This ***Market Assessment Report*** was prepared by the Business Council for Sustainable Energy with financial support from the US Trade and Development Agency as part of the "Eastern Africa Geothermal Market Acceleration Conference" to be held in Nairobi, Kenya, from April 9 to 11, 2003. The Conference is sponsored by:

- US Trade and Development Agency (USTDA)
- United Nations Environmental Programme (UNEP)
- US Agency for International Development (USAID)
- United Nations Education, Scientific, Cultural Organization (UNESCO)
- Global Environmental Facility (GEF)
- US Department of State (USDOS)

BUSINESS COUNCIL FOR SUSTAINABLE ENERGY

Formed in 1992 following the Rio Earth Summit, the Business Council for Sustainable Energy (BCSE) is dedicated to implementing market-based approaches to reducing pollution and providing a diverse, secure mix of energy resources. The BCSE is comprised of companies and industry trade associations in energy efficiency, natural gas, renewable energy, independent power and electric utility industries. Our membership includes companies on the cutting edge of efficient, economic and environmentally sound fuels and technologies, such as natural gas, wind, solar and geothermal power, combined heat and power, insulation and fuel cells. Among our objectives, we advocate the implementation of cost-effective programs and policies that recognize the environmental attributes of various energy sources and reduced reliance on imported fuels. Sister organizations have been formed in the European Union (e^5 in 1996), United Kingdom (UKBCSE in 2001) and in Australia (ABCSE in 2002).

1200 18th Street, NW, Ninth Floor, Washington, DC 20036
Phone (202) 785-0507 Fax (202) 785-0514 Website www.bcse.org Email info@bcse.org

THE US TRADE AND DEVELOPMENT AGENCY

The US Trade and Development Agency (USTDA) advances economic development and US commercial interests in developing and middle income countries. The agency funds various forms of technical assistance, feasibility studies, training, orientation visits and business workshops that support the development of a modern infrastructure and a fair and open trading environment. This assistance is provided through grant funding for host country public and private sponsors to utilize US private-sector expertise.

USTDA's strategic use of foreign assistance funds to support sound investment policy and decision-making in host countries creates an enabling environment for trade, investment and sustainable economic development. Operating at the nexus of foreign policy and commerce, USTDA is uniquely positioned to work with US firms and host countries in achieving the agency's trade and development goals. In carrying out its mission, USTDA gives emphasis to economic sectors that may benefit from US exports of goods and services.

1000 Wilson Boulevard, Suite 1600, Arlington, VA 22209-3901
Phone (703) 875-4357 Fax (703) 875-4009 Website www.tda.gov Email: info@tda.gov

TABLE OF CONTENTS

LIST OF FIGURES

KENYA COUNTRY GEOTHERMAL REPORT

DJIBOUTI COUNTRY GEOTHERMAL REPORT

ETHIOPIA COUNTRY GEOTHERMAL REPORT

ERITREA COUNTRY GEOTHERMAL REPORT

UGANDA COUNTRY GEOTHERMAL REPORT

TANZANIA COUNTRY GEOTHERMAL REPORT

ZAMBIA COUNTRY GEOTHERMAL REPORT

LIST OF TABLES

KENYA COUNTRY GEOTHERMAL REPORT

DJIBOUTI COUNTRY GEOTHERMAL REPORT

ETHIOPIA COUNTRY GEOTHERMAL REPORT

ERITREA COUNTRY GEOTHERMAL REPORT

UGANDA COUNTRY GEOTHERMAL REPORT

ZAMBIA COUNTRY GEOTHERMAL REPORT

INTRODUCTION

Eastern Africa Geothermal Overview

The restructuring of the electric power industry, the growing demand for energy and the increasing private sector participation in the Eastern African countries are creating a market for the development of geothermal energy projects. Many of the Rift Valley countries of Eastern Africa are dependent on fossil fuels as their primary energy source. To decrease imports, they are increasingly turning to their own natural resources to help them meet their growing energy needs. Geothermal energy also presents a clean and more environmentally friendly alternative to more traditional fuels.

Using today's technologies, Eastern Africa has the potential to generate 2,500 MW of energy from geothermal power. To put this in an international perspective, approximately 8,100 MW of geothermal power is generated worldwide. Indonesia produces 589 MW, Japan 546 MW and the Philippines over 1900 MW of electrical power from geothermal energy. Kenya and Ethiopia have a total installed geothermal energy capacity of 65 MW. Since the early 1980's, 45 MW of geothermal electrical power has been operating in Kenya at Olkaria (near Naivasha) at greater than 98 percent availability. In 2000, independent power producer ORMAT International began to generate an additional 12 MW of electricity using geothermal energy in Kenya. By 2019, Kenya plans to add a total of 576 MW of geothermal power.

Varying degrees of geothermal exploration and research have been undertaken in Djibouti, Eritrea, Uganda, Tanzania, Zambia, Malawi and Madagascar. The potential to use geothermal energy for grid-connected electrification is greatest in Kenya, Djibouti, Ethiopia, Uganda and Tanzania. In addition, all have the potential to use geothermal energy for grid-connected electrification and government representatives from Ethiopia, Uganda, Tanzania and Eritrea have also expressed interest in using small-scale geothermal plants for rural electrification mini-grid systems.

Market Acceleration Conference

This *Market Assessment Report*, prepared as part of the "Eastern Africa Geothermal Market Acceleration Conference," seeks to provide an overview of the political and economic climate, the energy sector and power demand, and the geothermal resources and project opportunities in Kenya, Djibouti, Eritrea, Ethiopia, Uganda, Tanzania and Zambia.

At the Conference, private companies will have the opportunity to meet one-on-one with over 40 representatives from energy and finance ministries, utility companies and geological institutes from Kenya, Djibouti, Ethiopia, Eritrea, Uganda, Tanzania, Malawi, Zambia, Rwanda and the Comoros Islands to explore geothermal energy market opportunities in the Rift Valley region. Representatives of international finance agencies, African ministries and project developers will discuss innovative financing options for accelerating geothermal development in Eastern Africa. Among the topics to be addressed will be the role and participation of host country governments, options for overcoming financial and regulatory barriers and a new "risk-sharing" geothermal initiative for resource exploration that is being established by UNEP with the support of the GEF, the German Development Bank (KfW) and others.

Geothermal Project Opportunities

Most of the geothermal projects outlined in this Report are in the conceptual or early planning stages. The projects require equipment, engineering and geoscience-related services for geothermal resource assessments, exploratory drilling, well testing, reservoir assessments and project feasibility studies. Environmental impact studies, project development and power plant design expertise will also be needed. In addition, Eastern African governments are looking for businesses to partner with, develop or bid on new or existing geothermal projects.

