya), solar water heaters and solar home systems have been installed in an attempt to familiarize EREDPC with these technologies.

Figure 2-6:
Wind Pump in the Rift Valley Region (close to Ziway)

Figure 2-7:
Wind Turbine of the Rural Energy Development and Promotion Centre, EREDPC (defective)

16) personal information Gianmarco Battaglia, responsible technician for the LVIA wind pumping project, February 2004

Installed in 1995, all this equipment is not functioning anymore today. In addition, the site has been surrounded by building and trees within the last years, as the town Addis Ababa has been enlarged. At present, on this site a three-storey building is erected, meant to be the new EREDPC office building. With the completion of this building, while allowing for short distances between office and demonstration site, these premises will become completely inappropriate as a site for the demonstration of new renewable technologies for rural development.

Another attempt for RE technology demonstration dates back to 1985: financed by the Italian cooperation, a village South of Addis Ababa was equipped with a 31.5 kW photovoltaic generator (900 modules) and inverters for a 220 V grid system (**Figure 2-5**). It was designed to cover the complete electricity needs of the village Mita, including water pumping, grain milling etc. While technically working correctly, the whole system was looted at the time of the downfall of the *dergue*.

Since then, attempts to rehabilitate the system have not been undertaken.

Also during the *dergue*, a biomass compacting and briquetting project was launched in Ethiopia, using technology from Denmark.[17] This project has been a complete failure with some of the delivered presses not even installed as planned. Since then, other projects involving modern biomass technology have not been carried out.

In Tigray, three photovoltaic pumping systems were installed within the framework of the GTZ project "Resource-conserving Irrigation with Photovoltaic Pumping Systems". While technically successful, the water usage of the pumps was far below expectations, rendering these systems economically inferior to competing diesel pumps.[18]

All in all, photovoltaic installations in Ethiopia are with approx. 450 kW extremely low.[19] Half of this capacity is used for the power supply of telecommunication devices, the rest mainly in government or NGO sponsored projects, such as rural hospitals, schools etc. A private market for solar home systems, such as in Kenya, is lacking in Ethiopia.

2.3 Energy Policy

No energy ministry exists in Ethiopia. Therefore, no single entity is responsible for formulating and enforcing energy policies and a lot of time and effort is spent in coordinating policies in the field of energy between these different ministries. This is viewed as a major disadvantage for an implementation of a comprehensive and appropriate energy policy in Ethiopia. [20] Some even speak of an "energy institution crisis" in Ethiopia.[21]

Instead, energy and natural conservation strategies are worked upon by several institutions, namely

- Ministry for Infrastructure;
- Ministry for Rural Development, and
- Ministry of Agriculture.

At present, a major reshuffle of responsibilities and mandates within these ministries is being discussed, a new structure is expected to be issued within the next months.

In the following, the general policies with regard to energy, environment and natural resources are discussed. These policies are not

17) see for instance KRIST-SPIT, C. E. and WENTINK, G. (1985), Suitability Tests of Briquettes from Ethiopian Agricultural Residues, TNO, Netherlands Ref. Nr 85011883.

18) BoANR/GTZ (B. Jargstorf), "Photovoltaic Pumping Systems for Irrigation of Tree Nurseries – Ethiopia. Evaluation after three Years of Operation", Wismar 2001

19) Energy Alternatives AFRICA, Ltd. (Mark Hankins), "IGAD Ethiopia - PV Solar Home System Market Study, The Potential for Commercial PV as a Complementary Tool for Rural Off-Grid Electrification", Nairobi, October 2000, p. 5

20) for example by the Ethiopian Network for Sustainable Energy Development (ENSED) in its Newsletter No. 1, Vol. 1, from October 2003, p. 3ff, or by

21) Ato Amare Hagdu, Consultant to EREDPC in an article in the newspaper "Capital" from 07th July 2003 (see **Annex 3**)

likely to being changed, even under a major ministerial reshuffle, as is underway at present.

The major formulated policies in Ethiopia are

- the National Energy Policy;
- the Environmental Policy;
- the Conservation Strategy of Ethiopia;
- the Ethiopian Forestry Action Plan, and
- the National Population Policy.

The Conservation Strategy of Ethiopia was approved in 1997 and includes the following points that are related to the energy economy of the country.

- provide technical and social research on the design of improved cooking stoves;
- promote local manufacture and distribution of improved charcoal and biomass stoves; and
- locate, develop, adopt or adapt energy sources and technologies to replace biomass fuels.

Similarly, under article 3.5 of the Environment Policy of Ethiopia, regarding energy sources, the following policy statements are provided:

- adopt an inter-sectional process of planning and development which integrates energy development with energy conservation, environmental protection and sustainable utilisation of renewable resources;
- promote the development of renewable energy sources and reduce the use of fossil energy resources both for ensuring sustainability and for protecting the environment, as well as for their continuation into the future.

Regarding forest, woodland and tree resources; the following are provided under article 3.2 of the policy:

- ensure that forestry development strategies integrate the development management and conservation of forest resources with those of land and water resources, energy resources, ecosystems and genetic resources, as well as with crop and livestock production; and
- find substitutes for construction and fuel wood whenever capabilities and other conditions allow, in order to reduce pressure on forests.[22]

In general, all the sectoral policy objectives and strategies focus on the integration of energy development with energy conservation, environmental protection and sustainable utilisation.

While all these policies, strategies and action plans are theoretically well focussed on the main problems in the Ethiopian energy sector, unfortunately, efforts in implementing them are far from adequate. As could be seen by the amount of money spent for different energy technologies (**Section 2.1.1**), practically all efforts within the energy sector are directed towards the electricity sector, and there exclusively to the standard grid-connected electrification by means of large hydro power plants.

Some critics go so far, as to point out that during the *dergue* especially the policies in the traditional energy sector were more closely followed and more effectively implemented as under the current government.[23]

In summing up the energy policy of Ethiopia one has to notice the absence of a coherent policy first and foremost visible through the lack of a single ministry in charge of energy aspects in the country. Secondly, as is the case with policies and strategies in other social and economic areas of Ethiopia, there exists a striking dichotomy between formulated policies or action plans and the reality, especially with regard to rural areas. While wide-ranging strategies for the dissemination of renewable energies, or for energy-saving cook stoves exist, its implementation is not being pursued as needed. If at all, individual bilateral or NGO sponsored projects take care of isolated aspects of the national energy policy.

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22) Getachew Olana, “Some Socio-economic Aspects of Biomass Energy in Ethiopia: A Review” in: Professional Associations’ Joint Secretariat (eds), Proceedings of Energy Conference 2002, p. 109

23) Megen Power (MGP) Ltd., “Profile of Household Energy in Ethiopia”, Ministry of Agriculture / GTZ-Household Energy / Protection of Natural Resources Project, Addis Ababa 1998

An evaluation of papers dealing with energy policy in the country shows clearly, that everywhere the same reasons for the lack of implementation efforts are cited:

- lack of funds and lack of transport, as well as
- a general lack of managerial skills on all levels of the public service in Ethiopia.

2.4 Institutions / Companies in the Field of Energy

2.4.1 Ethiopian Rural Energy Development and Promotion Centre (EREDPC)

The Ethiopian Rural Energy Development and Promotion Centre (EREDPC) is a government institution engaged in adaptive research, development and dissemination of appropriate technologies.

The centre was established by proclamation no. 269/1994 by the Ministry of Agriculture and Rural development. As of the time of writing, the centre had about 100 employees of which 42 are support or sub-professionals.[24]

EREDPC mandate focuses on four major areas:

1. enhance and diversify rural energy supplies;
2. develop and disseminate resource conserving appropriate technologies;
3. maintain a nation-wide data base on energy resources, supplies and demand;
4. develop the capacity of regional energy bureaux.[25]

On-going projects of EREDPC include, among others,

- trials on energy tree production
- development of efficient charcoal kilns and production of charcoal from agricultural residues (such as cotton stalks, coffee husks etc.)
- energy sector assessment for Northern Ethiopia (Amhara and Afar regions)
- demonstration of biogas plants
- setting up a Mobile Exhibition on Renewable Energy in Ethiopia[26]

Since 2003 EREDPC is the responsible secretariat of the Rural Development Fund, financed within the frame of the World Bank Energy II Project.[27]

This Rural Development Fund emphasizes on the promotion of private, cooperative and local communal engagement in rural electrification activities through loan based finance and technical services specifically for those projects operating on renewable energy sources. The fund serves as a source of finance to any commercial-based off-grid rural electrification undertakings.

As the implementing organ of the Fund EREDPC has the following powers and duties:

1. to review applications from rural electrification project operators and decide on the applications;.
2. to prepare for approval transparent directives, selection criteria and procedures to be used in the issuance of loans and identification of appropriate rural electrification projects.

24) Foreword of Asress W. Giorgis, Director EREDPC to GTZ/EREDPC (eds.), “Renewable Energy & Development, Brochure to accompany the Mobile Exhibition on Renewable Energy in Ethiopia” Addis Ababa, April 2004

25) from a leaflet of EREDPC and Ministry of Rural Development (MRD), March 2002 (see **Annex 4**)

26) supported by GTZ self-financed measure (Eigenmassnahme) Processing No. 2002.9231.8

27) See World Bank, Report No. PIC5051, Ethiopia Energy II Project, Project Brief April 28, 1997. The main components of Energy II are: (i) power sector reform program in Ethiopia; (ii) construction of the Gilgel Gibe Hydroelectric Plant (180 MW); and (iii) improvement in utilization of rural renewable energy, mainly through the Rural development Fund.

Approved projects have to be licensed by the Ethiopian Energy Agency (see **Section 2.4.2**). The agency shall apply relevant laws to issue, renew, terminate and revoke licenses for rural electrification projects.

A total of US$132.7 million from the International Development Association, in association with US$4.93 from the Global Environmental Facility Trust Fund has been approved for the Energy Access Project. In total, this project has 5 components, namely

1. institutional and capacity building;
2. urban distribution and load dispatch;
3. rural electrification;
4. biomass, and
5. environmental mitigation.[28]

Apart from being the secretariat of the Rural Development Fund, EREDPC is going to play an important role for components 3 and 4, details of which are currently being negotiated.

2.4.2 Ethiopian Energy Agency

This regulation agency has been established in 1997, in order to regulate and co-ordinate activities in the energy sector and to "promote efficient, reliable, high quality and economical electricity services".[29]

The major duties of the Ethiopian Energy Agency (EEA) are

- supervision of generation, transmission, distribution and sale of electricity;
- determination of the quality and standards of the electricity services;
- issuance of professional competence certificates;
- study and recommendation of tariffs.

In Ethiopia, all generation, transmission, distribution, as well as sale, importation and exportation of (commercial) energy requires licensing, and, thus, the involvement of the Ethiopian Energy Agency.[30]

2.4.3 The World Bank Group

Ethiopia joined the World Bank Group in 1945. Since then, a total of 87 credits have so far been approved, totalling US$3.1 billion in disbursements. Currently the portfolio comprises 19 active projects in all major sectors with commitments of US$1.8 billion.[31]

Of this sum, 41 % are invested in the infrastructure sector, a majority of which goes to electricity/energy projects. With 28 %, emergency relief funding comes second.

The Country Assistance Strategy (CAS) for Ethiopia, covering the financial years 2003-05 includes, among others, a Poverty Reduction Support Credit, a Water Supply and Sanitation Project, and the Public Service Delivery Capacity Building Program (PSCAP).

To increase the effectiveness of the aid that Ethiopia receives, the Government and donors, under the auspices of the local Development Assistance Group (DAG), are actively engaged in working to harmonize the ways in which the various donors provide their assistance. These efforts include the alignment of donors' development assistance strategies with a common policy matrix, and synchronization with the Government budget cycle following the Ethiopian fiscal year.

Furthermore, the shift from project-based assistance to direct budget support by a number of donors is expected to reduce transaction costs, enhance the significance of the national budget, increase predictability of aid, and augment mutual accountability processes.

Also the International Finance Corporation (IFC), the Multilateral Investment Guarantee Agency (MIGA) and the World Bank Institute (WBI) are involved in Ethiopia.

28) World Bank, Report No. PID11060, Energy Access Project Brief, Bank Approval Date June 25, 2002

29) Ethiopian Electricity Agency, Information and Public Relations Service, p.7

30) For details, see **Section 3.5** Legal Framework

31) the following information from World Bank documents and the Bank's official web site: http://www.worldbank.org/afr/et/ctry_brief.htm

In the energy sector, major activities of the World Bank Group concern the Energy Access and the Energy II Project, as mentioned in the previous sections.

During a visit at the local World Bank office in Addis Ababa on March 09 2004 possible TERNA activities in Ethiopia were discussed with the energy desk officer, Ato Yussuf Haji Ali. The preliminary findings of the information for project proposal mission were presented and met by concise interest.

The energy responsible of World Bank in Ethiopia indicated his interest to participate in the wind park financing should a full-fledged feasibility study confirm the preliminary figures with regard to wind regime, unit costs of electricity and suitability of wind power to complement hydro power in Ethiopia.

2.4.4 Private Companies

According to a recent study within the private sector, 25 private companies were identified in Addis Ababa region which deal with renewable energies.[32]

Of these 25 companies – listed in full in **Annex 5** – only 3 indicate experience with wind power applications: however, exclusively wind pumps.

Two of these companies, namely Selam Technical and Vocational Centre and Equatorial Business Group have actually manufactured and installed wind pumps. The third company, IZUR only imported one wind charger (50 W) to use it as en "eye catcher" on its workshop in Addis Ababa.

Selam and Equatorial Business Group cooperate in the field of wind pumps. Since 1996, they both gained experience working for, and paid by, L.V.I.A. Co-operation Centre, an Italian Non-Governmental Organization.

Today, Equatorial Business Group offers two different wind pumps, one manufactured locally (6 m rotor diameter, 18 blades) with a maximum water lifting capacity of 18.000 l/h at 4.5 m/s wind speed at hub height. Of this type, three units have been installed so far. The other wind pump is imported from India (tower manufactured locally) and has a maximum capacity of 6.000 l/h. However, none of this type has been installed so far.

All in all, the private sector in Ethiopia is only slowly gaining experience with renewable energy appliances, primarily solar home systems and solar water heaters and, to a lesser extent, photovoltaic pumping and refrigeration systems.

Wind power applications (apart from very few wind pumps) are limited to a few wind chargers, practically exclusively employed in donor projects.

Major constraints for the dissemination of renewable energy systems can be identified, according to the view of the consultant, in high import duties and taxes for imported RE applications, the lack of knowledge about renewable applications and what they actually can provide and, last but not least, the low level of buying power in rural areas of Ethiopia.

2.4.5 Private Individuals

With only very little renewable energy applications working in the country, the know-how base for wind and solar engineering requirements stretches from very basic to non-existent. In spite of several training courses on renewable energy technologies in recent years – such as a part of the World Bank Energy I project and others – in the absence of actual working RE technologies in Ethiopia, no practical expertise could be gained.

In addition, a large number of government employees, after having been trained in solar and wind technologies, have left government ser-

32) Address List of Companies and Institutions, working in the field of Renewable Energies in Ethiopia, based on the work of Jan Philipps, trainee with the GTZ Household Energy/Protection of Natural Resources Project in September 2003, see **Annex 5**

vices and are working for donor projects or opened up their own businesses.[33]

In fact, the "exodus" of better qualified experts from government service to donor funded projects in Ethiopia has been so great lately, that it is the policy of the GTZ office in Addis Ababa now to not accept any job applications from civil servant posts.[34]

Looking for a consultant for renewable energy in Ethiopia during the first quarter of 2004, only one candidate offered his services. It turned out that this former ELPA employee did not really have any practical experience with renewable energies.[35]

Under this situation, capacity building for the planned wind park both among EEPCO personnel and in the private sector remains a high priority. Therefore, both EEPCO and the interested public during the "National Symposium on Renewable Energy in Ethiopia" have been informed by the consultant about the training course offered to participants from Africa by InWEnt, Capacity Building International, to start in September 2004.[36]

In summing up, it must be said that a project planning procedure for large grid-connected wind parks in Ethiopia will have to rely to a large extent on foreign consultancy expertise.

33) some of the 25 companies listed in the previous **Section**, have been founded or co-founded by ex-civil servants from Ethiopian energy institutions.

34) Personal information, Winfried Zarges, GTZ programme director for Food Security and Protection of Natural Resources, February 2004

35) See **Annex 6** for the Curriculum Vitae of this expert.

36) See **Annex 8** for an announcement of this course, as well as for the programme of the RE symposium.

3. Electricity Sector

The Ethiopian electricity sector knows only one utility company: The Ethiopian Electric Power Corporation (EEPCO), which is a public agency and responsible for the generation, transmission, distribution and sales of electricity throughout the country. The corporation maintains two supply systems, the Interconnected System (ICS) and the Self-Contained System (SCS).

3.1 Interconnected System (ICS)

3.1.1 Description

The Interconnected System (ICS) has a total installed generation capacity of about 400 MW and an average energy capability of about 1850 GWh/yr. However, the dependable capacity is reduced to less than 360 MW due to de-rates. Six hydroelectric plants and eleven thermal plants provide this capability.

Demand on the Interconnected System is concentrated in the cities of Addis Ababa, Mekelle, Nazareth, Dire Dawa, Harar and their immediate surroundings. Even with a number of major ICS extensions in recent years, these four cities still form the base of the ICS with nearly 70% of total ICS sales. Addis Ababa is by far the largest single consumption centre in the system and itself accounts for half of the sales on the ICS. ICS sales exhibited an annual growth rate of 7.9% in the late 1960s, but the rate fell to approximately half this value (3.6%) between 1973 and 1978 reflecting a slowdown in the economy during the initial period of the *dergue*.