The geothermal projects highlighted in this Report include:

Kenya	Anticipated request for proposals (RFP) from the government of Kenya for the development of a 50- to 60-MW geothermal power plant at Olkaria Domes.
Djibouti	Provision of goods and services toward the development of a 30-MW geothermal plant at Lake Assal in support of public and private sponsors.
Ethiopia	Collaboration with the Ministry of Mines in the development of a five to 20-MW geothermal energy plant in Tendaho that is currently under consideration by the Ministry.
	Rehabilitation, purchase or lease of the Aluto Langano 8.5-MW geothermal plant, depending on the strategy adopted by the Ethiopian Electric Power Corporation.
Eritrea	Collaboration with the Ministry of Energy and Mines on further geothermal assessments and plans to develop a five-MW pilot plant at the Alid Volcano Complex.
Uganda	Collaboration with the Ministry of Energy and Mineral Development on geothermal feasibility studies and exploratory drilling at the Katwe, Burganga and Kibiro prospects.
Tanzania	Partnering with First Energy Company, a private Tanzanian company, to develop a five-MW pilot geothermal energy plant in the Rufiji district.
	Collaboration with the Ministry of Energy and Mines on further geothermal exploration and development in the Mbeya and Arusha areas.
Zambia	Work with the Ministry of Energy and Water Development and the Zambia Electric Supply Corporation to design and develop a project to rehabilitate the 200-kW Kapisya geothermal installation located at Sumbu on the shores of Lake Tanganyika.

USTDA has actively promoted energy sector projects in East Africa and regionally in sub-Saharan Africa at large. In the field of geothermal energy, in addition to co-sponsoring this conference, USTDA partially funded a feasibility study, on a 50/50 cost-shared basis with Geothermal Development Associates (GDA), of Reno, Nevada, for the development of a 30-MW geothermal energy plant in the Lake Assal region of Djibouti. Based on the outcomes of this Conference, USTDA hopes to be able to provide additional feasibility study grants to East African project sponsors for geothermal energy projects in the Rift Valley region.

Preparation of Country Reports and Project Summaries

The BCSE was enlisted by USTDA to conduct a review of the geothermal prospects in Eastern Africa and identify and assess potential private sector project opportunities. The BCSE retained geothermal energy consultant Stephen Hirsch to review all geothermal documentation available for the region and prepare geothermal energy market reports for the countries of Kenya, Ethiopia, Eritrea, Djibouti, Uganda, Tanzania and Zambia.

Much of the geothermal information in this report is based on initial work previously carried out by Stephen Hirsch under the auspices of the Idaho National Engineering and Environmental Laboratory (INEEL) for the US Department of Energy. Initial draft geothermal country reports were sent to public and private sector representatives in Kenya, Ethiopia, Eritrea, Djibouti, Uganda, Tanzania and Zambia for comment.[1]

---

[1] Draft reports for Malawi and Rwanda were also prepared but insufficient information was available for them to be included in the final report.

With the support of USTDA, USAID, UNEP, USDOS and GDA, field visits were undertaken in late 2002 and early 2003 to all of these countries (except Zambia). During and following the field visits, feedback on the reports and additional information was received from host country officials and integrated into the final documents.

OVERVIEW OF GEOTHERMAL COMMERCIAL OPPORTUNITIES

KENYA - Olkaria Domes IV

Kenya is the first African country to use geothermal energy for electric power generation and has involved the private and public sectors in its geothermal development. In 1981, a 15-MW geothermal power plant was commissioned at the Olkaria I field followed by second and third units of the same capacity in 1982 and 1985. The 45-MW plant has been operating at over 98 percent availability. A second 64-MW power station, (Olkaria II) owned by KenGen, is currently under construction and will be commissioned at the end of 2003. Olkaria II is funded by the World Bank, European Investment Bank, KfW and the government of Kenya. In 1997, ORMAT International received a license from the Kenya government to generate between 64 to 100 MW in the Northwest sector of the Olkaria field (Olkaria III). Thus far, 12 MW have been commissioned.

Exploration drilling has also been undertaken at other sectors of Olkaria field, the most recent being in the Olkaria Domes area to the south of Olkaria I where three deep exploration wells were drilled by KenGen in 1998 and 1999. This year KenGen plans to carry out appraisal drilling including six additional deep wells in this area.

Thus far, 103 geothermal wells have been drilled in Kenya for exploration, production, monitoring and re-injection with depths varying from between 180 and 2,600 m. Of these, 97 wells are in the Olkaria area and the remaining six are in the Eburru Field. Based on Kenya's Least Cost Power Plan adopted in 2001, Kenya intends to develop an additional 548 MW of geothermal power between now and the year 2019. It is anticipated the private sector will be asked to bid on the various phases of this development. If the appraisal drilling program at Olkaria Domes (IV) is successful, bids to develop and build a 64-MW power plant will be requested from the business community.

DJIBOUTI – Lake Assal Geothermal Power Plant

Djibouti is entirely dependent on imported petroleum supplies for its power generation needs. Exploratory drilling that was carried out in the Lake Assal area in the 1970's and 1980's discovered geothermal resources at two depths. With the support of the USTDA, Geothermal Development Associates (GDA) completed a feasibility study in August 2000 for the development of a 30-MW geothermal power plant at Lake Assal that established the commercial viability of the proposed facility.

As the project moves forward, the following equipment and services will be required: (a) drilling and well completion (cementing and casing); (b) reservoir assessment; (c) water and mineral extraction (possible); (d) well testing; (e) environmental studies; (f) financing; (g) power plant design; and (h) machinery parts, maintenance and repair.

ETHIOPIA – Refurbishment of the Aluto Langano Plant and Three-to 20-MW Geothermal Pilot Project at Tendaho

Ethiopia has an installed generating capacity of 714 MW and 94 percent is from hydroelectric power. The remaining five percent comes from diesel generators and one percent from geothermal energy. Ethiopia has one of the lowest per capita electricity consumption levels in Africa (averaging 21.5 kWh per annum). Only four percent of the population and less than half of Ethiopia's towns have access to electricity. Ethiopia's geothermal resource potential is estimated to be a few thousand MW. Of this, at least 170 MW is from sites in the Lakes District, 260 MW from Central Afar, 120 MW from Southern Afar and 150 MW from sites in the Danakil Depression.

In 1999, a pilot geothermal plant with a net generating capacity of 7.3 MW was completed at the Aluto Langano geothermal prospect by ORMAT International under a turn-key contract. The plant was then turned over to the Ethiopian Electric Power Corporation (EEPCO). From the outset, the generating capacity of the wells declined, and in December 1999 EEPCO was forced to shut down one of the four units due to a pentane leak. EEPCO is in the process of developing a plan to refurbish the Aluto Langano plant.

Meanwhile, additional geological testing at the Tendaho geothermal prospect is being carried out by the Geological Survey of Ethiopia. Assuming suitable test results, the government of Ethiopia intends to contract with a private company to build a 2.5- to three-MW plant and eventually expand the installation to 20 MW.

Anticipated geothermal goods and services will be required at Tendaho for the following: (a) drilling and well completion (cementing and casing); (b) reservoir assessment; (c) water and mineral extraction (possible); (d) well testing; (e) environmental studies; (f) project pre, feasibility studies, and analysis; (g) financing; (h) gathering systems; (i) power plant design, construction, operation and maintenance; and (j) machinery parts, maintenance and repair.

ERITREA - Feasibility Study for Five-MW Pilot Plant at Alid

Eritrea is entirely dependent on imported petroleum supplies for its power generation needs, and the potential for carbon offsets is significant. Eritrea has a total generating capacity of 113 MW that includes 88-MW from the Hirgigo/Massawa and 25-MW from the Asmara power plants. Present peak power demand is 47 MW. The Eritrean Electric Agency believes it has three to five years before it will need to develop additional power generation capacity. The government is finalizing its electricity law to include private sector participation in the generation and sale of electrical power.