Between 1978 and 1990, there was an average sales growth of 6.7% per year on the base ICS, despite of tariff increases and an absolute decline in consumption in 1984. Extensions to the base ICS centres (to Shashemane, Dessie, and many others) from 1978 to 1990 added an additional 1.9% per year to the overall average sales growth bringing the total annual growth on the ICS to 8.6%. Total ICS growth since 1990 has averaged 4.8%, of which 3.1% has been associated with growth in the base ICS while growth on the earlier extensions and additional sales through new extensions (to Bahir Dar, Mekele, etc) have provided an apparent ICS growth average of 10.5% per year.

3.1.2 Consumption by Category

Patterns of consumption on the ICS have shown consistently higher growth in the residential, commercial and small industrial categories than in large industry.

About 37% of total sales is accounted for by domestic consumption, being a typical distribution for a poor developing country with underdeveloped industrial and commercial sectors.

Domestic Sales

Average growth of domestic sales on the ICS from 1990 to 1999 is 6.8% per year. Addis Ababa accounted for nearly 76% of domestic sales in 1990; however, this proportion dropped to 66% by 1999 in response to strong domestic growth in the existing extensions and the domestic consumption at the new branches.

Commercial Sales

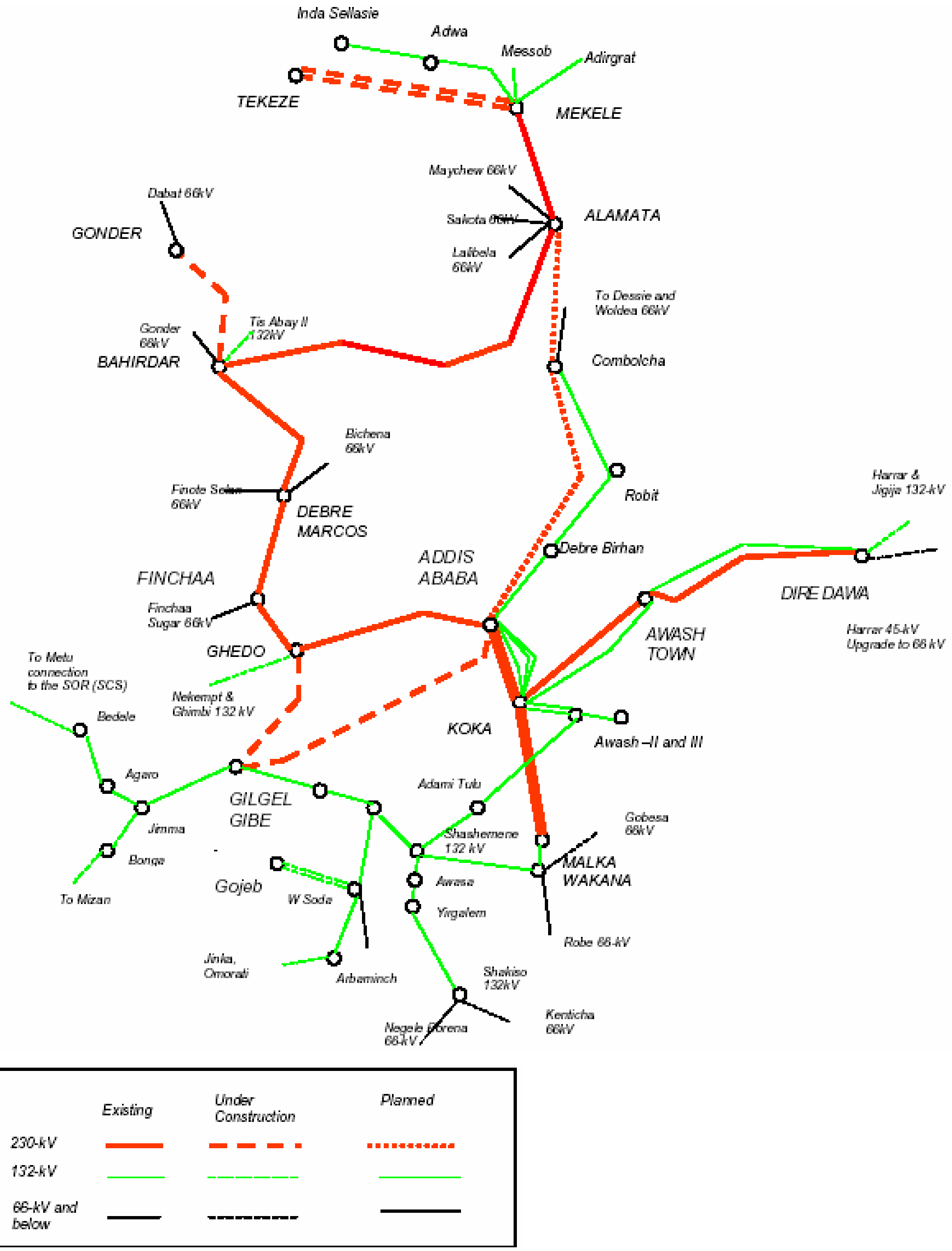
The average annual growth of commercial sales on the ICS from 1990 to 1999 is 13.6%. The proportion of these sales which occurred in Addis Ababa remained essentially constant at about 60%. The proportions in the remainder of the Base ICS, however, dropped.

Industrial Sales

Industrial sales were essentially stagnant from 1990 to 1999. The changes to the industrial tariff structure over the period make comparisons by categories meaningless.[37]

37) EEPCO and ACRES 2003, p. 4-6ff

Figure 3-1: Existing and Planned Transmission System



Source: EEPCO and ACRES International, "Ethiopian Power System Expansion Master Plan", Final Report, Addis Ababa, January 2003, Figure 3.4

3.1.3 Transmission System

The existing transmission system comprises about 6,447 km of transmission lines, 1,715 km of which are at the 230 kV level, 2,514 km at the 132 kV level, 1,742 km at the 66 kV and 475 km at the 45 kV voltage level.

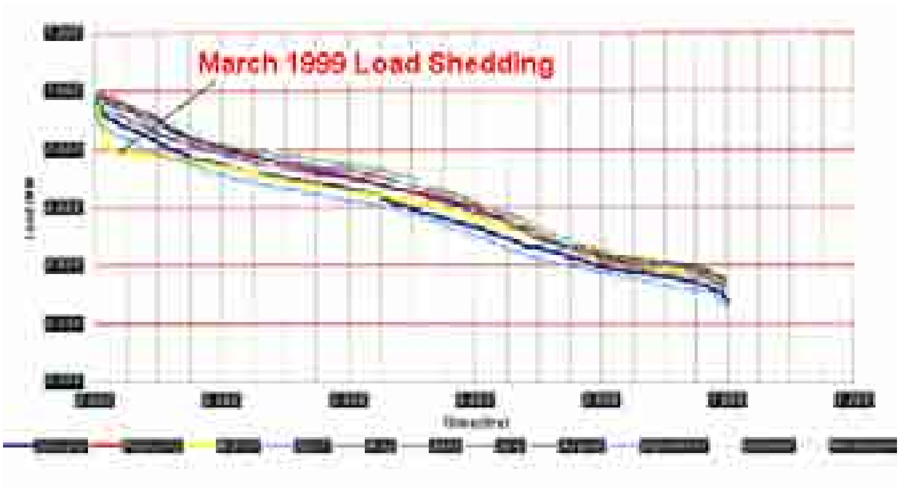
The 230-kV system extends from Addis Ababa about 400 km eastward to Dire Dawa, south to Melka Wakena and about 1,000 km toward the west and north (**Figure 3-1**). The 45-kV system is not being extended further. Some sections of the 66-kV and 45-kV system are not in use. Some areas of the above system are operated as Self-Contained Systems (SCS) being remote from the main grid.

There is a total of 104 transmission substations in the system, of which 10 are at 230 kV, 45 at 132 kV, 26 at 66 kV, and 23 stations at the 45 kV level. Substation layouts are based on the double bus concept at the major generating stations and single bus at many other stations. About 211 MVAr of reactors are used to control the voltage levels on the system, particularly at light load conditions. Of these reactors, 9 are at the 230-kV level, 4 at the 132-kV level and 6 at the 15-kV level. The reactive power situation in the transmission system is an important factor for the operation of large wind parks with standard induction generators.

The major load centres are Addis Ababa, Nazareth, Dire Dawa, Harar and Bahir Dar. The Addis Ababa load centre accounts for over 60% of the total demand. There are presently two 230 kV substations, namely Gefarsa and Kaliti-I. These two substations are connected by two 132 kV lines. Two 230 kV, seven 132 kV and six 45 kV substations feed the Addis Ababa Region loads.

According to **Figure 3-3**, the peak demand in the ICS has increased by 55.2 % during the last 10-year period, practically exactly as did the electricity demand, which grew by 53.4 %. These figures, however, do not represent real values, because, since spring 1999, EEPCO could not serve the demand at the end of the dry season.

Figure 3-2:
Load Duration Curves for 1999 – Load Shedding



Source: EEPCO and ACRES International, "Ethiopian Power System Expansion Master Plan", Final Report, Addis Ababa, January 2003, Figure 3.3

Figure 3-3:
Historic Loads and Energy Demand

Fiscal Year	Energy Demand (GWh)	Annual Growth Rate	Peak Demand (MW)	Annual Growth Rate
1994	1319	9.1 %	261	7.9 %
1995	1402	6.3 %	282	8.0 %
1996	1496	6.7 %	287	1.8 %
1997	1552	3.7 %	295	2.8 %
1998	1565	0.8 %	318	7.8 %
1999	1619	3.5 %	328	3.1 %
2000	1689	4.3 %	327	-0.3 %
2001	1812	7.3 %	352	7.6 %
2002	2009	10.9 %	391	11.1 %
2003	2064	2.7 %	405	3.6 %
10 year		**53.4 %**		**55.2 %**

Source: EEPCO and ACRES International, "Ethiopian Power System Expansion Master Plan", Final Report, Addis Ababa, January 2003, Table 3.1 up to 1999, then own compilations based on EEPCO Facts & Figures

A nation-wide load shedding had to be introduced in 1999, which lasted, in some years, more than two months. As an example, the load duration curves for the year 1999 are given: one can see clearly, how the suppressed demand altered the shape of the curve for March (yellow) in **Figure 3-2**.

Looking at the historic data it becomes clear, that the new economic policy of the Government of Ethiopia shows effect on the electricity demand in recent years. The ACRES study had data up to 1999 – so from 2000 to 2003 they had to predict the demand according to their forecast models. When we compare the forecasted and the actual figures, we see that the ACRES figures are nearly accurate for the peak load (**Figure 3-4**).

Figure 3-4:
Forecasted and Actual Energy Demand & Peak

Fiscal Year	Energy Demand in GWh		Peak Load in MW	
	forecast	actual	forecast	actual
2000	1,616	1689	325	327
2001	1,784	1812	351	352
2002	1,911	2009	376	391
2003	2,065	2064	406	405
	5,760	7,574		
4 year		**31.5 %**		

Source: Own compilation on the basis of Figure 3-3 and ACRES, Table 10.1 (a)

However, ACRES has underestimated the energy demand by nearly 32 %, because they did not take into account correctly the extent of load shedding and - we might conclude - the actual increase in electricity demand. Even though the data covers only a 4 year period, we can conclude that the basic forecast tools of ACRES do not accurately model the Ethiopian situation.

Of course, when we have such an excessive load shedding as encountered during the past 5 years, we have to deal with a considerable suppression of peak load. It is obvious that – without load shedding – a higher peak load would have occurred. In the same way, when we already register an electricity demand in the 4 year period which is 32 % higher in times with considerable load shedding, the unsuppressed demand would have been much higher than ACRES has forecasted.

When working with the ACRES demand forecasts as put forward in the System Expansion Master Plan we have to bear in mind that this forecast is underestimating the current development taking place in Ethiopia. In any case, the ACRES study has not been officially committed. Most likely, some of the forecast figures are being recalculated in view of recent developments.

3.2 Self Contained System (SCS)

The self contained system is not – in a true sense of the word – a single system, but consists of several individual isolated electric grids which are treated by EEPCO under one heading. In practice, however, the characteristics of the individual electric grids are completely different, i.e. they can be supplied by diesel power plants ranging from kW to MW size, or by hydro power, or by a combination of both.

In 2003, the aggregate capacity of the diesel generators in the SCS was 14.6 MW, while the total hydro power capacity amounted to 6.1 MW. Only 2 % of the total energy demand was generated in the SCS, the remaining in the ICS.

There is a tendency that larger isolated grids within the SCS are to be connected to the ICS, while smaller ones are left out. Therefore, even if we were able to identify an existing isolated grid within the SCS suitable for grid-parallel operation of wind turbines, it would be likely to be connected to the ICS soon. Under this situation, we will not deal in more detail with the individual situation of the SCS grids, but concentrate on the possibilities to operate large wind parks in parallel with the ICS, even though the specific generation costs in the SCS are generally much higher than in the ICS.

In addition, the daily load curves in the SCS have extreme minimum to maximum ratios, allowing only relatively low wind power installations in standard grid-parallel operation, and, consequently, low penetration rates.

3.3 Generation

3.3.1 Current Situation

At the end of 2003, the ICS had a total installed generation capacity of about 478 MW and an average energy capability of about 2000 GWh/yr. However, the dependable capacity is reduced to about 460 MW due to derating of the nominal installed capacities. The average annual load factor, according to **Figure 3-5**, amounts to 50 %.

Seven hydroelectric plants, ten thermal plants and one geothermal power plant provide EEPCOs generating capacity.

In the first quarter of 2004, an eighth hydro power plant – Gilgel Gibe – has started operation, at present with two of three 60 MW turbines. This gives, for the time of writing, a total dependable capacity in the ICS of 500 MW. However, only after the height of the dry season - end of May, June – one will see, whether Ethiopia will not again experience load shedding, as in the 5 years before.

Figure 3-5:
Generation by Source and Capacity Factors (2003)

	Installed Capacity (MW)	Commission Year	Annual Production (MWh)	Plant Peak (MW)	Capacity Factor
Hydro					
Koka	43.2	1960	58,357	33	20.2 %
Awash I	32	1966	97,797	28	39.9 %
Awash II	32	1971	108,924	32	38.9 %
Finchaa	134	1973/2003	969,660	130	85.1 %
Melka Wakana	153	1988	312,186	153	23.3 %
Tis Abay I	11.4	1964	14,202	11	14.3 %
Tis Abay II	73	2001	445,969	73	69.7 %
Sub Total Hydro	**478.6**		**2,007,095**	**460.3**	**49.8 %**
Geothermal					
Aluto Langano	7.3	1999	0	0	0.0 %
Diesel					
10 Plants	19.2	1954-1998	21,105	12	20.1 %
Total ICS			**2,028,200**	**472.3**	**49.0 %**
Total SCS			**35,500**		
Total EEPCO			**2,063,700**		

Source: EEPCO Facts & Figures 2003, own compilation

In **Figure 3-5** one can see how the total electricity generation of 2,065 GWh was met predominately by hydro power. Looking at the hydro power plant's **capacity factor**[38], however, the major problem of Ethiopia's generation base becomes obvious: the low capacity factor of the majority of hydroelectric plants.

3.3.2 Low Capacity factor

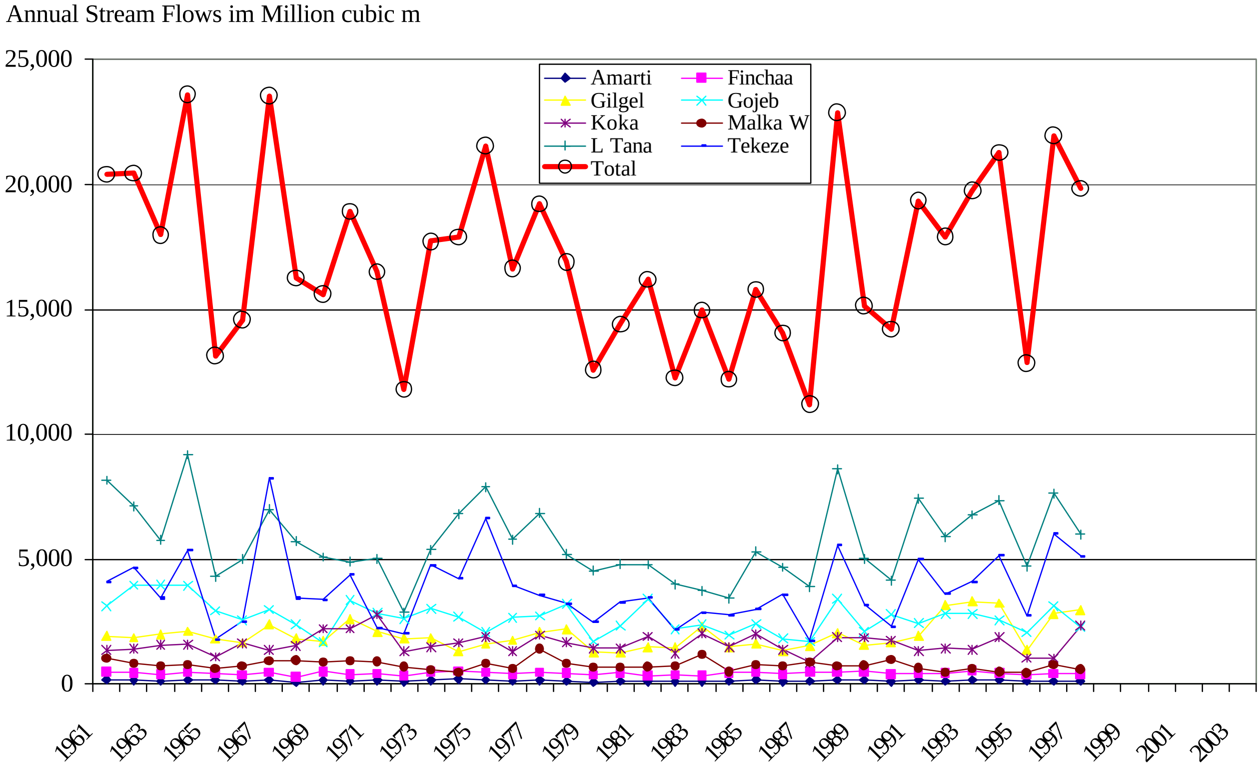
Under normal operation, a hydro power plant is designed for base load in a way that it should, theoretically, produce nominal power practically throughout the year. Realistic capacity factors of well-run hydro power plants lie in the range above 75 %. In Ethiopia, however, only two of seven plants reach these values.