The Department of Mines within the Eritrea Ministry of Energy and Mines is currently seeking financing for the upfront exploration work needed to prove the capacity of the Alid geothermal resource. The studies needed include:

- Upgrading geologic, geochemical, and geophysical information; establishing a geothermal model; and identifying high-probability borehole targets for drilling.
- Identifying, drilling and testing exploratory wells (including reservoir assessments and possible water and mineral extraction) to document the geothermal resources at Alid.
- Preparation of technical and financial plans for the purchase and installation of a geothermal pilot plant that will meet the region's increased power demand.

The Alid is a region in need of electrical power and well situated for electricity production. Located 120 km from Masawa, electricity form the geothermal field could be used by the local fishing industry and for cement production. The Masawa – Asab road that is presently under construction will run close to Alid and will also increase the need for power in the area. Assuming the technical studies at Alid are successful, the Eritrean government wishes to install a five-MW pilot geothermal power plant. The plant could be owned and operated either by the Eritrean government or the private sector. The government of has indicated it would help arrange financing for the project if it were implemented by a private company.

UGANDA - Geothermal Assessment at the Katwe, Buranga and Kibiro Geothermal Prospects

Uganda presently has a total generating capacity of 300 MW, most of which is from large hydro. Peak demand is about 265 MW. The country's energy surplus is expected to be short term, with electricity demand growing at approximately two percent per month. Despite its abundant hydro resources, the Ugandan government recognizes that it must diversify its energy resources. The present level of uncertainty regarding the future of the Bujagali hydro project has caused the government to take a closer look at the country's geothermal potential. The government is especially interested in including village-scale geothermal power plants as part of its rural electrification program.

At present there are three geothermal prospects that are being assessed in western Uganda. An African Development Bank (AfDB) funded study is researching the Katwe and Buranga fields and the government of Iceland is conducting research at the Kibiro geothermal prospect near Lake Albert. All three studies are expected to be completed and analyzed by the end of 2003. Based on the results, a feasibility study will be needed and test wells drilled to fully assess the resource and the commercial viability of one or more of the sites.

Ugandan officials recognize that they do not have sufficient geothermal data to negotiate binding PPAs with geothermal developers at the present time. Nevertheless, the government is interested in negotiating preliminary "non-financial PPAs" with interested private geothermal energy companies willing to partner with the Ministry of Energy and Mineral Development to obtain grant or "partial risk guarantee" funds[2] for the work required following completion of AfDB and Icelandic studies. Further work will require goods and services including: (a) drilling and well completion (cementing and casing); (b) reservoir assessment; (c) water and mineral extraction (possible); (d) well testing; (e) environmental studies; (f) project pre-feasibility studies and analysis; (g) financing; (h) power plant design; and (i) machinery parts, maintenance and repair.

TANZANIA – Six-MW Geothermal Power Plant in Rufiji

The Government of Tanzania considers its hydro power the most important indigenous source of commercial energy. The country is reported to have a potential of 4.7 GW. To date, 560 MW of hydropower has been developed. In the 1990s, Tanzania's dependency on hydropower became apparent when low rainfall created persistent power shortages. Tanzania also has proven reserves of natural gas.

Geothermal exploration was carried out from 1976 to 1979 in the north near Arusha, Lake Natron, Lake Manyara and Maji Moto and in the south in the Mbeya region by SWECO, a Swedish consulting group, in collaboration with Virkir-Orkint of Iceland. Approximately 50 hot springs were mapped, and two potential target areas were singled out for further geothermal exploration: (a) the Arusha region near the Kenyan border in the north and (b) the Mbeya region in the southwest.

Based on 1995 petroleum exploration data provided by Shell, First Energy Company Limited (FEC), a small Tanzanian company based in Dar es Salaam, received a geothermal exploration license for the Rufiji region (150 km from Dar es Salaam along the Rufiji River). FEC has researched the economic feasibility and developed plans for a six-MW geothermal power plant in Rufiji and the construction of a transmission line from Luhoi to Utete, Kibiti and Ikwiriri.

FEC is looking for an international partner for an estimated US$14.8 million project. Anticipated geothermal goods and services required near-term for the FEC project will include: (a) project pre and full feasibility study; (b) project development; (c) exploration program design and analysis; (d) drilling and completion; (e) well testing; (f) reservoir assessment; (g) power plant design; (h) financing; (i) environmental studies.

ZAMBIA - Refurbishment of the 200-kW Kapisya Geothermal Power Plant

Zambia has an installed capacity of 1,774 MW with a peak load of 1,028 MW, most of which comes from three main hydro electric stations: Kariba North Bank (600 MW), Victoria Falls (108 MW) and Kafue Gorge (900 MW). Despite the country's surplus of available electricity, only 20 percent of the total population and two percent of the rural population has access to the electricity grid. Zambia currently is pursuing plans to construct 200 km of 123 kV transmission lines between the Western province of Zambia and parts of Namibia. Discussions are also underway to interconnect the grid with Tanzania and Kenya.

Zambia has a widespread occurrence of hot springs (over 80 recorded), some of which could be utilized to generate electricity using binary cycle technology. Two geothermal energy projects have been initiated: the first included the construction of a small geothermal plant while the second was planned but never implemented.

In 1986 the Zambian Geological Survey, in conjunction with DAL, SpA (Italy), determined that the hot springs in Kapisya are favorable for commercial power generation. A pilot plant located in Sumbu on the shores of Lake Tanganyika was subsequently built with funding from the Italian government. The plant uses a total of 15 shallow

[2] "Partial risk guarantee" funds may be made available under a program being discussed to cover loans for part of the cost of high-risk exploratory drilling. The loans must be repaid from electricity revenues if the exploratory drilling is successful. The guarantee funds will repay the portion of the loan guaranteed if the exploratory drilling is not successful.

exploratory and production wells, four of which have submersible pumps installed. The plant also has two Organic Rankine Cycle (ORC) turbogenerators, with a nominal capacity of 200 kW which were last inspected by the Italian government in 1988.

The project never became operational because the construction of a transmission line to deliver electricity to the communities near Nsumbu (to boost fishing and tourism) was never completed. The government of Zambia is currently exploring options for commissioning and refurbishing the Kapisya geothermal plant after 15 years of being idle. Proposed project objectives include:

- Commission the turbogenerators by replacing missing and faulty parts and conduct trial operations.
- Train local technical personnel in the maintenance and operation of the geothermal plant.
- Construct a transmission line from the geothermal plant to Nsumbu to supply power to consumers in nearby communities.
- Form a consortium of local communities and the private sector in Nsumbu to operate the power plant and pay for its operation and maintenance.

The second project involved planning for the development of a health resort and construction of a geothermal power plant to provide electric power to the local community at Chinyunyu Hot Springs, that is located 50 km east of Lusaka on the Great East Road. The Japanese International Cooperation Agency, in conjunction with the Zambian Geological Survey, undertook this project, which remains in the planning stages due to lack of funds.