Of course, there can be several reasons for the low capacity or plant factor: long outage times on account of maintenance or repair, reduced carrying capacity of the transmission lines etc. The main reason in the case of Ethiopian hydroelectric plants is a combination of low level of maintenance (look at the commission date in **Figure 3-5**), high variability of precipitation and the increasing siltation of the reservoirs.[39]

38) the **capacity factor** of an electric generation plant is defined as the actual (annual) production in MWh divided by the theoretical production in MWh, being the firm capacity of the plant in MW multiplied by 8760 hours (= one year)

39) Normally, siltation of a high dam reservoir is counteracted through opening of sludge gates at regular intervals, thus draining the reservoir, during times of high water levels. In Ethiopia, however, this "maintenance" has not been done in all cases. Personal information by EEPCO workers from Koka dam, 2001.

Figure 3-6:
Variability of Stream Flows at Rivers for Hydro Plants



Source: ACRES 2003, modified

This siltation is responsible for the reduced working capacity of the water reservoirs, and thus, in a final analysis, for the load shedding in recent years.

The cutting down of trees and over-utilisation of agricultural lands around the reservoirs must be regarded as one of the major causes for the siltation processes, which becomes more and more obvious through the capacity factors of the older power plants'.

3.3.3 High Variability of Rainfall

The other reason for the reduced capacity factor, and, consequently, the reduced economic benefit of the hydro power plants, lies in the high variability of rain fall, being typical for this region of Africa. In **Figure 3-6** the available data since 1961 are compiled for 9 different rivers, some of them not yet equipped with hydro power plants.

One can see that the minimum of accumulated stream flow lies at about 12,000 million m^3 and the maximum at 23,000 m^3. While this high ratio is remarkable by itself, the fact that a minimum year can be followed by a maximum year is remarkable (see 1988 and 1989 in **Figure 3-6**).

It shows that, in Ethiopia, it is practically impossible to construct a hydroelectric power plant with a reliable economic performance: If one would design the installed capacity according to the absolute minimum of stream flow, the installed capacity would be too low and render the construction uneconomical. If you take the mean value of a stream flow for a given river, you have to be aware that quite often the calculated energy demand cannot be generated, on account of lack of water.

In practice, this high variability of precipitation means a reduced economic value of the investment in hydro power, since the firm capacity varies from year to year.

Figure 3-7:
Soil Erosion close to Hydro Power Reservoir

Source: Prof. Dr.-Ing. G. Förch, Prof. Dr. Britta Schütt, Research Centre of Water Resources Management and Environment, University of Siegen, “Management of Natural Resources”, Presentation held at Awassa Agricultural College, 2001

Furthermore, since the lack of a **sound watershed management** upstream of the reservoir leads to a gradual siltation behind the dam. As a result, the working capacity of the dam is reduced in addition year by year over time. To compensate this situation Ethiopia would need to introduce a radical change in the environmental policy, not only in the watershed of the existing and planned hydro power projects, but everywhere in the country.

This would include in particular:

- to stop the felling of trees for building construction and fire wood;
- to plant new trees to reduce soil erosion and top soil losses;
- to revert to sustainable agriculture not only in the watershed of hydro power plants, so that top soil losses do not occur in such an alarming rate as it does today;
- to start a sound watershed management simultaneously with the planning of any new hydro power scheme as well as for the existing ones.

As these combined measures are not likely to be implemented as strictly as the grave environmental situation in Ethiopia would require, EEPCO is likely to install more and more (expensive) hydro power plants with capacity factors that experience **wide fluctuations** and a gradual decline over time on account of siltation.

Under these conditions the combination of hydro power plants with large wind parks has evident advantages, since

- hydro and wind resource are absolutely complementary (**see Section 6** Wind Resource);
- wind power can act as a “water saver” and thus avoid load shedding at the end of the dry season, and
- the economic value of (all) the hydro power investment can be augmented through a relative limited investment in wind power generation.[40]

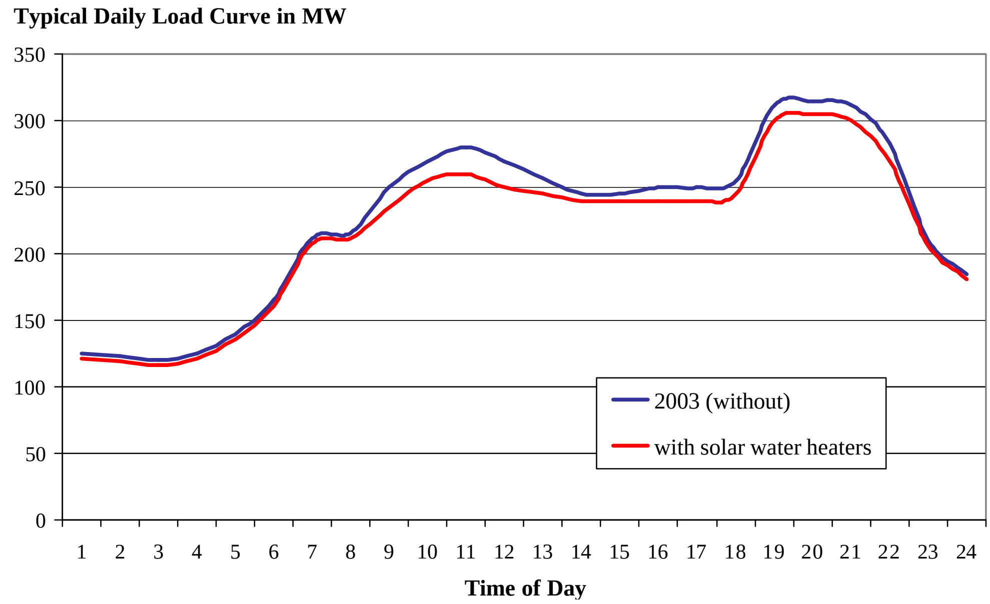
40) this hypothesis will be discussed in more detail in **Section 7.3.5** (Comparison with Hydro and Thermal Options)

Figure 3-8:
Number of Customer according to Tariff Category (ICS+SCS)

Tariff Category	1998/99	1999/2000	2000/2001	2001/02	2002/03
Domestic	486525	508407	534106	559205	597976
Commercial	78619	78899	81794	85913	90167
Street Light	881	918	970	1043	1207
LV Large Industry	7956	7926	8121	8180	8444
HV Large Industry	96	89	94	99	96
Own Consumption	329	398	411	445	470
Total	574406	596637	625496	654885	698360

Source: EEPCO, Facts & Figures 2003

Figure 3-9:
Daily Load Curve and Replacement of Electric Boilers



Source: EEPCO, EEPCO, own calculations, basis: replacement of 80,000 electric boilers of 1.2 kW each with solar water heaters

3.4 Consumption

3.4.1 Overview

Currently, EEPCO serves close to 700,000 customers, of which nearly 600,000 are domestic customers, the rest are commercial, industrial and street light customers (**Figure 3-8**).

This is a typical situation for many utilities in developing countries: the great majority of customers are domestic, often with special social low-consumption tariffs.

Energy sales in 2003 were 1,706,800 MWh, out of a production of 2,063,700 MWh (= 82.7 %). Out of this roughly 600,000 MWh (35 %) were domestic sales, 400,000 MWh commercial and the rest industrial sales.

Approximately half of all domestic consumers live in the Addis Ababa region. When the EEPCO/ACRES study was started in 1998, a wait list of some 124,000 customers was estimated. By mid 2000, no further backlog of customers awaiting connection was observed.[41]

The average consumption per customer had risen steadily after 1991 from 925 kWh to more than 1,300 kWh per year. However, tariff increases in recent years have reduced the specific consumption to about 1,100 kWh per customer.

In conclusion a note of caution: these figures are compiled figures and do not really represent the actual consumption per customer. It is estimated that in some urban settings two families are connected to one meter, thus the effective consumption per customer would be halved. Apart from connecting two or more households to one meter, pilfering of electricity is wide-spread in Ethiopia.

41) EEPCO/ACRES 2003, p. 4-19

3.4.2 Demand Side Management

Even though household appliances become more and more easily available in Ethiopia, by far the largest electricity consumption is for lighting. Unfortunately, most of the lighting is by incandescent lamps with low energy efficiency, while fluorescent lamps (compact fluorescent lamps, CFL) are not yet widely in use.

In the 1980s, surplus hydro power led the predecessor of EEPCO (EELPA – Ethiopian Electric Light and Power Authority) to introduce special electric boiler tariffs. This has been revoked, since surplus energy is no longer available.

It is estimated that EEPCO could considerably reduce peak load and general consumption through the introduction of demand side management, for instance with solar water heaters or CFL.

Figure 3-9 demonstrates, how the load curve of the ICS could be influenced through the replacement of 80,000 electric boilers with domestic solar water heaters.

Other demand side management actions are thinkable, in particular for the further dissemination of compact fluorescent lamps.

In doing so, EEPCO could greatly increase its efficiency and performance. It is proposed that, alongside with the further detailed planning of the integration of the wind park into the existing grid, demand side management options should also be considered.

3.4.3 Load and Demand Forecast

The EEPCO/ACRES Power System Expansion Master Plan (PSEMP) has forecasted the demand in the Ethiopian ICS until the year 2025. Different scenarios have been made with varying assumptions, which are not appropriate to be discussed within the scope of this study.

However, the basic approach of the load forecast is to be described here shortly: Using the further construction of large hydro power plants as the generation base, the Power System Expansion Master Plan proposes a moderate development of existing and new geothermal plants and large thermal power plants to fill the gaps.

These gaps are, according to the Power System Expansion Master Plan, unavoidable, because the planning and construction of a hydro power plant takes a certain time.

In **Figure 3-10** this approach is illustrated: for a proper operation, EEPCO always needs a reserve capacity – approximately 15 to 20 % in excess of peak demand. In the year 2015, according to the Power System Expansion Master Plan, this reserve capacity cannot be supplied by hydro power plants, since only four years later a larger plant is scheduled to go online.

This capacity gap is going to be filled through large thermal power plants of the combustion turbine type, having been identified as the least cost alternative within the Power System Expansion Master Plan.

In the same way, the electricity generation according to source is shown in the diagram of **Figure 3-11**. One can see that, starting in 2015 thermal power plants are needed. They are expected to contribute up to 1,000 GWh annually.

We do not want to go into much detail about the applied methodology for the Least Cost Expansion Plan.[42] But it is argued here, that the **installation of additional large thermal plants in Ethiopia can be avoided** – and, simultaneously, the emission of large amounts of CO_2, the dependency from fuel imports and the environmental impact of the transportation of large quantities of fossil fuels from the coast to the land-locked country.

As a first hypothesis, large wind parks could be at the core of an **alternative expansion strategy**, flanked by demand side management and other appropriate measures to reduce electricity consumption in the country.

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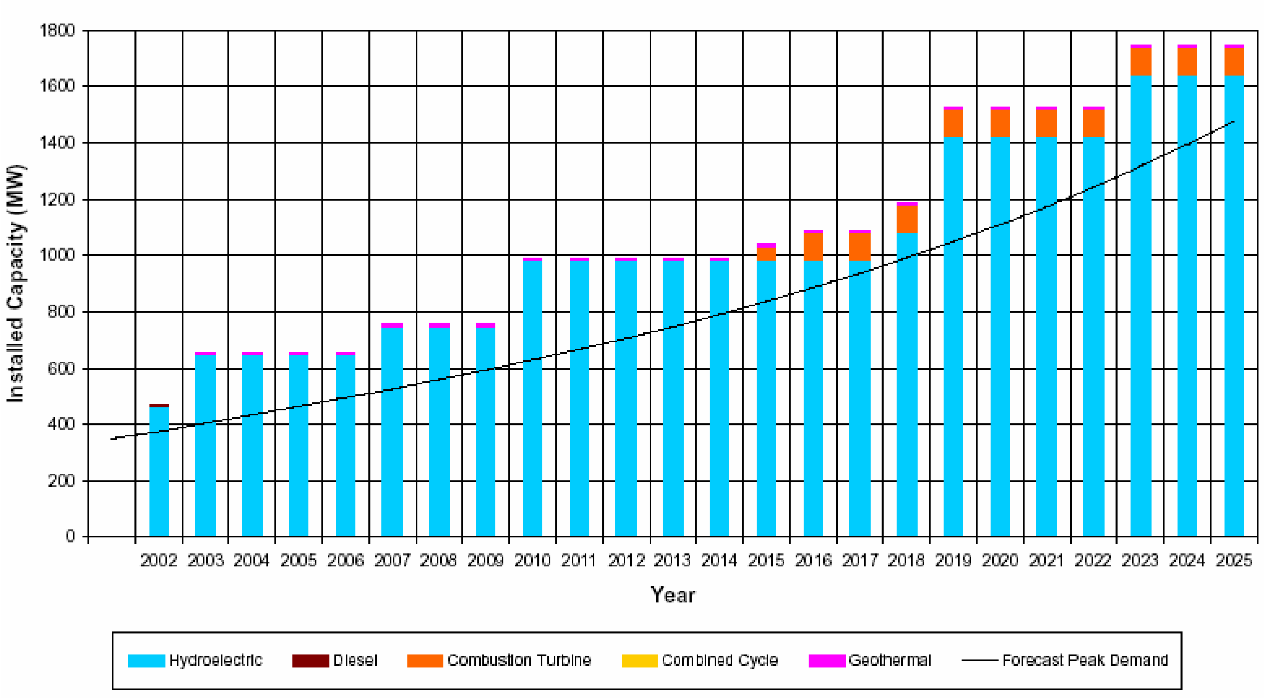
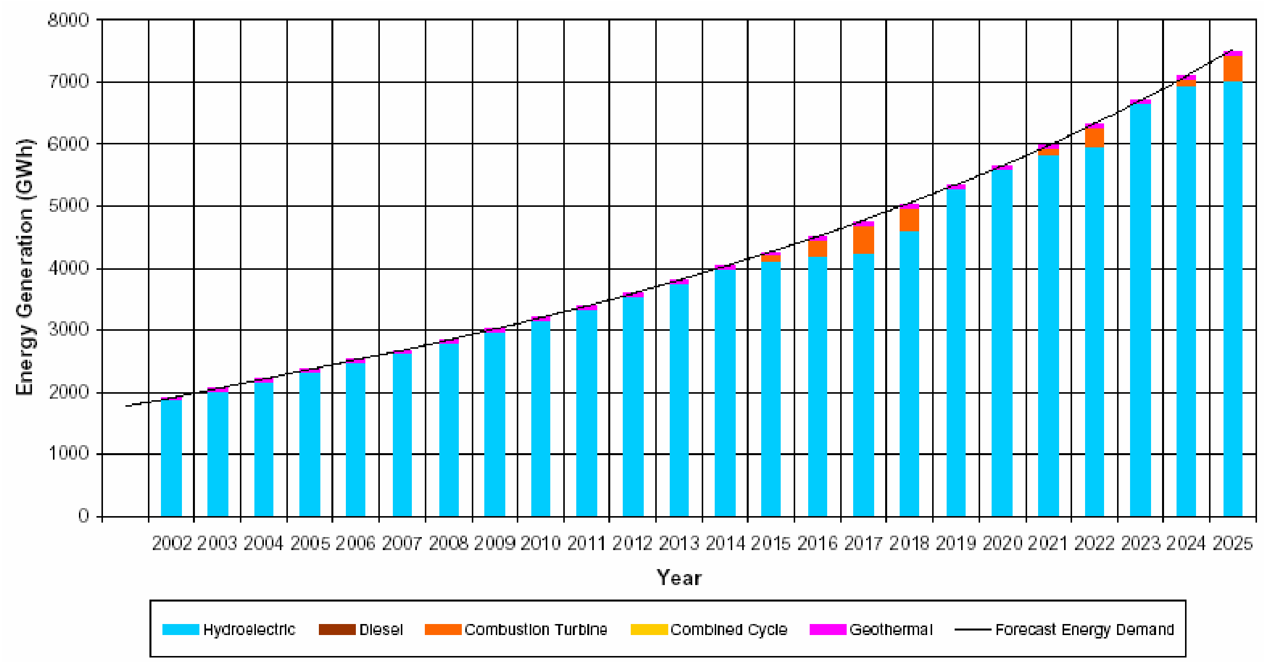
42) The EEPCO/ACRES Power System Expansion Master Plan is an excellent piece of work and a thorough planning instrument for long-term decisions within EEPCO. The section on Alternative Energy Resources (Chapter 8, see **Annex 7**) with only 2 ½ pages, however, does not do justice to the excellent renewable energy resource base of the country.