ABBREVIATIONS

$\geq$	More than or equal to
$\leq$	Less than or equal to
$\pm$	Plus or minus
AERDP	Alternative Energy Resources Development Programme (Uganda)
AfDB	African Development Bank
bbl	Billion barrels of liquid
BOO	Build-Own-Operate
BOT	Build-Own-Transfer
BRELA	Business Registration and Licensing Authority (Tanzania)
^{o}C	Degrees Celsius
CGSC	Calub Gas Share Company (Ethiopia)
CERD	Centre de Recherche Scientifique de Djibouti
DF	Djibouti francs
DRC	Democratic Republic of Congo
EdD	Électricité de Djibouti
EEA	Eritrea Electric Authority
EEPCO	Ethiopian Electric Power Company
EELPA	Ethiopian Electric Light and Power Authority
EIGS	Ethiopian Institute of Geological Surveys
EMCA	Environmental Management and Coordination Act 1999 (Kenya)
EPRDF	Ethiopian People's Revolutionary Democratic Front
ERB	Electricity Regulatory Board (Kenya)
ERA	Electricity Regulatory Authority (Uganda)
ERP	Economic Recovery Program (Tanzania)
ERT	Energy for Rural Transformation Programme (Uganda)
ESAF	Enhanced Structural Adjustment Facility
ESTC	Ethiopian Science and Technology Commission
F	Fahrenheit
FEC	First Energy Company Limited (Tanzania)
ft.	Feet
Ft^3	Cubic feet
GCCU	Geothermal Combined Cycle Unit
GDA	Geothermal Development Associates
GDP	Gross domestic product
GEEP	Geothermal Energy Exploration Project (Uganda)
GEF	Global Environment Facility
GSE	Geological Survey of Ethiopia
GSMD	Geological Survey and Mines Department (Uganda)
GW	Gigawatt
GWh	Gigawatt Hours
IAEA	International Atomic Energy Agency
ICJ	International Court of Justice
ICS	Interconnected System (Ethiopia)
ICSID	International Center for the Settlement of Investment Disputes
IDA	World Bank International Development Association
IFC	International Finance Corporation
IGIC	Inter-Arab Guarantee Investment Company
IMF	International Monetary Fund
IPP	Independent power producer
IPTL	Independent Power Tanzania Limited (Tanzania)
ISERST	Institute Superieure pour les Etudes et la Recherche Scientifique et Technique
KfW	Kreditanstalt fuer Wiederaufbau (The German Development Bank)
KBO	Kagera Basin Organization
km	Kilometer

km^2	Square kilometers
KPLC	Kenya Power and Lighting Company Limited
KenGen	Kenya Electricity Generating Company
KPC	Kenya Power Company
kV	Kilovolts
kW	KiloWatt
kWh	KiloWatt Hour
lb	Pound
LCPDP	Least Cost Power Development Plan (Kenya)
m	Meters
m^3/sec	Cubic meters per second
mm	Millimeters
masl	Meters above sea level
MEM	Ministry of Energy and Minerals (Tanzania)
MER	Main Ethiopian Rift
MEMD	Ministry of Energy and Mineral Development (Uganda)
MEMWR	Eritrean Ministry of Energy, Mines and Water Resources
MEM	Eritrean Ministry of Energy and Mines
MIGA	Multilateral Investment Guarantee Agency
MOU	Memorandum of Understanding
MoF	Ministry of Finance
MT	Magnetotelluric
MW	Megawatts
NEMA	National Environmental Management Agency (Uganda)
NGO	Non-governmental organization
OEC	Ormat Energy Conversion unit
OPEC	Organization of Petroleum Exporting Countries
ORC	Organic Rankin Cycle
PPA	Power purchase agreement
PV	Photovoltaic (technology)
PSC	Production sharing contract
REF	Rural Electrification Fund (Zambia)
SADC	Southern Africa Development Community
SAPP	Southern Africa Power Pool
SIDA	Swedish International Development Authority
SCS	Self-Contained System (Ethiopia)
TANESCO	Tanzania Electric Supply Company Ltd.
T_{max}	Maximum temperature
TPDC	Tanzania Petroleum Development Corporation
TWh	Trillion watt hours
UEB	Uganda Electricity Board
UNDP	United Nations Development Programme
UAERAUS	Uganda Alternative Energy Resources Assessment and Utilization Study
UIA	Uganda Investment Authority
USDOE	US Department of Energy
USGS	US Geological Survey
US$	US dollar
VAT	Value added tax
ZESCO	Zambian Electricity Supply Corporation

ACKNOWLEDGEMENTS

Host Country Governments

The BCSE would like to express its deepest appreciation to the government officials from Eastern Africa who provided documentation and comments on various drafts of this report. In particular, we would like to acknowledge the support of:

- Martin Mwangi, Kenya Electricity Generating Company, Ltd. (KenGen)
- Godfrey Bahati, Uganda Geological Survey
- Amos Lugolobi, Uganda Investment Authority
- Dison Okumu, Uganda Electricity Distribution Co.
- Gerald Muganga, Uganda Electricity Transmission Co.
- Herman Ssenyondwa, Uganda Electricity Transmission Co.
- Dr. F.B. Sebbowa, Electricity Regulatory Authority, Kampala, Uganda
- Alem Kibreab, Eritrean Ministry of Energy and Mines
- Michael Abraha, Eritrea Geological Survey
- Meseret Teklemariam, Geological Survey of Ethiopia
- Getahun Demissie, GeoMet Plc., Addis Ababa, Ethiopia
- Ngosi Mwihava, Tanzanian Ministry of Energy and Minerals
- Hubert E. Meena, The Centre for Energy, Environment, Science and Technology, Tanzania
- Abdi Farah Chideh, Djibouti Ministry of Energy and Natural Resources
- Issac M. Marobhe, University of Dar es Salaam, Tanzania
- George Kibakaya, First Energy Co., Dar es Salaam, Tanzania
- Geoffrey Musonda, Sparknet, Zambia

US Trade and Development Agency

The "Eastern Africa Geothermal Market Acceleration Conference" and this Report were funded by USTDA. The BCSE wishes to express its deepest appreciation to USDTA for its leadership and dedicated support for geothermal energy in Eastern Africa.

US Department of State

The US Embassies in Eritrea, Ethiopia, Djibouti, Tanzania, Kenya and Uganda provided valuable contacts and background information for the Eastern African countries visited. A special note of thanks is owed to Dan Balzer, Regional Environmental Officer for Eastern Africa for his participation in the site visits to Kenya, Eritrea, Ethiopia, Uganda, Tanzania and Rwanda and the information he provided for the country reports and to Moges Worku and Janet Petersen for their assistance in Addis Ababa. A special note of thanks is given to Dr. Fernando Echavarria, Office of Space and Advanced Technologies, for his tireless support for geothermal development in Eastern Africa and this conference since its inception. USDOS is also a financial sponsor of this Conference.

US Agency for International Development

USAID for providing travel funding for the Eastern Africa site visits and is a financial sponsor of this Conference. A special thanks to Henderson Patrick, USAID/Rwanda and Kevin Warr, USAID/Energy Office, Washington, DC for their assistance in identifying country contacts and speakers for the Conference.

United Nations Environmental Programme

UNEP is Co-organizer with the BCSE and one of the primary financial sponsors of this Conference. In addition, UNEP provided funding for Martin Mwangi, KenGen Geothermal Development Manager to participate in the Eastern African country site visits and for Geoffrey Musonda to provide information on Zambia's geothermal prospects. The BCSE extends its gratitude to Tom Hamlin, Project Officer, UNEP Division of Technology, Industry and Economics in the Energy and Ozone Action Unit for his support, assistance and guidance in preparing the country reports and in organizing and promoting the Conference. The BCSE also wishes to thank Ann-Marie Verbeken, Lisa Masila and Milka Ngara for their assistance with logistics.

Others

The BCSE would also like to extend its appreciation to the numerous other supporters of this Report and the Conference, including: Martin Booth, GDA; Joel Renner, INEEL; Mike Foose, US Geological Survey; Karl Gawell, US Geothermal Energy Association; Ted Clutter, Geothermal Resources Council; and Jim Randle and Peter Barnett, Sinclair Knight Merz.