Figure 3-10:
Least Cost Plan – Target of Installed Capacities



Source: EEPCO/ACRES 2003, Figure 10.6

Figure 3-11:
Least Cost Plan – Expected Electricity Generation by Source



Source: EEPCO/ACRES 2003, Figure 10.7

3.5 Legal Framework

3.5.1 From Ethiopian Electricity Agency

The legal framework for “Electrification Investment” is described as follows:[43]

Transmission and supply of electrical energy through the interconnected grid is exclusively reserved for the Government. All other areas of investment are open for foreign investors. This does not, however, include those areas exclusively reserved for the Government or joint venture with the same or for Ethiopian nationals or other domestic investors, which is specified by the Regulation No. 84/2003 issued by the Council of Ministers.

Investment Incentives and Privileges

- An investor shall be allowed to import duty-free capital goods and construction materials necessary for the establishment of a new enterprise or for the expansion or upgrading of an existing enterprise unless they are not produced locally with competitive price, quality and quantity.
- An investor granted with a customs duty exemption privilege shall be allowed to import duty-free capital goods necessary for his enterprise unless they are not produced locally with competitive price, quality and quantity.
- An investor eligible for duty-free importation of capital goods shall be given the same privilege for spare parts whose value is not greater than 15% (fifteen percent) of the total value of the capital goods to be imported.
- Any investor may import duty-free ambulances that are needed for emergency cases. It is worth noting that capital goods imported free of customs duty shall not be transferred to third parties not entitled to similar duty-free privileges, unless prior payment of the customs duty is effected.
- Expatiates may remit, in foreign currency, salaries and other payment in accordance with foreign exchange regulations.
- A foreign investor: a) re-investing his profits or dividends; or b) exporting at least 75% of his outputs shall not be required to allocate a minimum capital.

Other Privileges and Rights

- Employment of expatriates if local labour market fails to provide Ethiopians with the necessary work qualification;
- Opening of foreign currency accounts in any authorized local bank pursuant to the directives of the National Bank of Ethiopia.
- Adequate compensations in case of nationnalization or confiscation of an enterprise for the sake of public interest.

Pre-conditions of the Investment Law

- A minimum capital of US $ 100,000 is required for a foreigner to invest on a single project.
- US $ 60,000 capital is required of a foreign investor to jointly invest with a domestic one.
- Any foreign investor having brought investment capital shall be registered at the National Bank of Ethiopia and obtain a certificate of registration.
- An investor should submit an agreement on technology transfer to the Ethiopian Investment Authority for approval and registration.
- An investor can acquire external loan upon registration of loan by the National Bank of Ethiopian.

3.5.2 Legal Framework in Practice

For the electricity sector, EEPCO is the sole institution responsible for the generation, transmission, distribution and sale of electricity in the country.

Until recently, there was an upper capacity limit for independent power producers (IPP) for hydro power plants (< 25 MW). This has

43) The following paragraphs are taken from: Ethiopian Electricity Agency, Information & Public Relation Service, “Profile of Ethiopian Power Sector Policies & Legal Frameworks for Electrification Investment”, Addis Ababa, not dated, p. 3

been removed and since then, also larger projects are possible.[44] However, even with the limit being 25 MW, very little IPPs have applied for license.

This might be the result of a generally difficult environment for private business in Ethiopia, which must be attributed to an over-regulation of business in general.[45] This over-regulation is, in the view of the consultant, a residue of the prior socialistic regime of the *dergue*. Changes towards a more modern, investment-friendly legal and socio-political system are only being introduces slowly.

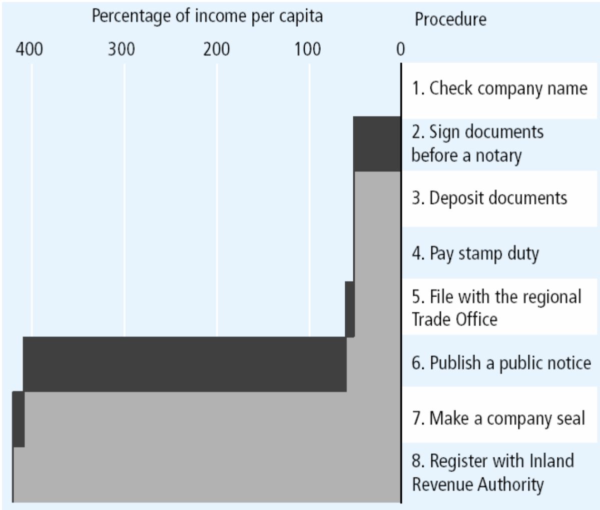
As such, the absence of private property of land must be regarded as one of the major constraints for a dynamic development of the private sector. In practice, this keeps young businesses from getting credit, as their (rented) houses are not accepted as collateral. Another constraint is the absence of credit information registers.

An example:

"Timnit, a young entrepreneur in Ethiopia, wants to expand her successful consulting business by taking a loan. But she has no proof of good credit history because there are no credit information registries. Although her business has substantial assets in accounts receivable, laws restrict her bank from using these as collateral. The bank knows it cannot recover the debt if Timnit defaults, because courts are inefficient and laws give creditors few powers. Credit is denied. The business stays small."[46]

In addition, Ethiopia was one of the most expensive countries in which to start a new business from a sample of more than 130 countries. The breakdown of the business entry process shows that the cost of entry—more than four times gross national income per capita—is driven mainly by the requirement to publish an official notice in the newspapers (see **Figure 3-12**).[47]

Figure 3-12:
Cost of Business Entry in Ethiopia



Source: WB, IFC, OUP (eds.), "Doing Business in 2004 – Understanding Regulation", Washington 2004, p. 2

Through reading the legal framework condition in **Section 3.5.1** carefully, one will notice how many business actions – like technology transfer, getting loans or opening up bank accounts – depend on getting approvals and licenses or being registered. These time consuming processes keep many people from entering into private business and drive the costs of business entry up.

In the same way, Ethiopia's legal system is not yet in a position to adequately deal with private business. As an example, the World Bank/IFC study about regulation, looked into the time periods to enforce a contract and found Ethiopia to be on the bottom of the country list (see **Figure 3-13**).

Finally, the labour laws in Ethiopia, in the view of the consultant, do not adequately reflect the situation on the labour market. For example, in employment regulation, Ethiopia has the most generous paid-vacation allow-

44) In 2002, MIDROC, the largest private corporation in Ethiopia, started work on the 150 MW hydro power plant in Gojeb, see **Section 2.2.1**

45) World Bank (WB), International Finance Corporation (IFC), Oxford University Press OUP (eds), "Doing Business in 2004 – Understanding Regulation", Washington 2004, throughout

46) op. cit., p. xi

47) In June 2003, the Ethiopian government reduced the cost of publishing the notice by 30 percent. Compare op. cit., p. 2

ance of any country in the world: at 39 working days a year.[48]

Figure 3-13:
Days to Enforce a Contract

The fastest …		… and the slowest	
Tunisia	7	Bosnia and Herzegovina	630
Netherlands	39	Italy	645
New Zealand	50	Lebanon	721
Singapore	50	Nigeria	730
Botswana	56	Angola	865
Japan	60	Ethiopia	895
Armenia	65	Poland	1000
Nicaragua	65	Slovenia	1003
Lithuania	74	Serbia and Montenegro	1028
Korea, Republic of	75	Guatemala	1460

Source: WB, IFC, OUP (eds.), "Doing Business in 2004 – Understanding Regulation", Washington 2004, p. 45

To sum up the legal framework for independent power producer in Ethiopia, one must say that the general conditions for private business in the country are still hindered by a level of over-regulation.

This situation is likely to keep IPPs for smaller project from entering business, since the efforts necessary for getting started are, more often than not, prohibitive.

Larger projects – such as the MIDROC financed hydro power plant in Gojeb (160 MW) – will be able to overcome the regulative barriers.

While it is basically imaginable that a private investor would be interested for a 40 to 60 MW wind park project in Ethiopia, it seems highly unlikely that such a project will materialize in the near future.

It is recommended that the TERNA project supports the efforts of EEPCO to plan, build and operate the first wind park in the country by itself. Once the technology is successfully demonstrated in the multi-MW range, much needed private capital might be attracted for further wind park projects.

48) op. cit., p. 83

4. Integration of Large Wind Parks

4.1 Basics

A conventional power supply system is structured according to **Figure 4-1**. Large power plants are generally far away from the load centres and require high voltage transmission lines.

In general, these systems are characterized by

- top down approach;
- unidirectional flow of energy;
- centralised dispatch / system operation.

When wind parks or other decentralized power generators are introduced into such a "conventional" system, the system design rules change to the following:

- network approach (several levels);
- bi-directional flow of energy (distance to consumption varies);
- de-centralised or no planning.

While typical distribution voltage levels (10 to 30 kV) are limited to the absorption of smaller wind park capacities (< 10 MW), the transmission voltage levels (> 33 kV) have to be used for large wind parks.

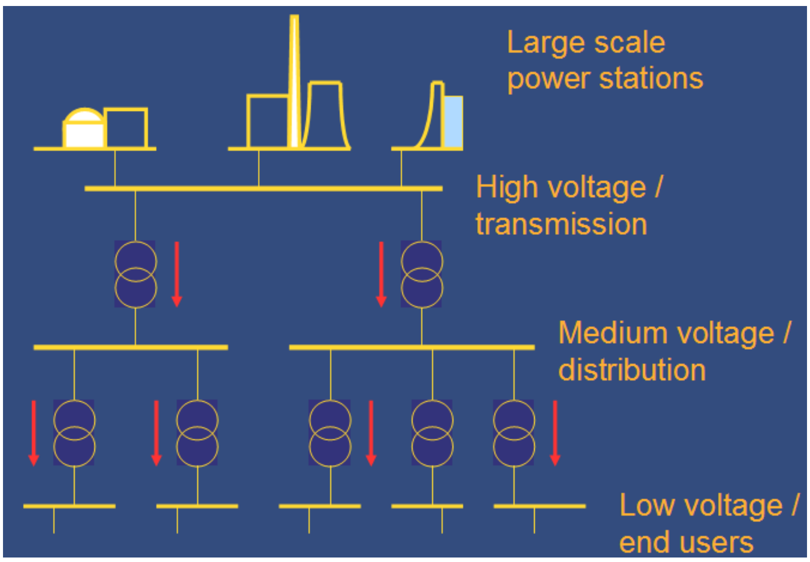
There are several basic stability rules to be adhered when integrating wind parks into an existing power supply system, the most important of which are:

- voltage levels (when a wind park feeds power, it increases the voltage);
- frequency variations (wind turbines with classic induction generators can influence the frequency in a weaker grid);
- harmonics and inter-harmonics (wind turbines operating with variable speed use power converters for grid connection);
- reactive power (induction generators are statically compensated, but need reactive power from the grid), and
- the short circuit capacity at the point of grid coupling.[49]

Basically, every functioning electric transmission grid can utilize large amounts of wind generated power, when these basic stability rules are taken into account.

As a rule, one can say that the voltage level in kV might be considered, in a first planning step, as a first indication for the maximum wind park size in MW.

Figure 4-1:
Conventional Power Supply System



Source: Dr. K. Burges, ECOFYS, Electrical Grid Integration of Large Wind Farms, InWEnt Training Course with Northwestern Polytechnical University Xi'an, PR China, Berlin 2003

49) Criteria for electricity quality are laid down in some detail in several product standards, such as IEC 61400 – 21 or EN 50160.

For Ethiopia, we get the following broad planning guide:

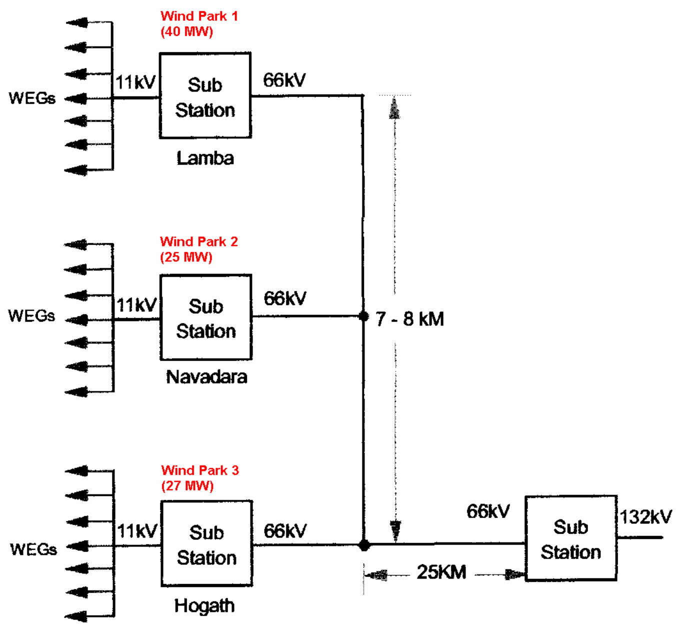
Voltage Level	Max. Wind Park Size
15 kV	~ 20 MW
45 kV	~ 50 MW
66 kV	~ 70 MW
132 kV	~ 150 MW
230 kV	~ 250 MW

If a double feeder is used as connecting line from the wind park to the next step-up transformer, the maximum wind park size could double. For instance, with 2 x 15 kV, a maximum wind park size of 20 to 30 MW would be possible.

4.2 Possible Feed-in Points in Ethiopia

The application of EEPCO proposed a wind park size of 50 – 60 MW, which would be a rather large wind park, considering the fact that it is the first of its kind in the country.

Figure 4-2:
Wind Park Integration (132 kV) – Example from India



Source: Paul Sørensen et. al., Risø National Laboratory),"Power Quality and Integration of Wind Farms in Weak Grids in India", Roskilde 2000, p. 11, modified

Other African countries, however, have also started with such a large wind park size (Kingdom of Morocco, for instance, with 54 MW in 1999), so principally it seems possible. For installation and maintenance, such a large wind park, provided a suitable location can be identified, offers a number of advantages.

Looking for principal locations within the structure of the Ethiopian transmission lines, we would be confined to areas close to transmission lines of 45 kV or higher, as indicated in **Figure 3-14**. In practice, the building of a complete new substation to connect the wind park to 132 or 230 kV transmission lines might be prohibitive, on account of the installation costs. Therefore the vicinity of these transmission lines – even though technically feasible – has been excluded from the definition of the first priority search areas.

In practice, the most suitable connection points are in the vicinity of 66 kV lines or within up to 40 km distance to 132/66 kV substations. A typical example for the connection of three larger wind parks with 25 to 40 MW each is shown in **Figure 4-2**. Here a three wind park layout from India is being shown in a single line diagram.

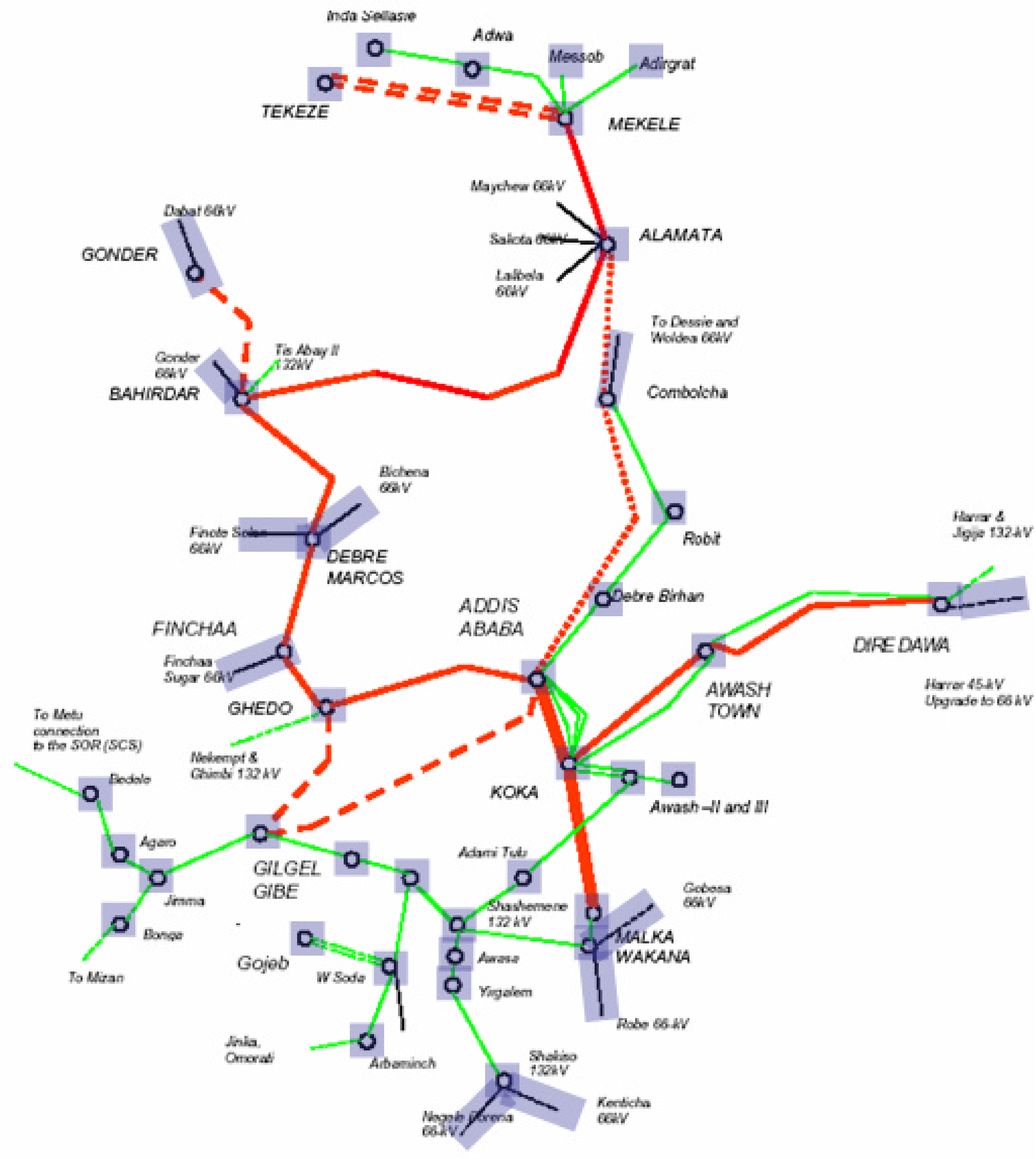
One can see that, within the wind park, the turbines are connected through 11 kV (medium tension) lines. The wind park substation consists of a 66/11 kV transformer, which delivers its power via 66 kV lines to the 132/66 kV substation.

This is a typical layout for wind parks of this size, and might be considered for Ethiopia as well.

Principally, as we can see in **Figure 4-3**, quite a large number of search areas for a technically feasible grid connection exist for wind parks > 30 MW. However, each and every possible site has to be checked in more detail later. Then, one has to consider, among others,

- the load flow at the connection point under different load conditions;
- future expansion plans of EEPCO,
- and anticipated load developments.

Figure 4-3:
Priority Search Areas for Wind Parks > 30 MW (Shaded Blue)



5. EEPCO's Performance

Naturally, within the scope of this 10-day consultancy mission, the evaluation of EEPCO's technical and financial performance with regard to its role of a future wind park operator has to remain on the surface. Neither the technical potential of EEPCO's personnel for planning and operation of wind parks nor EEPCO's effective financial means for investment in wind parks can be evaluated with certainty in this section.

Instead, an overview of the man power resources of the company and its technical performance in everyday utility tasks is given, as well as some information regarding the audit findings from EEPCO's last financial year.[50]

Counting time: the Gregorian and Ethiopian calendars

Ethiopia uses a calendar in which the year begins in mid-September and contains 12 months of 30 days plus a 13th month of five or six days. The Ethiopian calendar (EC) is based on solar cycles and is the traditional calendar of the Ethiopian church. The EC is roughly seven years and eight months "behind" Western Gregorian calendars; 2003 is thus 1996 EC, while 1997 EC began in September 2003 (Ethiopian New Year usually begins on 11th September Gregorian). However, the Ethiopian fiscal year begins on July 8th, and all domestic economic statistics are produced on an annual July 8th-July 7th basis; 1996 EC in National Bank of Ethiopia statistics therefore refers to July 8th 2002-July 7th 2003. Hourly time in Ethiopia is conventionally expressed as beginning at 6 am; 1 am is thus equivalent to 7 am in the West, 6 am to 12 noon etc. However, all businesses and ministries use the conventional 24-hour clock.

The 13 months of the year are as follows:

Maskarem–January	*Tikimit*–February	*Hidar*–March
Tahsas–April	*Tir*–May	*Yekatit*–June
Megabit–July	*Maiza*–August	*Ginbat*–September
Sene–October	*Hamle*–November	*Nahasse*–December
Paguemen		

Source: The Economist Intelligence Unit, Country Profile Ethiopia, January 2004, p. 30

5.1 Manpower

Over the past 5 years EEPCO's personnel base has been fairly constant at around 8,000 Employees ± 100. In 2003, there were 8,105 employees working for EEPCO, of which 1,255 were female.[51] EEPCO's statistic registers 433 employees with a university degree, of which 130 have left university with a second degree (M.Sc) and 3 with a third degree (Ph.D.). A technical diploma or certificate have 2,314 employees, while another 2,368 or 2,328 have high school or primary school leaver certificates, respectively. 662 employees are registered with the ability to "read & write".

In general, the education level of EEPCO's personnel is merely a mirror image of the country's poor fairing in education matters. With an illiteracy rate for men of 58 % and for women of 70 %, Ethiopia does not have a good starting point in any technical or non-technical education.

The performance of EEPCO in providing electricity services to its customers must be regarded, even under African conditions, as sub-standard.

A useful figure for an easy evaluation of utility personnel's performance is the annual MWh distributed per employee.

50) The EEPCO fiscal year counts – like that of the government of Ethiopia and all national companies from July 8 to July 7. Reference is made to the years of the Gregorian calendar, i.e. the Gregorian year is indicated, when the Ethiopian year ends.

51) This and the following information is derived from EEPCO, Facts in Brief 2003

Figure 5-1:
Typical House Connection with kWh-meter

Figure 5-2:
66 kV Overhead Line (between Woliso and Addis Ababa)

For 2002, this figure amounts to 248 MWh/employee and shows that EEPCO is a really labour-intensive utility.

For comparison, average annual MWh per employee in Brazil are in the range of 1,200 to 1,700, while European companies reach values in the range above 5,000.[52]

5.2 Services

House connections, for one, are historically often made in a rather make-shift manner, such as in **Figure 5-1**. Only recently, the standard of connections has improved, both technically and with regard to a reduced waiting time. Until about 2002, wait times of up to one year for new customers were usual and had to be tolerated.

While the service of EEPCO has improved lately, and has become slightly more customer-oriented, it still must be regarded as unsatisfactory, since the perceived improvement can be attributed, in part, to the fact that the backlog of more than 100,000 customers waiting to be connected has been worked up by now.[53]

The low level of service had been noticed, however, and the Ethiopian Electricity Agency recently issued a questionnaire concerning EEPCO's performance with regard to customer service. The results of its evaluation has not yet been published.

Unfortunately, EEPCO's performance in the field of maintenance of overhead lines, switch gear and generation equipment, also leaves

52) GTZ TERNA Wind Energy Programme, "Project Identification Mission Federal Republic of Brazil", Wismar 1997, p. 56

53) EEPCO/ACRES 2003, p. 56

Figure 5-3:
Manually controlling a 375 kW Water Turbine

much to be desired. Badly or not at all maintained overhead lines, on the verge of collapse (**Figure 5-2**) are an equally common sight in the country as are amateurishly connected transformers and switch gears.

This must be attributed to a general low level of supervision in both construction and maintenance work, combined with a lack of tools, equipment and transport as well as deficiencies in basic technical and in-service training. As a rule, one can say that, the larger the distance to Addis Ababa, the worse the level of services and maintenance.

During a visit to one of EEPCO's smaller hydro power plants in Dembi, about 560 km away from Addis Ababa, it was observed that the personnel of the hydro power plant was manually regulating the Pelton turbine – on a 24 hour basis! This was because spare parts for this North Korean turbine (installed in 1995) were no longer available and the locally manufactured brushes for the governor only lasted a few weeks (**Figure 5-3**).

In this situation, both voltage and frequency could not be maintained in acceptable levels: voltage fluctuated in the self contained system of Dembi-Mizan Teferri-Tepi from ~150 to ~270 V, while the frequency varied from 42 to 58 Hz.

Logically, all more sophisticated electrical equipment, such as copy machines, scanners and desktop computers, could not be operated with this bad electricity quality. Some of this equipment was even damaged beyond repair.

Even in the Addis region where 50 % of EEPCO's customer live, frequent complaints about low and fluctuating voltage levels are voiced. This is mostly on account of the fact that more customers are connected to a distribution transformer than is technically feasible to maintain acceptable voltage levels. Thus, people living on the end of a low voltage feeder to a distribution transformer, just get 180 V or less. With these low voltages, fluorescent lamps do not spark, so that only candescent lamps are used, this, in turn, increasing the voltage drop on the line.

5.3 Financial Performance

For comments on the financial performance of EEPCO, the latest report on "Audit Findings and Recommendations on the Accounts" was available for the financial year 2002. The year 2003 was still being audited.

5.3.1 Balance Sheet

The balance sheet saw an amount of 8,969 million Birr as the total assets employed, of which 5,896 million Birr (= 66 %) were fixed assets.[54] However, a proper physical veri-

54) All figures in this section are from Audit Services Corporation, "Ethiopian Electric Power Corpora-

Figure 5-4:
Contributions and Grants to EEPCO in 2002 (~ 115 million €)

	Birr	1993 (2001) Birr
Government contributions and rebates for rural electrification	927,718,389	918,257,190
Community contributions	32,721,611	36,317,263
United Nations Development Programme (UNDP) grant	557	557
United Nations Department of Technical Cooperation for Development (UNDTCD) grant	41,967	41,967
Japanese Government grant	83,799,609	79,925,003
Italian Government grant	444,680	444,680
African Development Fund grant	26,281,661	26,281,661
Netherlands Minister for Development Cooperation	3,831,591	3,831,591
Government of Finland grant	743,859	743,859
Agence Francaise de Development (AFD) grant	12,846,667	11,841,383
Belgium Government grant	52,929	52,929
Government of the Kingdom of Norway grant	61,571,822	61,571,822
	1,150,055,342	1,130,304,005

Source: "Ethiopian Electric Power Corporation – Audit Findings and Recommendations on the Account for the Year ended 30 Sene 1994 (7 July 2002), Addis Ababa, 10 March 2003, p 12, note grant from UNDP with 557 Birr = 55.7 € (sic!)

fication of the fixed assets could not be made, since a complete physical inventory of all of EEPCO's assets was carried out by July 7th 2002, but has not been approved by the management since. Thus, the effective value of EEPCO's total equipment might not correctly be accounted for in the balance sheet.

Erroneously, some assets were still included, although they are no longer under the control of EEPCO, such as the former possession in Eritrea (former EEPCO branch in Assab with 117 million Birr). Long outstanding deposits of nearly 200 million Birr could not be regained by EEPCO, as well as 18 million Birr in form of long outstanding bills. The auditor recommends to write them off.

The auditing report lists a total long term loan balance of 3,188 million Birr, of which 240 million Birr qualifies as current maturity portion (= 7.5 %). The largest loans come from the World Bank (International Development Association, IDA) – nearly 1,000 million Birr or approx. 100 million €. Other donors include African Development Fund, African Development Bank, European Investment Bank and Kreditanstalt für Wiederaufbau (KfW).

Additionally, contributions and grants in the range of 1,150 million Birr were received by EEPCO during the financial year 2002 (see **Figure 5-4**).

From electricity sales, EEPCO received in 2002 at total of 760 million Birr or – when referenced to the official electricity consumption of 2,009,000 MWh – an average **of 0.378 Birr or 0.038 €/kWh**. Since the official electricity consumption includes also technical and non-technical losses in the range of 17.3 to 22 %,[55] this figure does not represent the actual money paid per kWh.

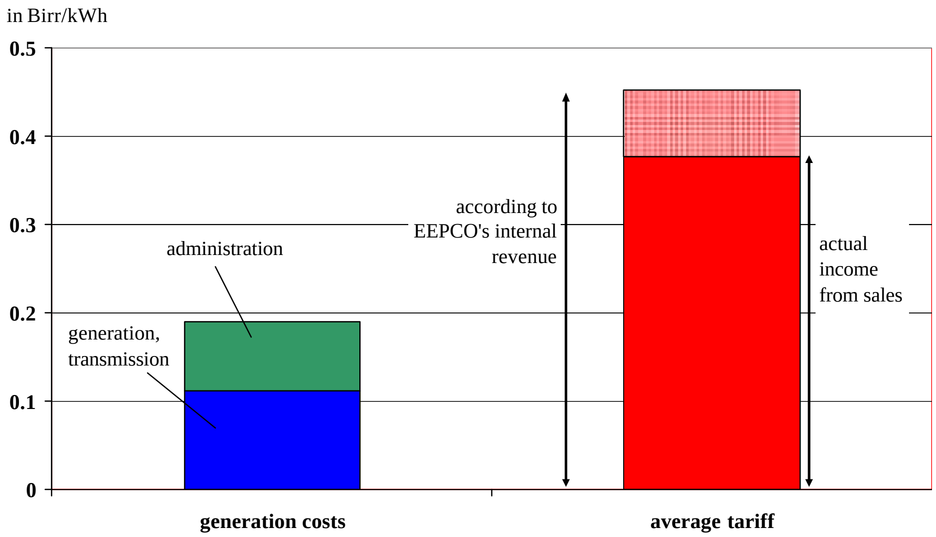
For calculations within EEPCO, an **rate of 0.4522 Birr per kWh** is used, for instance to evaluate losses occurred through load shedding (**Figure 5-4**). Comparing these two figures with eachother, one can conclude that only 84 % of the electricity demand is actually paid for. As such, we can assume that the 16 % of electricity demand not paid for represents the system losses, more or less.

Thus, under the current situation, the tariffs of EEPCO seem appropriate, for the time being

tion – Audit Findings and Recommendations on the Account for the Year ended 30 Sene 1994 (7 July 2002), Addis Ababa, 10 March 2003

55) 17.3 % losses were given by EEPCO, 22 % losses indicated in a paper from November 2003: European Union Energy Initiative for Poverty Eradiation and Sustainable Development, Desk Study Ethiopia.

Figure 5-4:
Generation Costs and average Tariffs (in Birr/kWh, 2002)



at least (this does not mean that they are sufficient to pay for long term investments or for maintenance or the replacement of the generation capacity).[56] However, current situation means that EEPCO is not able to operate without major government contributions, the exact level of which could not be obtained.

Various studies estimate the Long Run-Marginal Costs of EEPCO's interconnected grid in the range between 3.3 and 12 € cents per kWh under different assumptions of load forecasts, asset values and investment costs.[57]

For a long-term sound management of EEPCO, the current tariffs are not sufficient.

5.3.2 Profit and Loss Account

EEPCO's profit and loss account gives the cost for production and distribution as 225 million Birr in 2002, or 0.112 Birr per kWh, while administration and other expenses are indicated as 156 million Birr (= 0.078 Birr per kWh).

The net profit for 2002 amounts to 423 million Birr, resulting in a net profit after taxation of 162 million Birr.

In summing up, the company's audit report for 2002 shows a number of unsolved discrepancies, namely assets not more under control of EEPCO and outstanding bills of more than 18 million Birr or nearly 3 % of the annual sales value. In addition, the auditing report discovers quite a number of accounting errors and/or frauds within the accounting and billing system of EEPCO.

With 248 MWh distributed per employee EEPCO allows itself a large number of staff, even for a utility in a developing country.

In the evaluated year, about 60,000 MWh were not delivered on account of **load shedding**. This means that EEPCO was not able – on account of lacking generating capacity and/or lack of water in the reservoirs – to supply about 3 % of demand. All in all, this meant sales losses for EEPCO of more than 22 million Birr and reveals the low level of reserve planning within the company.

Calculating with the validated wind resources from Mekelle 60,000 MWh would be the production of a 25 MW wind park (see **Section 7.3.3**).

56) This evaluation is in contrast to other information, according to which EEPCO makes about 35 % losses on each kWh sold. See The Economist Intelligence Unit (ed), "Country Profile Ethiopia 2004",p. 27

57 World Bank, Report No. 17170-ET, Project Appraisal Document Energy II Project, November 1997, p.9

5.4 Tariffs

EEPCO has suffered from a low level of average tariffs and long delays in revision.

As a consequence, EEPCO has not been able to carry out proper maintenance of its assets or generate sufficient cash from operations. The Government has recently changed its sector policy: EEPCO will be required to operate as a financially independent commercial entity. EEPCO will no longer receive free budgetary contribution except for some activities to be taken up by EEPCO due to past policy failures or for social purposes.

EEPCO will be able to maintain its tariff at the level that its revenues will be able to cover its operation and maintenance expenses, financial and administrative charges, an appropriate return on equity and income tax. The Government will require an appropriate return on its equity share holding in EEPCO with a premium over the cost of EEPCO's long-term loans. EEPCO will be required to maintain an optimal capital structure to minimize its cost of capital.

A tariff revision was approved on April 7, 1997: the average energy tariff was increased by 39 percent to 4.76 US cents.[58] Two other increases for domestic users were implemented in April 1998 and July 1, 1999.

The tariff structure of EEPCO today differentiates between 6 tariff groups:

1. Domestic consumption
2. Commercial consumption
3. Low voltage industries (380 V)
4. High voltage industries (15 kV)
5. High voltage industries (132 kV)
6. Street light consumption

Apart from street light which only knows a flat rate, all other tariffs have different tariff categories – for the industrial consumers to account for peak and off-peak times, and for domestic and commercial consumers, to encourage energy saving.

Figure 5-5 gives an overview of all the different tariffs of EEPCO. However, for special large industrial consumers, individual tariffs are negotiated (such as for cement and sugar factories and the like).

Figure 5-5:
Tariff Structure (Jan 2004)

Tariff Category	Differentiation	Birr/kWh	€/kWh
Domestic	first 50 kWh	0,2730	0,0273
	Next 50 kWh	0,2921	0,0292
	Next 100 kWh	0,4093	0,0409
	Next 100 kWh	0,4508	0,0451
	Next 100 kWh	0,4644	0,0464
	Next 100 kWh	0,4820	0,0482
	Above 500 kWh	0,5691	0,0569
Commercial	first 50 kWh	0,4990	0,0499
	Above 50 kWh	0,5691	0,0569
LV Industries (380 V)	Equiv. Flat rate	0,4736	0,0474
	Peak	0,6087	0,0609
	Off-Peak	0,4455	0,0446
HV Industries (15 kV)	Equiv. Flat rate	0,3349	0,0335
	Peak	0,4168	0,0417
	Off-Peak	0,3224	0,0322
HV Industries (132 kV)	Equiv. Flat rate	0,3119	0,0312
	Peak	0,3882	0,0388
	Off-Peak	0,3003	0,0300
Street light	Equiv. Flat rate	0,3970	0,0397

At the time of writing, a major tariff study, being part of the World Bank Project Energy II, was underway. It results are to expected in the second half of 2004.