KENYA COUNTRY GEOTHERMAL REPORT

Figure 1: Map of Kenya

I. COUNTRY OVERVIEW

1.1. Geography, Population and Government Structure

The Republic of Kenya straddles the equator, covering 582,640 km^2. It borders the Indian Ocean and Somalia to the east, Sudan and Ethiopia to the north, Uganda and Lake Victoria to the west and Tanzania to the south. The segment of the Eastern Africa Rift referred to as the Kenya Rift Valley extends from Lake Turkana to northern Tanzania near Lake Natron.

Kenya's varied terrain rises from sea level at the coast to Mount Kenya (5,199 m) to the east of the Great Rift Valley and Mount Elgon (4,321 m) to the extreme west. The country is bisected by the Rift Valley (see Fig. 1) that runs the whole length of the country from north to south.

Kenya's population is approximately 30 million. While the majority of the people live in the rural countryside, the urban centers are rapidly growing. Kenya is also a land of ethnic contrasts. There are some 42 different tribes deriving from three major groups – the Bantu (the majority), the Nilotics and the Cushites.

Kenya gained independence in December 1963. Mzee Jomo Kenyatta was the first elected President and kept this position until his death in 1978. Between 1963 and 1978, Kenya became a one-party state ruled by the KANU political party. In 1978, Kenyatta was succeeded by Daniel Arap Moi. Moi was defeated in December 2002 by Mwai Kibaki's NARC coalition. Kibaki was sworn in as the third President on December 30, 2002.

1.2. Political and Social Issues

At the domestic and international levels few people doubt President Kibaki's sincerity in fighting corruption and promoting economic growth. However, it is seen as essential that he pick his government's priorities carefully. Of prime concern to Kenya's immediate development are the once-prized public services: health, power and telecommunications that deteriorated dramatically during Moi's rule. Kenya's roads are also riddled with pot holes and crime and AIDS are rampant.

1.3. Economy

Agriculture is the mainstay of Kenya's economy, contributing over one-third of the GDP. Agricultural crops include tea, coffee, horticultural products, pyrethrum, pineapples, sisal, tobacco and cotton. Food crops for domestic consumption include maize, beans, cane sugar, wheat, rice, bananas, cassava, potatoes, sorghum, and millet. Livestock is also prominent.

Exports include tea, coffee, horticultural products, hides and skins, pyrethrum, pineapples and beer. Imports include industrial machinery, crude petroleum, motor vehicles and transport equipment, minerals, iron and steel, chemicals, food and manufactured goods.

Key industries include food and beverage processing, manufacture of petroleum products, textiles and fibers, garments, tobacco, processed fruits, cement, paper, pyrethrum products, engineering products, wood products, pharmaceuticals, basic chemicals, sugar, rubber and plastics.

Kenya's financial sector consists of a Central Bank, 32 commercial banks, 51 non-bank financial institutions, 36 insurance companies, six development finance institutions and a number of building societies. Some of these institutions are locally owned while others are foreign-owned.

II. COUNTRY ENERGY CONTEXT

2.1. Electricity Sector

Eight-four percent of electric power generating capacity is owned by the Kenya government through the Kenya Electricity Generating Company (KenGen), previously known as The Kenya Power Company (KPC). Independent power producers (IPPs) own the remaining 186.5 MW of power capacity, equivalent to 16 percent of the total.

In 1996, the Kenyan government restructured the power sector. The power stations, originally owned by various government institutions, were transferred to KPC, and the transmission facilities previously owned by KPC were transferred to Kenya Power and Light Company Limited (KPLC). KPLC is currently the only company licensed for transmission, distribution and sale of electricity purchased from public and private bulk supply companies. The Electricity Regulatory Board (ERB) was established in 1998 to undertake the regulatory functions that were previously performed by the Minister of Energy.

2.2. Electricity Capacity and Demand

Kenya's current electricity system capacity is 1,172 MW. This includes 30 MW imported from Uganda and 74 MW from the Kipevu II diesel plant that has been commercially operated since August 2001. Current effective Kenyan capacity is 987 MW. This is derived from the following sources:

- 584 MW (59.2 percent) - hydro
- 57 MW (5.8 percent) - geothermal
- 346 MW (35 percent) - conventional thermal
- 0.55 MW (0.1 percent) - wind turbines

There are an additional three projects currently under construction in Kenya that command a total capacity of 172 MW, Olkaria II (64 MW) and Olkaria III (48 MW), both geothermal plants, and Sondu Miriu (60 MW) a series of hydropower projects. These are expected to come into service in 2003, 2004 and 2005, respectively.

Only nine percent of the total population in Kenya has access to electricity. This has resulted in an extremely high level of repressed demand and a vast potential for load-growth nationwide.

In 2000/2001, Kenya's load forecasts for its net system peak (see Table 1) were estimated at 817 MW. This is projected to grow to 2,131 MW by 2018/2019, an annual rate of 5.5 percent as illustrated below.[3]

Table 1: Kenya Electricity Forecast Update for January 2001 (Mwangi, 2001)

Year	**Low Forecast**		**Reference Forecast**		**High Forecast**	
	Energy (GWh)	**Peak Power (MW)**	**Energy (GWh)**	**Peak Power (MW)**	**Energy (GWh)**	**Peak Power (MW)**
2000/01	4,781	815	4,791	817	4,801	818
2003/04	5,245	894	5,364	915	5,441	929
2006/07	6,032	1,030	6,343	1,085	6,615	1,133
2009/10	6,960	1,191	7,512	1,288	8,042	1,381
2012/13	8,023	1,376	8,880	1,526	9,755	1,680
2015/16	9,239	1,587	10,841	1,805	11,807	2,038
2018/19	10,630	1,828	12,352	2,131	13,397	2,315
Average Growth per Year (%)	**4.5**	**4.6**	**5.4**	**5.5**	**5.87**	**5.95**

2.3. Competing Resource Options

There are two main indigenous resources in Kenya available for large-scale power development: geothermal and hydro. Kenyan geothermal energy has a capacity estimated at 2,000 MW (Mwangi, 2001) with near constant availability, and hydro has an estimated capacity exceeding 1,400 MW with an average availability of about 50 percent. These are each equal to a generation yield of approximately 6,000 GWh per year. The majority of economically viable hydro sites in Kenya have been developed. Indigenous geothermal energy sites have yet to be fully exploited. Apart from Kenya's Least Cost Power Development Plan (LCPDP), which helps shape Kenya's future power development,[6] new construction of power plants will also be influenced by a Regional Master Plan that is being developed by Kenya, Uganda and Tanzania jointly.

At present, Kenya is working with the governments of Tanzania and Zambia to prepare and promote projects for interconnecting Nairobi, Kenya with Arusha, Tanzania (220 kV), and Mbeyam, Tanzania and Pensulo, Zambia (330 kV) including a requisite 220 kV reinforcement within Tanzania.

Kenya and Uganda are also renegotiating their contract in which Uganda is committed to supply 30 MW to Kenya until 2008, and as of mid-2000 Uganda and Kenya have been studying joint plans to upgrade transmission capacity between the two countries' power systems.[7]

[3] Kenya's load forecast is based on econometric models using sectoral GDP, growth rates and moving average electricity tariffs as main independent variables. In recognition of the inherent uncertainties in load forecast, low, reference and high forecasts are prepared.
[6] The LCPDP is updated on an annual basis.
[7] According to Ugandan officials even if the country had the additional power to export, Uganda would not be able to supply more than 80 MW to Kenya in the near future because of a shortage in transmission capacity.