5.5 Wind Park Financing

As equity financing of a wind park, generally 20 % is assumed to be appropriate. As a first estimation for a 50 MW wind park a total investment of approx. 50 million € would be needed, of which 20 % would represent 10 million € or approx. 100 million Birr.

With an annual average of 800 million Birr from kWh sales, the equity spending for a 50 MW wind park would amount to about 12 % of EEPCO's annual electricity sales.

58) World Bank, Report No. 17170-ET, Project Appraisal Document Energy II Project, November 1997, p.9

According to personal discussion with EEPCO's director of corporate planning, the investment of such an equity would not be problematic for the company. EEPCO is prepared to raise this equity, should an economic operation of a wind park of this size be established by a full-fledged feasibility study.

As a first indication for the motivation of EEPCO to go ahead with the further implementation of the wind park project one has to register that the company has already earmarked 1.2 million Birr for Phase 1 and 2 of the project (i.e. wind measurement and wind data evaluation).[59]

Further information on the financial performance of EEPCO, as well as on the actual ability of EEPCO to raise the necessary equity for a wind park project, could not be obtained during the 10-day mission of the consultant.

The interest of the World Bank in financing a wind park in Ethiopia, however, as shown during a meeting with its local energy desk officer, might be a positive indication.[60]

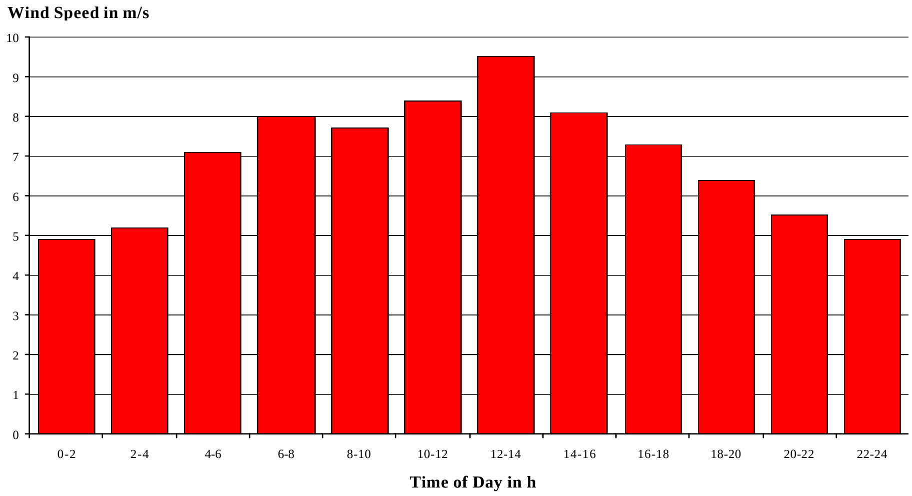
59) See **Annex 10** for the Financial Statement

60) See **Section 3.4.1**

6. Wind Resources

The wind pumping project carried out by the Italian NGO Laymen Volunteer in International Assistance (LVIA) did not measure long-term data. In the absence of other projects involving wind energy, this means that no wind data for energy purposes have been recorded in Ethiopia so far. Thus, for a first assessment of the country's wind resources, we have to rely on meteorological data.

Figure 6-1:
Diurnal Variation for Mekelle (10 m above Ground)



Source: Own measurements, carried out with support of GTZ-Household Energy/Protection of Natural Resources Project and Rural Technology Promotion Centre (RTPC) Mekelle

6.1 Meteorological Data

Meteorological wind speed data in Ethiopia come, like in so many other countries, from three different sources:

1. from meteorological weather stations in the major towns of Ethiopia, generally measured at 10 m above ground, being the standard height for weather stations;
2. from agro-meteorological stations, often located away from towns and agglomerations, but always measured at only 2 m above ground, and finally
3. from military or civil airports, where generally the anemometer is very well exposed to wind, however at odd measuring heights (such as 6 or 8 m above ground).

As a rule, even though the measuring height of airports are not at standard height (10 m above ground), among these three sources, airports give the most useful data for a wind energy resource analysis.

Meteorological data generally comes from anemometers which used to be well exposed at the time when the meteorological station was established (sometime around 1900). By today, these meteorological stations are surrounded by the town, by high buildings and trees, so that their wind data is not representative for the region any more.

Moreover, meteorological service requires that synoptical measurements are taken, i.e. the instantaneous wind speeds at fixed times (8.00 h, 12.00 h, 18.00 h etc.). While these instantaneous measurements might be representative for the wind energy content, when there is no marked diurnal wind speed variation, they are prone to a high error margin under typical African wind conditions with a strong diurnal pattern (see **Figure 6.1**).

Therefore an evaluation of these data – the more so, if they have to be extrapolated from non-standard heights to 10 m above ground – can only serve as a first indication of wind resource. In practice, considerably higher and more evenly distributed wind speeds can be expected at sites particularly selected for wind power utilisation and measured with a classifying data logger.

Figure 6-2:
Wind Data from AAU Study

Station	v_0 (m/s) At 2m AGL	v' (m/s) At 20m AGL
Addis Ababa	3.9	7.0
Awash	3.8	6.9
Dire Dawa	3.6	6.5
Debre Zeit	2.9	5.2
Gode	3.3	5.9
Gondar	4.2	7.6
Gore	2.9	5.2
Jijiga	3.2	5.8
Jimma	3.3	5.9
Kebri Dare	3.1	5.6
Mekelle	3.5	6.3
Neghelle	3.4	6.1

AGL: height above ground level

In the following, two different sets of meteorological data are presented: one comes from a study charged by EEPCO and undertaken by the Addis Ababa University, which looked into renewable energy sources for rural electrification.[61] The other data set had been collected especially for this mission by EEPCO's planning department directly from the meteorological service of Ethiopia.

The agro-meteorological data, when extrapolated to 20 m above ground level, in several instances give values above 6 m/s, namely for Addis Ababa, Awash, Dire Dawa, Gondar, Mekelle and Neghelle (**Figure 6-2**).

These data might be a first indication in what search areas to intensify the efforts and start looking for suitable wind park sites.

The 10 m above ground data, obtained from EEPCO in December 2003, are shown in **Figure 6-3**. In contrast to the wind data from the AAU study, here only meteorological data from 10 m above ground were used. In addition, no long-term averages as in **Figure 6-2**, but two sets of one year data are indicated.

It is obviously difficult to find a correlation between these two (raw) data sets: For example the average wind speed for Dire Dawa is indicated in 2 m above ground as 2.9 m/s, while measurements in 10 m show only 2.3 m/s. This might be a typical case, where the agro-meteorological data in 2 m above ground are registered at a well exposed site outside of town, whereas the 10 m data come from the meteorological station in the centre of town with lots of buildings and trees around.

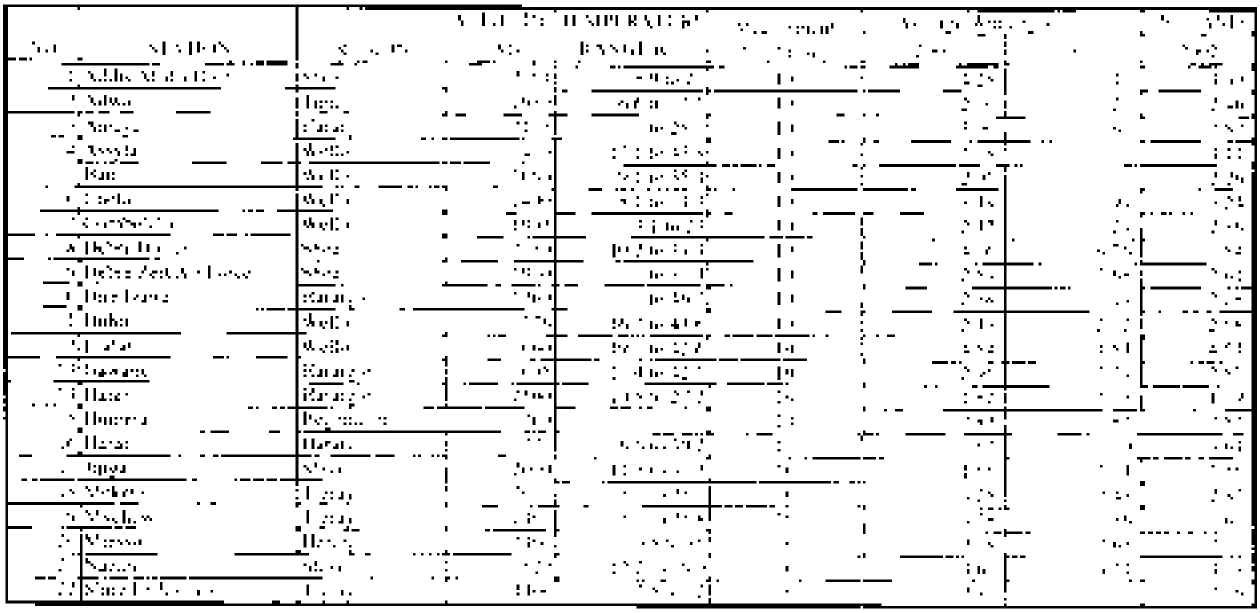
A surprise are the data for Debre Birhan: in 2002, an average wind speed of 6.76 m/s was registered, as opposed to 2001 with only 4,06 m/s. Maybe, the anemometer has been replaced between these two years. In any case, such discrepancies have to be looked at in more detail, should the region around Debre Birhan be considered for further study.

Summing up on the situation of meteorological wind data in Ethiopia it can be said that indications for a suitable potential are there, but not in a consistent manner.

Therefore, these data do not do more than act as a very first and superficial hint for areas of interest, where further measurements have to be undertaken.

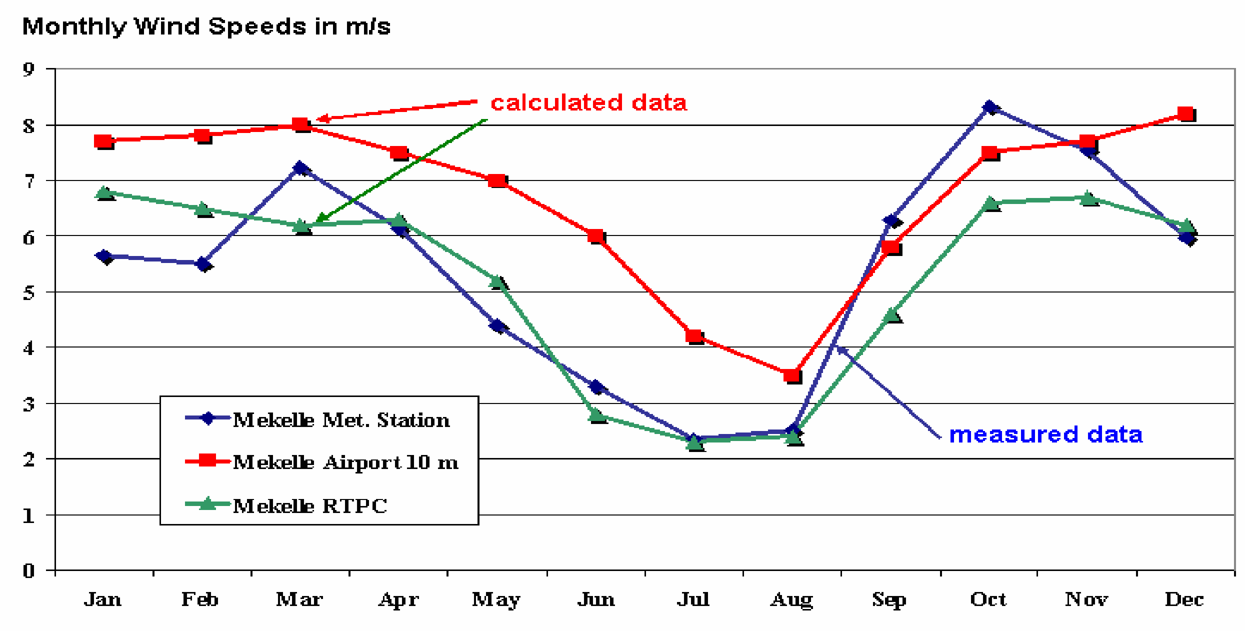
61) Addis Ababa University, Faculty of Technology – Electrical Engineering Department, Study of Feasible Options for Rural Electrification in Ethiopia – Final Report, Part II "Renewable Energy Resources and Technology", Addis Ababa, August 2001

Figure 6-3:
Sample of Meteorological Data according to EEPCO's Data Collection



Source: EEPCO, Corporate Planning Office, "Reply for Questionnaires sent from GTZ", December 2003, p. 22, modified

Figure 6-4:
Mekelle – Wind Data from three Different Sources



Source: InWent Internationale Weiterbildung und Entwicklung gGmbH (Capacity Building International), Benjamin Jargstorf, „Windverhältnisse in Afrika – Komparative Auswertung von Winddaten ausgesuchter Länder", Wismar 2003, p. 50, modified

6.2 Measurements Explicitly for Wind Resource Analysis

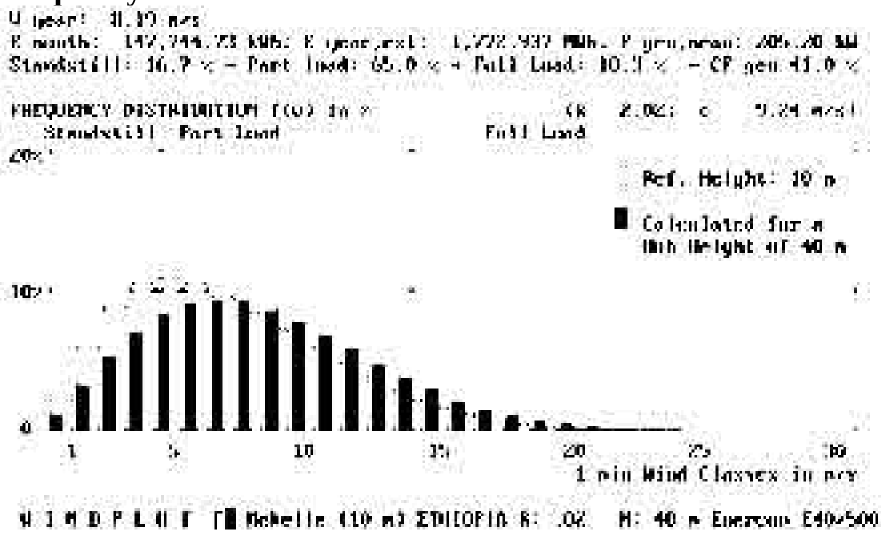
With regard to the airport data, we are fortunate in Ethiopia: for the old **airport of Mekelle** (regional capital of Tigray) there exists a data set for the year 1988 which gives monthly wind speeds. The anemometer from which these data are derived has been inspected by the consultant, however, no photo could be made, as this part of the airport is currently used by the Ethiopian military. The 10 m mast stands about 80 m away from the new runway of the Mekelle airport; there is very little vegetation close by and, apart from a 1-storey barrack 50 m downwind, no other obstacles around.

After discovering the one-year wind data from the airport in Mekelle in 1998 (**Figure 6-5**), the consultant tried to find out about how these measurements were obtained. As no additional information could be obtained, he decided to have a classified data logger (WICOM EL from Ammonit GmbH, Berlin) installed in the same region to validate the airport data.

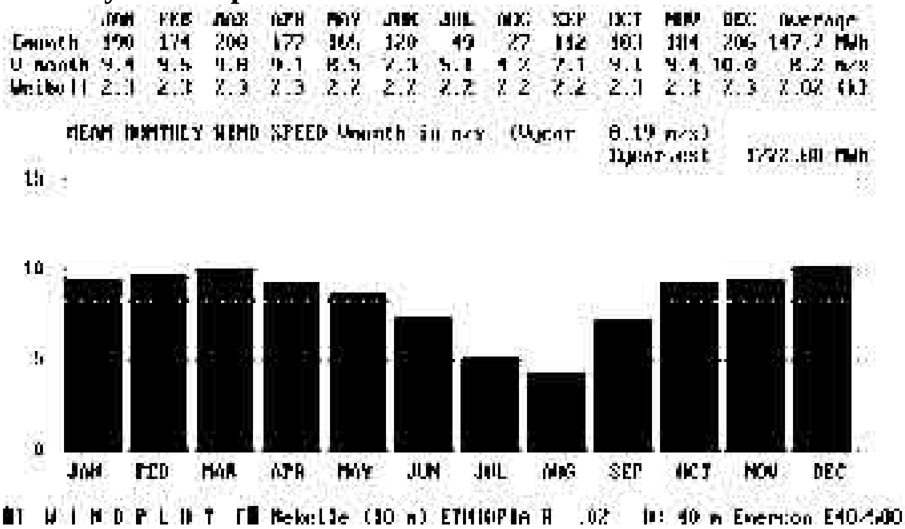
With the support of the GTZ-Household Energy / Natural Resources Project and its local partner in Mekelle – Rural Technology Promotion Centre (RTPC) – an anemometer was installed in December 2001 on the premises of the RTPC and operated for 12 consecutive months. Even through this was not an ideal measuring position – it was selected more because of the security of the place than its exposure to the wind – the wind speed data recorded confirm the airport data and indicate the high wind energy potential of the Mekelle region (**Figure 6-4**).

Figure 6-5:
Mekelle Airport Wind Speeds 1987/88
(Extrapolated from 10 m to 40 m height above Ground)

Frequency Distribution



Monthly Wind Speeds



Source: Data from Ministry of Mines an Energy, Ethiopian Energy Study and Research Center "Tigray Energy Resources, Household Energy Consumption and Policy Issues", 1995, extrapolated with an average surface roughness of 20 mm

The correlation of different Mekelle data is shown in **Figure 6-4**. The data from the different sources agree very well. A Weibull shape factor k of 2.0 was assumed for further calculations, after the evaluation of the RTPC measurements revealed a distribution with k = 1.71 for a complete year.

Figure 6-6:
RTPC Anemometer with Surrounding Vegetation (Wind Breaks)

Thus, the old airport data set from 1987/88 is a valid, representative measurement and can be used for preliminary resource assessment.

The vegetation in close vicinity of the measuring station show that there are strong wind speeds and that there is a marked predominant wind direction (**Figure 6-6**). When a sub-optimal location, surrounded by trees and buildings, already gives an annual average of 5,2 m/s in 10 m above ground, one might expect considerable higher values in the range of 7 m/s at a well exposed site on top of a mountain.

6.3 Summary: Wind & Hydro

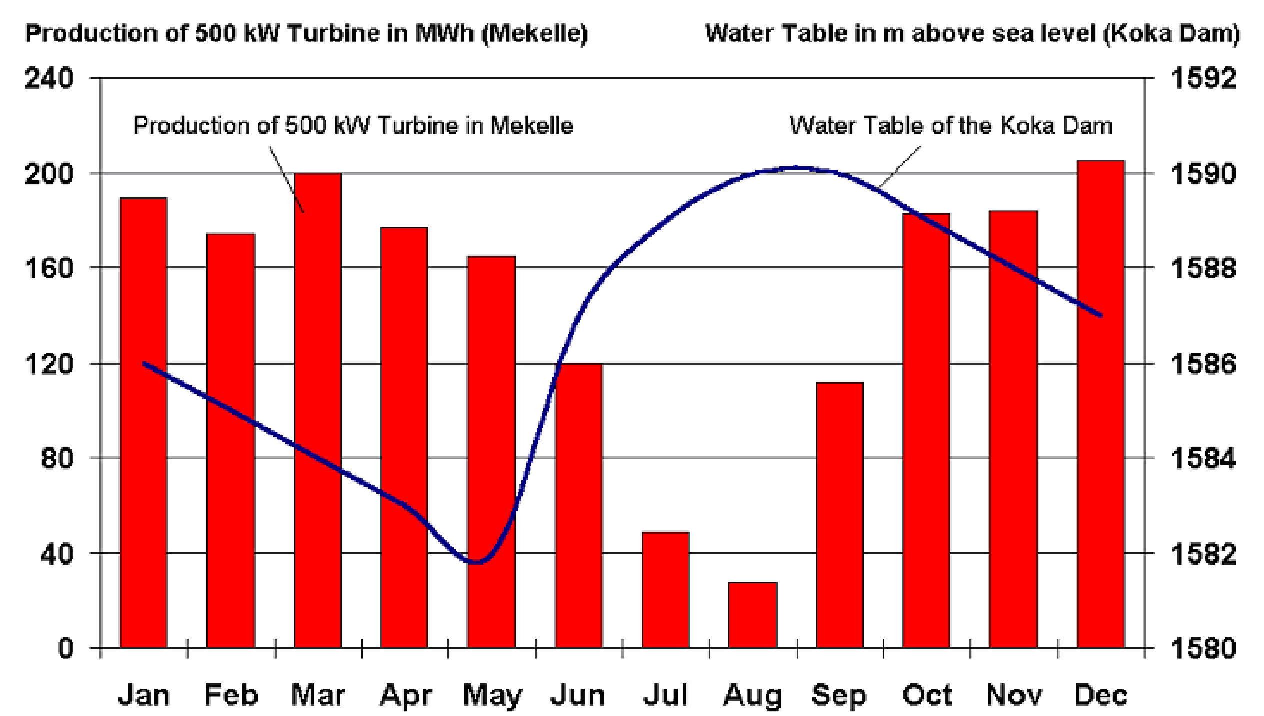
Up to now, the wind resource in Ethiopia has been regularly underestimated, as the limited evaluation that has been made was based on (non-representative) meteorological data.

In combining the existing power generation park based on hydro power with large wind parks, one can be sure that the wind parks will produce with high capacities during the dry season, thus saving water to increase the amount of firm power for the hydro plants.

Ethiopia, with its large tropical highlands, acts as a "humidity island"[62] in an otherwise semi-arid and arid lowland. This situation leads to highly differing reflection rates of high- and lowlands for the strong solar irradiance in this region, causing regularly considerable local and regional winds with a marked diurnal variation (**Figure 6-1**).

62) Wilhelm Lauer, "Klimatische Grundzüge der Höhenstufung tropischer Gebirge" in: Wolfgang Eriksen (ed.) „Klimateographie“, Darmstadt 1985

Figure 6-7:
Ethiopian Advantage: Wind Production Complementary to Hydro Power



Source: Benjamin Jargstorf "Wind Energy for Electricity Production – Experiences World-wide and Prospects for Ethiopia" in: Proceedings of Energy Conference 2002, Addis Ababa 2002, p. 205, modified

As can be seen in **Figure 6-5** with the data of the Mekelle airport, the monthly wind speeds in 40 m above ground drop below 6 m/s only during the rainy season (June – August). A preliminary output estimation for a 500 kW turbine results in a 100 % production of approximately 1,770 MWh per year, or a capacity factor of 41 %.

If we assume 90 % technical availability and an additional output loss of 10 % on account of the altitude of the site, we still arrive at an annual production of 1,430 MWh or a capacity factor of 33 %. If this estimated wind regime can be validated at a suitable site, an economic operation of larger wind parks in Ethiopia can be assumed.

This **annual wind speed pattern** is expected to be fairly typical for the whole country, as during the rainy season on account of cloud coverage the difference in reflection for sun light decreases.[63] These seasonal variations of wind speeds in Ethiopia have some important ramifications with regard to the integration of larger wind parks into the existing power supply system based on hydro power.

We have seen that the high variability of stream flows combined with an increasing sedimentation led to reduced generating capacity during the end of the dry season. In particular, the **low capacity factor** of the older hydroelectric power plants of EEPCO (f.i. Tis Abbay 14 %, Koka with only 20 % or Melka Wakana with 23 %) is an indication of the sub-optimal operation of these plants.

In **Figure 6-7** the wind data from Mekelle airport have been used to calculate the monthly production of a typical 500 kW wind turbine. The complement of the wind production with the water availability of the Ethiopian hydro power plants becomes immediately obvious – in this case, with the height of the water table

63) The North-Western parts of Ethiopia generally experience only one rainy season, while Central and South-East Ethiopia has two rainy seasons (a small one in February to April and the main one in June to September)

of one of the oldest hydroelectric plants, Koka.[64]

In **combining wind power with hydro power** the negative effects of the high variability of stream flows in Ethiopian rivers can be alleviated, since during the dry season we have the highest production from wind turbines. Thus, wind turbines operating in parallel with the interconnected grid would act as a "water saver" and – if dimensioned correctly – could avoid a situation when hydro power plants have to be switched off on account of lack of water.

Thus in effect, the combination of wind power with existing and future hydro power plants in the Ethiopian situation allows to earn high **capacity credits** for wind power. Normally, wind power installations – due to its non-dispatchable nature – are credited with only about 10 to 20 % capacity, i.e. being the amount of new installation of generation capacity offset by wind power installation. In combination with hydro power storage, the capacity credit increases considerably.

With a more thorough data base on hydro power operation by EEPCO – for example the average water demand per MWh sent out for individual plants – one could calculate how much wind power is needed to have a marked effect in avoiding reduced hydro capacity in the dry season.

The targeted wind park size of the EEPCO TERNA-application of 50 MW is regarded a suitable size, judging from current estimated data.

For the **economic analysis** of wind parks in parallel to the interconnected grid, the wind /hydro combination has an important effect: one should not only compare the specific dynamic generation cost with the (calculated) generation costs in hydro power, but has to account for the added benefit of wind power in avoidance of dry season de-rating of the hydroelectric plants.

In addition, and seen under a medium-term expansion perspective, the other benefit of wind power has to be taken into account, namely the fact that due to its **short lead times for construction** it can offset thermal power plants. These plants are, according to present EEPCO expansion planning, considered the only way to bridge capacity shortage in the Ethiopian grid foreseen to occur otherwise after 2014 (see **Section 3.4.2**).

64) Koka has been used as an example, because this power plant has just been rehabilitated (new control mechanism, new generators etc.) and will serve EEPCO for quite some time to come

7. Possible Wind Park Sites

7.1 Harena Plateau (Mekelle)

Naturally, at this early stage of project development no wide variety of possible wind park sites can be presented.

However, there seems to be one obvious candidate site north of Mekelle town – the Harena Plateau – which appears suitable on account of several factors, namely

- the wind regime at Mekelle area has been validated, a minimum annual wind speed of 6.7 m/s in 10 m above ground is highly probable;
- a huge plateau approximately 3 x 12 km and around 200 m above the altitude of Mekelle offers ample space for up to 80 MW of 500 kW class machines (see **Figure 7-1**);[65]
- the 132/230 kV substation is in the immediate vicinity at the Eastern foot of the Harena Plateau (**Figure 7-2**);
- an alternative connection point (132 kV) exists possibly on the Western part of the Harena Plateau, as this is the location of the newly constructed and now operating cement factory of Mekelle;
- there are no conflicting land uses for this site, the little rain-fed agriculture going on there will not be affected by a wind park (**Figure 7-3**);
- a telecommunication tower (~ 35 m) in a fenced area at the Eastern part of the plateau might offer an easy possibility for wind measuring.

Naturally, this is just a very preliminary site assessment from a recent half-day visit to Mekelle. In any case, the Harena Plateau might give a first impression of possible wind park sites in Ethiopia.

7.2 Further Sites

No information about further candidate sites could be obtained during the short consultancy mission. But it is assumed that further sites exist.

7.3 Preliminary Economic Analysis

7.3.1 Assumptions

We shall assume a 50 MW wind park at the Harena Plateau, consisting of 100 wind turbines with 500 kW each.

For a preliminary output estimation we will take the wind data from the Mekelle airport from **Section 6.1.3**, i.e. 6.7 m/s in 10 above ground and 8.2 m/s in the hub height of 40 m.

To be on the safe side, we will calculate with a technical availability of 90 % and a park efficiency of 85 %. For foundations, access roads, substation etc. we will estimate rather high costs, as well as for transportation and cranes. Thus, we expect the outcome of this first economic calculation to be fairly conservative.

For the calculatory interest or discount rate 10 % seems reasonable realistic under Ethiopian condition.[66] If a project will be implemented later, most likely special interest rates from international financing institutions can be obtained, which will be much lower.

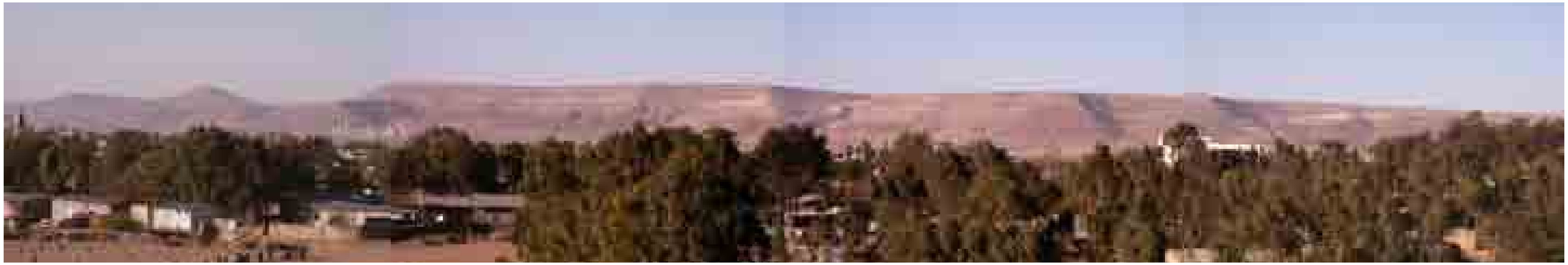
Under European conditions, wind turbines have a (calculated) life time of 20 years.

65) this is only a first estimation after one site visit. Once map material can be analysed, a more accurate figure for the capacity of the site (which might be higher) can be given.

66) We want to compare the unit price of electricity with other power plants, calculated by the World Bank. They also assume a discount rate of 10 %.

Figure 7-1:
Harena, North of Mekelle – Panorama View

35 m telecommunication tower ⇩



⇧ Centre of Mekelle Town ⇧ Cement Factory Lonely Tree ⇧ ⇧ 230/132 kV Substation (hidden)

Figure 7-2:
Substation as Seen from the Wind Park Plateau

Figure 7-3:
Harena Partial View of Plateau

However, the 500 kW class has not been on the market for that long.

Additionally, the climate conditions, as well as the technical and personnel infrastructure in Ethiopia have quite a different level when compared with Europe. Therefore, we shall assume an economic life time of 15 years for the wind park instead of the usual 20 years in Europe.

In conclusion, with regard to financing cost and project life time our economic analysis will be on the safe side.

7.3.2 Investment Costs

Based on the list price of the turbines in Germany and ad hoc estimations for transport and erection etc. we arrive at the following preliminary investment cost breakdown (**Figure 7-4**).

With a specific investment cost of practically 1 € per installed kW we have assumed investment costs on the upper level.

Figure 7-4:
Wind Park Harena - Investment Costs (prelim.)

	Unit costs	Total costs
100 Wind turbines with 500 kW each	450,000	45,000,000
Grid connection including transformers	15,000	1,500,000
Substation 132/66 kV, 60 MVA		1,750,000
Foundation and cable trenches	15,000	1,500,000
Access roads and building of grid station		150,000
Spares and special tools		40,000
Training course at site		20,000
Installation and commissioning	3,000	300,000
Wind measuring equipment. remote control		30,000
Consulting engineer		80,000
Transport, insurance		1,000,000
Sub total		51,370,000
Constingencies		500,000
Total costs in EUR		**51,870,000**

Figure 7-5:
Wind Park Harena – Annual Production (prelim.)

100 % production per turbine	1,770	MWh/year
10 % reduction (altitude)	-177	MWh/year
effective production/turbine	1,593	MWh/year
gross wind park production	**159,300**	**MWh/year**
at 90 % technical availability	143,370	MWh/year
at 90 % wind park efficiency	129,033	MWh/year
5 % line and transformer losses	-7,169	MWh/year
net wind park production	**121,865**	**MWh/year**

7.3.3 Annual Production

According to **Figure 7-5** we can expect an annual net production of the wind park of 121,865 MWh. This represents a **net capacity factor of 28 %**, which compares favourably with typical European capacity factors of around 20 to 25 %.

In relation to the 2003 energy demand of EEPCO (2,064,000 MWh), a wind park in Harena would produce ~ 6 % of Ethiopia's annual demand.

7.3.4 Specific Energy Costs

Using a simple Net Present Value calculation method we want to estimate the dynamic specific energy costs. This method is explained in **Figure 7-6**: the net present value of investment costs on the one hand, and of production on the other hand, are calculated. To arrive at the unit cost per kWh, we only have do divide these two figures.

According to this preliminary calculation, we can expect typical specific generation costs of

5.463 € cts per kWh

with a range from 4.552 to 6.828 € cents/kWh, assuming ± 20 % variation of annual net output (**Figure 7-6**).

Figure 7-6:
Wind Park Harena – Calculation of Specific Energy Costs (prelim.)

Year	Investment Costs in 1,000 EUR	O/M Costs in 1,000 EUR	Annual Production pessimistic in MWh	average in MWh	optimistic in MWh
2007	46.683		48.746	60.933	73.119
2008	0	45	97.492	121.865	146.238
2009	5.187	45	97.492	121.865	146.238
2010	0	450	97.492	121.865	146.238
2011	0	450	97.492	121.865	146.238
2012	0	450	97.492	121.865	146.238
2013	0	450	97.492	121.865	146.238
2014	0	450	97.492	121.865	146.238
2015	0	450	97.492	121.865	146.238
2016	0	450	97.492	121.865	146.238
2017	0	450	97.492	121.865	146.238
2018	0	450	97.492	121.865	146.238
2019	0	450	97.492	121.865	146.238
2020	0	450	97.492	121.865	146.238
2021	0	450	97.492	121.865	146.238
2022	0	450	97.492	121.865	146.238
Sum	**51.870**	**5.940**	**1.511.126**	**1.888.908**	**2.266.689**

1) Net Present Value of Production in MWh	718.434	898.043	1.077.652
2) Net Present Value of Investment in 1,000 EUR	49.056	49.056	49.056
3) specific Energy Costs	**pess.**	**average**	**optim.**
in € cents/kWh (2:1)	**6,828**	**5,463**	**4,552**
in Birr cents/kWh (1 € = 10 Birr)	**0,683**	**0,546**	**0,455**
4) Calculatory Interest Rate	10 %		
5) Reference Year	2007		

6) First Year of Operation: 50 % of Production, on account of 6 Months Construction Time
7) Operation and Maintenance Costs = 1 % of ex-factory price of turbines
8) During 2 year Warranty Period only 10 % of annual O/M Costs
9) 10 % of Investment Cost withheld until End of Warranty Period
10) Pessimistic Production 80 % of Average, Optimistic Production 120 % of Average

Even though these figures are only preliminary - and based, in part, on assumptions - they shall be used for a comparison with generation costs from hydro and thermal power in the next section.