III. GEOTHERMAL ACTIVITIES, PLANS AND RESOURCES

3.1. Overview

Geothermal investigations in the Rift Valley began in 1956. Two exploratory wells were drilled at Olkaria in the late 1950s and between 1970 and 1972, investigations were carried out at Olkaria, Lake Bogoria and in the Eburru area. Concerted exploratory drilling started in 1973, and by 1975 an additional four wells had been drilled in the Olkaria area. Through 1982, a more or less continuous program of exploration, delineation and production well drilling occurred at Olkaria.

Kenya is the first African country to use geothermal energy for electric power generation. The first geothermal unit of 15 MW capacity was commissioned in June 1981 at Olkaria. This was followed by the commissioning of a second and third unit of 15 MW at the same site in November 1982 and March 1985 respectively. This 45 MW power plant, now called Olkaria I, owned by KenGen is located in the Olkaria East field where 33 geothermal wells have been drilled. Thirty one of these wells are connected to the Olkaria I power plant for steam supply, and the plant has operated since commissioning with high availability factors of over 98 percent.

A second 64-MW power station, Olkaria II, also owned by KenGen, is currently under construction and is expected to be commissioned at the end of 2003. Olkaria II is located in the Olkaria North East Field where another 33 wells have been drilled. Of these, 20 wells will be connected to the plant for steam supply, and the rest will be used for re-injection and reservoir monitoring. This plant has two medium pressure condensing turbines, each with a capacity of 32 MW. Olkaria II has been funded by the World Bank, European Investment Bank, KfW and the Government of Kenya.

In 1997, ORMAT International was licensed by the Kenya Government to generate 64 MW to 100 MW in the northwest sector of the Olkaria resource now called the Olkaria III field. In August 2000, ORMAT commissioned eight MW of geothermal generation that was soon increased to 12 MW.[8] The first phase cost $35 million, financed by ORMAT following an international bid issued by the Kenya Government under World Bank supervision. As part of the first phase, nine new wells have been drilled to further appraise the Olkaria III field. Following this appraisal program, ORMAT has projected it will be capable of producing 48 MW over the next 20 years.[9]

Exploration drilling has also been undertaken in other sectors of the Olkaria field, the most recent being in the Olkaria Domes to the south of the Olkaria I development. Three deep exploration wells were drilled by KenGen here in 1998 and 1999, and KenGen plans to commence appraisal drilling – comprised of another six wells – in 2003. If this program is successful, it is likely that an Olkaria IV power development of about the same generation capacity as the Olkaria II development will be committed in 2004.

KenGen has also carried out detailed surface work at Eburru, Suswa and Longonot volcanic centers. Between 1988 and 1990, six deep exploration wells were drilled at the Eburru prospect. Only one well produced steam but this was at a sub-commercial wellhead pressure, and the field is considered capable of producing no more than 20-25 MW.

There are an additional 12 other prospective areas, besides Olkaria and Eburru, that are also considered to have potential for medium to high temperature geothermal resources. Exploratory drilling (≥ 2.2 km) was planned for Longonot in 2001. However, this has been delayed until appraisal drilling has been completed at Olkaria Domes.

Thus far, 103 geothermal wells have been drilled in Kenya for exploration, production, monitoring and re-injection with depths varying from between 180 and 2,600 m. Of these, 97 wells are in the Olkaria area; the remaining six are in the Eburru Field. KenGen studies have also shown that electricity generation from

---

[8] These units are all based on a binary cycle power plant.

[9] This production level is related to the present Purchasing Power Agreement (PPA) not potentially available geothermal field capacity.

geothermal is one of the least cost base-load sources of energy. Based on Kenya's LCPDP (April 2001), they expect an additional 548 MW to be generated from geothermal resources by the year 2019 (see Table 2).

Direct use of geothermal energy also has been on a trial basis in Kenya. One floricultural farmer near Olkaria has successfully used geothermal fluids for green-house heating for roses and is now planning to expand this on a long-term basis.

Table 2: Kenya Recommended Least Cost Power Development Plan (April 2001)

Year	Config.	Plant name	Generation						Total Additions	Effective Installed Capacity	Peak Forecast
			Hydro	Imports	Geothermal	MSD	Steam	GT			
2001			639.2	0	57	127	56	113		992	817
2002	7x11	Kipevi II				74.2			74.2	1066	843
2003	-1x14	Nairobi GT						-13..5			
	2x32	Olkaria II			64				50.5	1116	878
2004	-1x8	Olkaria III			-8						
	-1x4	Olkaria III			-4						
	2x24	Olkaria III			48						
	-1x76	Retire Kipevu steam					-76		-39.5	1077	915
2005	2x30	Sondu Miriu	60								
	5x20	MSD				100					
	-1x43	Westmont GT						-43			
	-8x5.6	Iberafrica D				-44.5					
	-2x6	Iberafrica D				-12			60.5	1137	968
2006	1x50	UEB2		50					50	1187	1024
2007	1x100	SAPP		100					100	1287	1085
2008	2x10	SAHP	20.6						20.6	1308	1149
2009	2x32	Geothermal IV			64				64	1372	1217
2010	-3x15	Retire Olk. I			-45						
	3x20	MSD				60					
	2x32	Geothermal V			64				79	1451	1288
2011	4x20	MSD				80			80	1531	1363
2012	2x32	Geothermal VI			64						
	1x20	MSD				20			84	1615	1443
2013	2x32	Geothermal VII			64						
	1x20	MSD				20			84	1699	1526
2014	5x20	MSD				100			100	1799	1614
2015	2x32	Geothermal VIII			64						
	2x20	MSD				40			104	1903	1707
2016	5x20	MSD				100			100	2003	1805
2017	2x20	MSD				40					
	2x32	Geothermal IX			64				104	2107	1908
2018	6x32	MSD				120			120	2227	2016
2019	3x20	MSD				60					
	2x32	Geothermal X			64				124	2351	2131
		TOTAL	**80.6**	**150**	**503**	**758**	**-75.5**	**-57**	**1359**	**2351**	

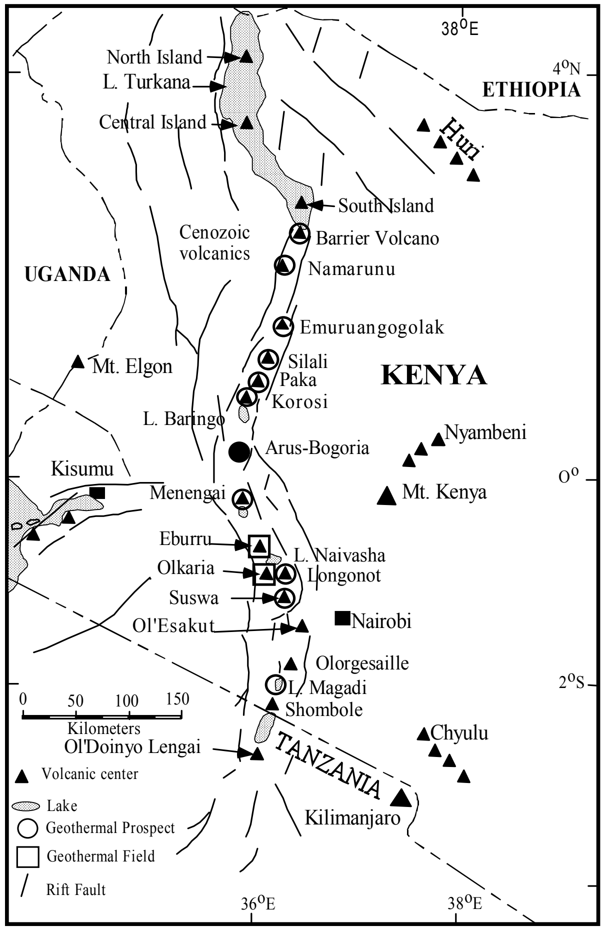


Figure 2: Map of Kenya Illustrating Geothermal Prospects

3.2. Summary of Geothermal Prospects[10]

The Olkaria Geothermal Area

The Olkaria geothermal area is located within the Greater Olkaria Volcanic Complex, which consists of a series of lava domes and ashes; the youngest of which was dated at 180 ± 50 yr BC (Clarke et al., 1990). To date, 97 wells have been drilled in the area. Olkaria geothermal area has been divided into seven reservoir sectors for ease of development (see Fig. 3). The sectors (fields) are Olkaria East, Olkaria North East, Olkaria South West, Olkaria Central, Olkaria North West, Olkaria South East and Olkaria Domes. The entire Olkaria geothermal area has a potential of more than 400 MW.

Olkaria East

Olkaria East field is the home of the Olkaria I power station. Olkaria I has been in operation for 20 years with availability of more than 98 percent. Initially, 23 wells were connected to the three turbines but 31 wells are presently connected to the station, of which six have been retired. Currently, Olkaria I station has steam equivalent to 69 MW available from an area of five km^2, implying an excess of steam of about 24 MW. KenGen is considering installing a ten to 15 MW power plant to utilize the excess steam. Results of tests indicate the field is able to support more than 90 MW.

---

[10] Omenda, P.A., (undated) *Geothermal Power Generation Potential in Kenya*, Kenya Electricity Generating Company Limited. Kenya

Olkaria North East

Thirty four wells have been drilled in this area, and 22 will be connected to Olkaria II power station. The developed steam from this field could generate about 80 MW for 25 years using conventional condensing turbine and single stage steam separation. However, the field is capable of producing more than 100 MW from the 8.8 km^2 area. KenGen is developing the field for a 64 MW Olkaria II power plant.

Olkaria South West

KenGen completed exploration drilling of seven wells in the field in June 1997. Five wells were able to discharge with output varying from one to four MW. The Kenya government put the Olkaria West field out for international bid in 1996. Two companies submitted responsive bids and, after evaluation, ORMAT International was awarded the right to develop Olkaria III with a capacity of 64 MW.

ORMAT is currently generating 12 MW from a combined-cycle pilot plant and will generate 48 MW when fully developed.

Olkaria Domes

Surface exploration in the Olkaria Domes field was completed in 1993. Three wells were sited and drilled between September 1998 and May 1999. The results led to the 8 km^2 field, now termed Olkaria IV, being designated for development with expectations it can generate over 100 MW for 25 years using a combined-cycle plant. Appraisal drilling of six wells was scheduled to commence in January 2003.

Olkaria Central

Four exploration wells have been drilled in the field and two of them, OW-201 and 202, produce 3.7 MW and 3.0 MW, respectively. The other two, 203 and 204, have maximum measured temperatures of 190^o C and 180^o C, respectively. Further development in the Central field has been suspended to monitor the response of the reservoir to production in the Olkaria West and North East fields. The area delineated as Olkaria Central field is about 3.3 km^2 and capable of producing more than 50 MW.

Olkaria North West

Four exploration wells have been drilled in the field, out of which OW-101 and OW-306 produce 1.6 MW and 1.1 MW, respectively. Additional drilling is required to better appraise and delineate the resource, which studies indicate covers an area of more than 9.4 km^2. This field has low enthalpy fluids (T_{max}=220^o C), moreso in the northern and western sectors. However, the field is capable of generating more than 50 MW by utilizing combined-cycle and binary systems.

Olkaria South East

Surface studies coupled with results of OW-801 drilled in the Olkaria South East indicate that the field is marginal and low enthalpy fluids probably cover more than half of the field. Well OW-801 drilled in the center of the field encountered a maximum measured temperature of about 219^o C. The temperatures were expected to decrease south of the well and even have temperature reversals with depth. The field covers about 6.4 km^2 and is capable of generating more than 30 MW using binary system technology.

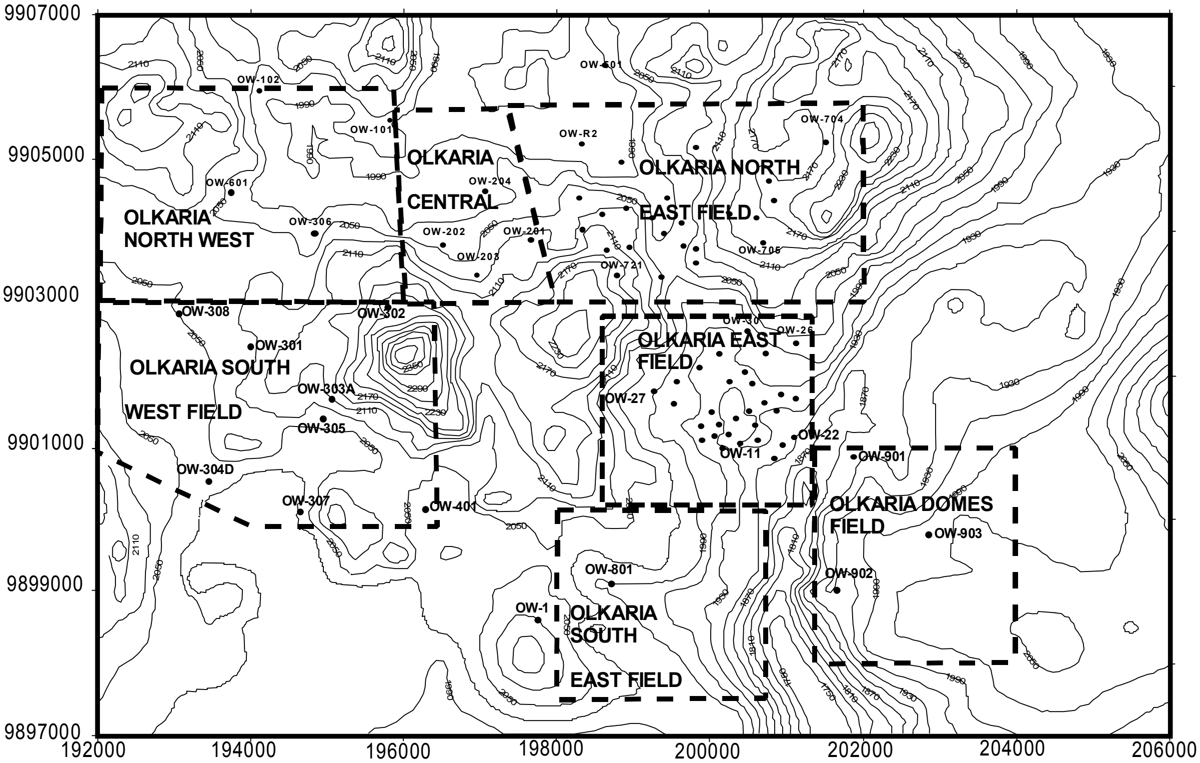


Figure 3: Geothermal Fields Within the Greater Olkaria Geothermal Area

Eburru Geothermal Field

Eburru volcano is located about 50 km north of Olkaria geothermal field (see Figs. 3 and 4). As part of the ongoing exploration program undertaken by KenGen within the Kenya Rift Valley, six wells were drilled in Eburru between 1988 and 1990.