7.3.5 Comparison with Hydro and Thermal Power Options

For a comparison of the calculated unit prices of production in the Harena wind park we use a document of the World Bank: The project appraisal document for the Gilgel Gibe hydro power plant (3 x 60 MW – currently under construction). This makes sense, as it is a document which was prepared – similar to the current report – for project appraisal before project implementation.

The project appraisal document for the ENERGY II PROJECT (of November 13, 1997) deals with a total of 295.89 million US $ (~ 238 million €), of which 281.88 million is for the construction of the hydro power plant in Gilgel Gibe.[67]

The unit cost of firm energy of the Gilgel Gibe Plant has been determined at

5.40 € cts per kWh.[68]

This lies in the same magnitude as the preliminary unit costs calculated for the Harena wind park (5.463 cts/kWh).

However, an important implication of the World Bank calculation for Gilgel Gibe concerns the assumptions, under which this unit price has been calculated:

The World Bank predicts that the net present value (NPV) of Gilgel Gibe becomes nil if the construction costs increase by 12 %. In the same way, a two-year delay in completion time brings the NPV of this project to zero.

At present, two of three turbines are operable at Gilgel Gibe – the formal inauguration took

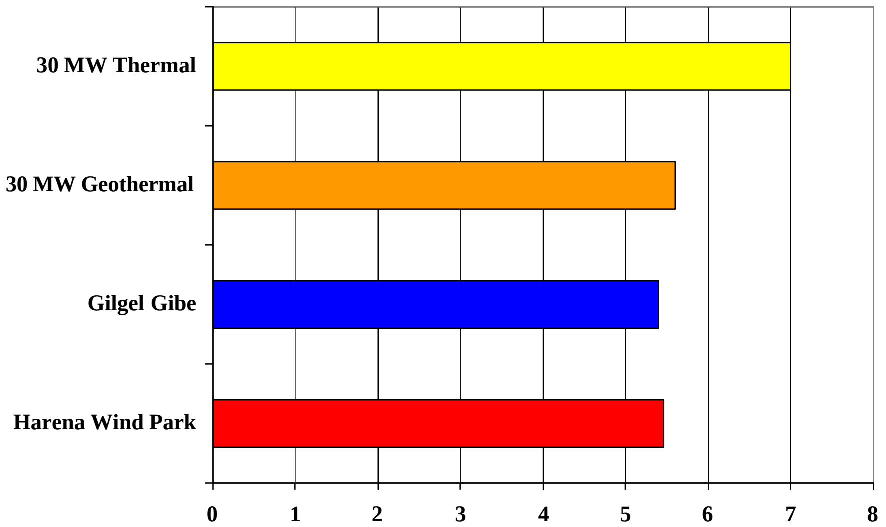
67) World Bank Energy Team Africa Region (ed.), "Project Appraisal Document – Federal Republic of Ethiopia – Energy II Project (Report No. 1717-ET), 1997

68) op. cit, p. 25, discount rate also 10 %

place in February 2004, about one year behind schedule.[69]

A final cost breakdown of the Gilgel Gibe hydro power project has not been made, but due to the longer completion time a higher investment must be assumed.

Figure 7-7:
Wind Park Harena:
Comparison of Unit Cost with other Options



Source: for Gilgel Gibe, geothermal and thermal, World Bank Energy Team Africa Region (ed.), "Project Appraisal Document – Federal Republic of Ethiopia – Energy II Project (Report No. 1717-ET), 1997, wind park own calculations

Therefore, it seems safe to assume that the unit price of electricity for Gilgel Gibe might be somewhat higher in an ex-post evaluation. This means that investing in wind – according to the preliminary calculation – might become even more favourable than the current figures show.

As an alternative to Gilgel Gibe, thermal power plants were calculated by the World Bank, giving average unit prices of between 8 and 10 US$ cents/kWh (~ 6.4 to 8 € cents/kWh). These relative elevated generation costs are due to the high transportation costs for the fuel, which has to be transported over long distances from Djibouti port.

Other generation options, such as geothermal are cited with 0.07 US $ per kWh, if larger units around 30 MW are constructed.[70] The World Bank economic evaluation did not take into account the indirect or **external costs of fossil fuel power plants** which are expected to be extremely high in case of Ethiopia (long-distance transportation of fuel on bad roads, etc.)

Concluding, the preliminary economic evaluation of a 50 MW wind park at the sole location, for which half-way reliable wind data exist (Mekelle) revealed that, principally, economic operation of larger wind parks seems possible in Ethiopia.

Before this preliminary economic evaluation can get more weight, however, a thorough wind measuring campaign has to be undertaken directly at site. In the same way, this economic comparison is in no way a substitute for a full-fledged feasibility study, which should be carried out once reliable wind measuring data of the site have been properly evaluated.

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69) op. cit., p. 26/27

70) The existing geothermal power plant of EEPCO at Aluto/Langano has 7 MW installed, of which zero MW are available at present

8. Summary and Recommendations

8.1 Summary

Chances for the economic operation of larger grid-connected wind parks in Ethiopia are favourable, due to the following reasons

- indications for reasonable wind regimes in several parts of the country are promising, primarily in the East and in the North. At least one of this sites could be validated through independent measurements (Mekelle) where annual averages of 6.7 m/s in 10 m and more than 8 m/s in 40 m above ground are expected;
- a preliminary cost estimation put the investment costs for a 50 MW wind park in the range of 52 million €. Based on this estimate, specific energy prices in the range of current hydro, but below thermal and geothermal plants are calculated;[71]
- even though EEPCO is both financially and with regard to qualified personnel a rather weak utility company, it can be assumed that it can be put into position to operate and maintain the wind park. This, however, only under the assumption, that for several years – at least during the warranty period of the turbine equipment – the manufacturer keeps permanent presence in the country, and high efforts in capacity building are made.

Therefore, it is proposed that GTZ approves the EEPCO application for a TERNA project in Ethiopia.

8.2 Recommendations

The complete absence of reliable wind data throughout the country requires a rather high effort for wind measurements. A two-stage measuring campaign is proposed, which employs 10 measuring stations at 10 m mast first, and continues after an intermediate evaluation of wind data, with 40 m towers later.

Taking into account the general low technical and personnel infrastructure of the country in general and EEPCO's in particular, the TERNA project requires a very strong component of training and capacity building.

This training of EEPCO's personnel should be done in part on the job, i.e. while looking for suitable wind park sites and installing measuring equipment, and in another, equally important part through intensive training courses, to be conducted in Ethiopia.

Without such capacity building, the measuring campaign and data evaluation, as well as further wind park planning, grid connection layout etc. cannot be effected by EEPCO's personnel.

71) These figures are subject to change, once a proper wind measuring campaign and thorough feasibility study have been made.

9. Project Implementation

9.1 EEPCO's Contribution

Based on the preliminary time schedule discussed on account of the visit of the GTZ representative in charge of the TERNA programme, Dr. Abramowski, to EEPCO in December 2003, EEPCO's head of Systems Planning, Ato Estiphanos Gebru has already established a work plan and a cost estimate for the following two phases of a TERNA project component in Ethiopia (see **Annex 10**)

It was the consultant's impression, that EEPCO's management already had decided to go ahead with the wind energy development plan. As such, they considered the current appraisal procedure (of which this consultancy report is only a part) as a mere formality. It could not be found out, whether this meant that EEPCO assumed that the project appraisal would have to have a positive result, or that they already had made up their mind and were prepared to go ahead (even with other donors).

In any case, a Canadian consultant currently employed by EEPCO for the rehabilitation of the underground cable system in the Addis Ababa region had offered EEPCO to apply for funding from the Canadian Government, dedicated to the development of grid-connected wind energy.[72]

In general, as can be seen in the attached project profile of EEPCO in **Annex 10**, the utility is prepared to provide the local transport for the site selection mission, as well as for the actual installation of the measuring equipment.

9.1.1 First Round of Site Selection

As the data base for wind energy utilisation is so scant in Ethiopia, the site selection process should be made in two steps:

The first step with a about 10 measuring stations on 10 m towers is to validate the meteorological data as presented in **Section 6.1.1.** The second step should consist of measurements in 40 m height at pre-selected sites.

If EEPCO wishes to accelerate the site selection process, one could consider to have measurements in hub height executed in Mekelle in parallel to the 10 m measurements. In doing so, the wind data of the proposed wind park site Harena would be available already at the end of the phase 1 measurements. At the Southern part of Harena, a telecommunication tower with approx. 35 m height could be used for this purpose (see **Figure 7-1**, far right side).

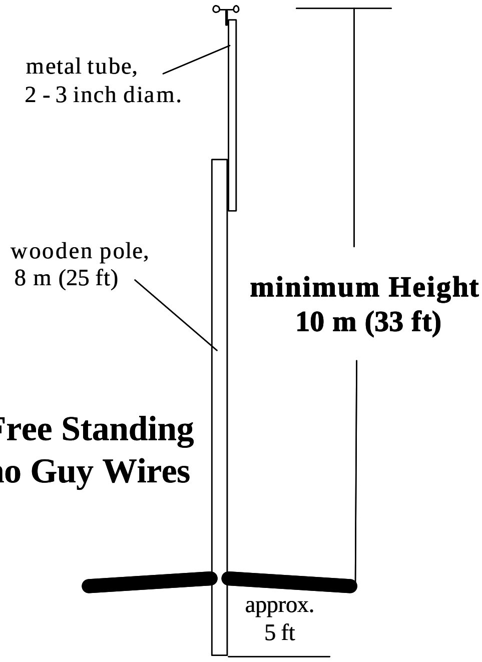
It is estimated that the site-selection procedure will take several weeks, since the measuring site should be principally suitable for a larger wind park installation of at least 60 wind turbines of the 500 – 750 kW class. Even though the space requirements of a wind park with larger units would be smaller (and the site evaluation process easier), it is argued here that larger individual units are not recommended for Ethiopia.

This is mainly due to requirements for transport and erection, but also for operation and maintenance. Here the 500 -750 kW class offers several advantages as compared with MW machines. In any case, should EEPCO decide in favour of the 1 MW class in a later project phase, the pre-selected sites will be suitable as well for a larger unit size and, consequently, for an even larger capacity.

Assuming a clearly defined main wind direction (as can be expected according to unsystematic evidence gathered so far) and standard

72) Personal information Ato Endegasew Negash, Director of Corporate Planning, EEPCO

Figure 9-1:
Sample for a 10 m Measuring Mast with Wooden Utility Pole



spacing,[73] a minimum of 3 km² would be needed for 50 MW, ideally 1 km by 3 km. Such a larger area in a well exposed situation is not easy to find, even in Ethiopia, where there are many large hill tops and plateaus with no trees and other obstacles due their topographic characteristic.

In case a single predominant wind direction does not exist, a larger area would be required, maybe even up to the double, i.e. about 6 km².

The main criteria for site selection are proposed as follows:

- no conflicting land use planning, such as military, infrastructure, communal buildings etc.;
- expected high wind speed, low surface roughness;
- close distance to 33, 45, 66 or 132 kV transmission lines;
- close distance to (larger) substations of the 66, 132 or 230 kV level
- easy to reach when transporting bulky, heavy and long structures;[74]
- sufficient distance to next agglomeration of houses;[75]
- not too far distance to (major) towns for establishing a maintenance base.

EEPCO is prepared to support this preselection process through transport (4 wheel drive vehicles) and through making available topographic and electric grid maps. It is estimated, that the selection of 10 measuring sites will take a minimum of 14 days in Ethiopia, i.e. excluding international travel.

For the measuring mast, EEPCO proposes to use 12 m concrete poles, a standard equipment normally used for medium voltage distribution lines. The employment of these poles is an appropriate suggestion, since EEPCO's personnel in the regions – line and cable men – is familiar with transportation, handling and erection of these poles. The measuring mast will look similar to the sketch in **Figure 9-1**, where a shorter wooden pole is used.

9.1.2 Final Site Selection

After a minimum of 6 and a maximum of 12 months an intermediate evaluation of the accumulated wind data should be carried out, aiming at identifying three of the most promising sites. These candidate wind park sites should be looked at in more detail with regard to

- integration of wind power in the grid (load flow analysis, as has been done for EEPCO's grid without wind parks by ACRES[76]);
- long term expansion planning of EEPCO;

73) Spacing perpendicular to the main wind direction 3 rotor diameter, in main wind direction 6 rotor diameter, rotor diameter of 50 m.

74) Rotor blade length of proposed wind turbine class approx. 18 to 24 m

75) Most likely, suitable wind park sites lie in an altitude of 1,000 to 2,500 m, meaning standard wind turbines are generating ca. 10 to 25 % less power than at sea level. To compensate this, one can increase the rotor speed by the same percentage, however, increasing noise levels of the machines.

76) See EEPCO/ACRES 2003, Appendix E

- planning consent of the local authorities;
- suitability for future expansions;
- and further criteria according to EEPCO's planning department.

At the end of this evaluation three candidate wind park sites should exist, where 40 m steel lattice towers with guy wires are to be installed.

These towers can be manufactured locally – they are used widely all over the country for telecommunication purposes – and are easy to transport in 3 or 5 m sections. For erection a truck mounted crane is needed, which is a standard equipment for EEPCO.

While the first 10 measuring masts only measure the wind speed at 10 m, these 40 m towers are to be equipped with anemometers at 10 and 40 m height and with a wind vane at 10 m above ground. In measuring at two different heights, we can establish the function of wind speed with height, while the wind direction data will enable the optimization of micro-locations within the wind park.

It is proposed to operate the three final wind measuring stations for at least 12 months before sufficient data for a well-founded output estimation is available.

Then a cross evaluation of all sites with regard to wind resource, availability, grid integration etc. should be made with the aim of final site selection.

9.1.3 Further Measures

Depending on the outcome of the wind measurements, further measures for gathering data might include:

- soil bearing tests for establishing more accurate cost estimates for foundation and access roads;
- information gathering about substation costs from previous EEPCO projects involving similar sizes (80 to 100 kVA);
- a sort of pre-qualification procedure with international wind turbine manufacturers, in order to find out about their willingness to enter the Ethiopian market;[77]
- discussion with interested manufacturers about technical modifications for standard utility wind turbines for Ethiopian altitudes (if applicable);
- contacts to transportation, forwarding and shipping agents to arrive at first estimations for transportation costs;
- further information which might be needed for the completion of a pre-feasibility study.

One might consider to conduct a pre-feasibility study using the data of two of the most promising sites in comparison instead of only one. This has two advantages: firstly, the comparative evaluation might result in a better overall economy of the site with the second best wind regime and secondly, should EEPCO go ahead, at a later date, with developing another wind park site the basic pre-feasibility data are already available.

9.2 TERNA's Contribution

9.2.1 Material

According to the outline of the measuring campaign a minimum of 13 data loggers with 16 anemometers and 3 wind vanes are needed. It is assumed that, theoretically, three of the data loggers of the pre-selection campaign can be used also for the three stations of the final round. In supplying 13 units, the EEPCO measuring plan has 3 units as a reserve, should equipment get damaged or stolen.

However, it is recommended to have at least 3 anemometers and 1 wind vane more than needed. Thus the total contribution of the GTZ with regard to material should be as shown on the next page.[78]

77) It is a well known fact that smaller manufacturers will accept even the most remote location, while larger wind turbine companies (with generally the more mature technology) will need a more long-term perspective to engage themselves in new markets and regions of the world.

78) Price estimation rounded, using current list prices of Ammonit Meßgeräte GmbH, Berlin

No.	Item	Estimated Price
16	metal anemometers	3,000 €
4	wind vane, 12 sectors	1,200 €
13	data loggers	20,000 €
13	sets of spare batteries[79]	1,700 €
	accessories (cables, etc.)	1,100 €
	Measuring Equipment	**27,000 €**

Professional evaluation software for wind data analysis (WASP, WindPro etc.) cost in the range of 5,000 € a package. Since it requires a prolonged training for its useful application and years of experience until it can be used in full, it is not recommended for the 13 measuring stations in Ethiopia.

Instead, data evaluation with free (simple) data management and evaluation programmes – such as ALWIN for Windows[80] – should be taught and used for the proposed wind data evaluation.

9.2.2 Consultancy

For the proposed three phases of project implementation the following consultancy services should be organized by GTZ:

Phase 1: Pre-selection of Sites

A wind energy expert is expected to work in Ethiopia for up to four weeks, of which at least one week should be used exclusively for capacity building. Due to a poor road network and the mapping system of the country (topographic maps) not being up-to-date, quite extensive search times for the 10 measuring sites are to be anticipated.

Phase 2: Final Selection (3 Sites 40 m)

After at least 6 months of data recording, the 10 sites of the first round are evaluated, and the three best sites selected. In the improbable case that no site has suitable wind regimes, the project has to be terminated.

During and after the installation of the 40 m towers, basic data on grid connection and wind power integration should be gathered. A week long training course on wind park layout, calculation of wake effects in wind parks, wind park efficiency, electric connection etc. should be included during this phase. Total estimated consultancy time in Ethiopia is three weeks.

Phase 3: Feasibility Study

After termination of the measuring campaign for three sites with 40 m towers, the wind data are processed and evaluated and used as a basis for a feasibility study. An effort of 10 weeks, including a two weeks stay in Ethiopia, is estimated for this phase.

In total, about 17 weeks are estimated for consultancy tasks for the next three phases, to be provided by GTZ. If need arises and EEPCO so wishes, additional time for capacity building in Ethiopia should be provided.

79) The batteries are special Lithium batteries which last more than one year, even under extreme high temperatures

80) This software has been developed by Deutsches Windenergie Instistut (DEWI) and is available for free on the web.