Three wells, EW-01, EW-04, and EW06, produce 2.4 MW, 1 MW and 2.9 MW, respectively. The other wells, EW-02, EW-03 and EW-05, recorded maximum temperatures of 131^{o} C, 161^{o} C, and 156^{o} C, respectively. The available data indicate that the high temperature portion of the Eburru geothermal field is about 2 km^2 and can support a 20-MW power station. However, if a binary system is considered, more than 200 MW can be produced.

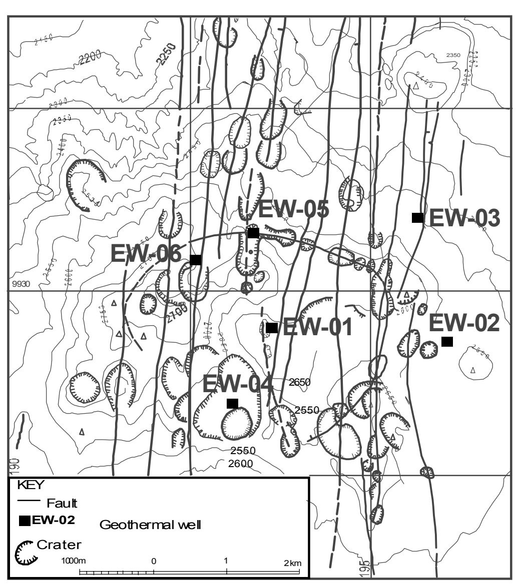


Figure 4: Structural Map of Eburru Highlighting Geothermal Wells

Investigations to date reveal that the Kenya rift has a potential of more than 2,000 MW that can be generated using conventional condensing turbines. However, the generation capacity may exceed 3,000 MW when combined cycle and binary systems are used. It is estimated that Olkaria alone is capable of generating more than 400 MW for 25 years when both medium and high temperature resources are exploited.

Other promising geothermal areas in Kenya include (from south to north): the volcanoes of Longonot, Suswa, Badlands, Menengai, Lake Bogoria and Arus, Korosi, Chepchuk, Paka, Silali Caldera, Emuruangogolak Caldera, Namarunu and the Barrier Volcanic Complex.

Longonot Volcano Caldera

Longonot Volcano Caldera is located east of Olkaria geothermal field on the floor of the rift valley (see Fig. 5). Development of the precursor of Longonot caldera started 800,000 years ago with the development of a broad shield volcano. Volcanism continued and culminated in the caldera collapse about 9,000 years ago. Subsequent volcanism occurred in the center of the caldera and resulted in the building of a trachytic massif and deposition of thick pumice deposits within the caldera and on the flanks. It is estimated that the most recent volcanism at Longonot occurred about 200 years ago within the summit crater and along a north-northwest trending volcano-tectonic axis.

KenGen conducted surface exploration work of Longonot geothermal prospects in 1998 that involved geological, geochemical, geophysical and environmental surveys (KenGen, 1998). The presence of hydrothermally-altered lithics indicates that the geothermal system under the volcano must have attained temperatures of more than 250^{o} C. Resistivity studies indicate an anomaly on the southern slopes of Longonot crater. These results have been used to site the first exploration well south of the volcano bound by the caldera structure. Scientific data show that the prospect area is more than 60 km^2 and, if proven, is enough to generate more than 200 MW. Drilling will commence once funding is secured.

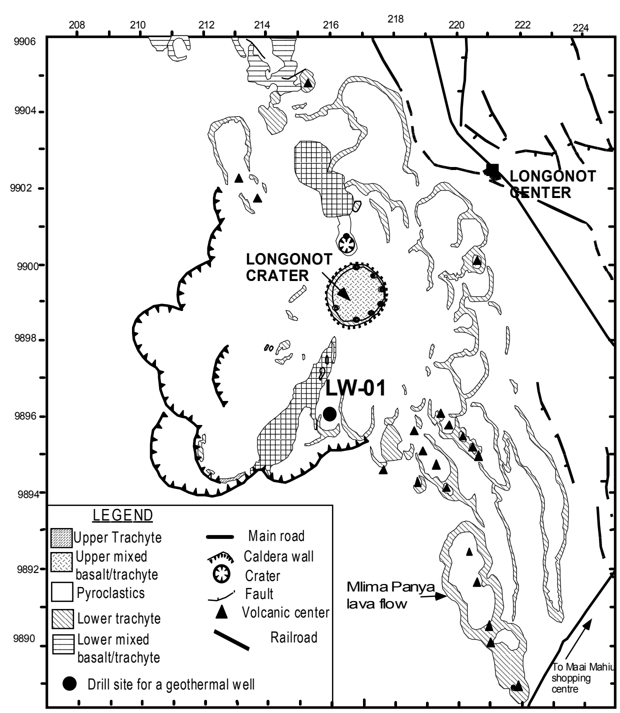


Figure 5: Geological Map of Longonot Volcano Illustrating Geothermal Exploration Sites

Suswa Volcano

Suswa is the southernmost Quaternary volcano in the central Kenya rift. The latest magmatic activity in Suswa is estimated to have occurred about 200 years ago within the annular trench in the caldera. The phonolitic nature of the lava implies medium level magma chamber, which could provide the present heat source for the system. The presence of a degassing magmatic body is also indicated by the presence of solfatara within the annular trench. Low pH of fumarole condensates also suggests close proximity to a magma body or up flow of a geothermal system. Magnetotelluric (MT) data to the north of the inner caldera indicate that the interpreted heat source is about ten km deep. Gravity indicates a northeast-southwest high-bouguer anomaly directly under Suswa caldera in the region of Ol' Doinyo Nyoke volcano. The body is at a depth of more than four to eight km and could be the heat source of the geothermal system. A positive magnetic anomaly that is centered under Suswa volcano further indicates the presence of hot rocks (see Fig. 6).

The geothermal system developed prior to the caldera collapse as hydrothermally altered lithics occur within the syn-caldera sequences. The geothermal system must have attained temperatures of more than 250^{o} C as evidenced by the presence of hydrothermal epidote within the lithics. Gas geothermometry indicate that gases sampled in the prospect originated from sources having temperatures of more than 200^{o} C. The size of the high potential area is not well defined but is probably within the caldera floor and to the south. Resistivity indicates that the top of the geothermal reservoir in the caldera is deeper than 1000 meters above sea level (masl). The prospect has a good recharge from both the west and east rift escarpments. However, the water table in the rift floor is deep, probably more than 300 m, due to intense faulting of the pre-Suswa formations.

KenGen carried out detailed scientific studies that included geology, geophysics and geochemistry in this prospect between 1992 and 1993. The studies identified the volcano as a good prospect, which possibly has a shallow heat source under the caldera. The studies resulted in the siting of three wells within the main caldera floor. Exploration drilling will be carried out after Longonot, and it is estimated that more than 200 MW can be produced from the Suswa resource.

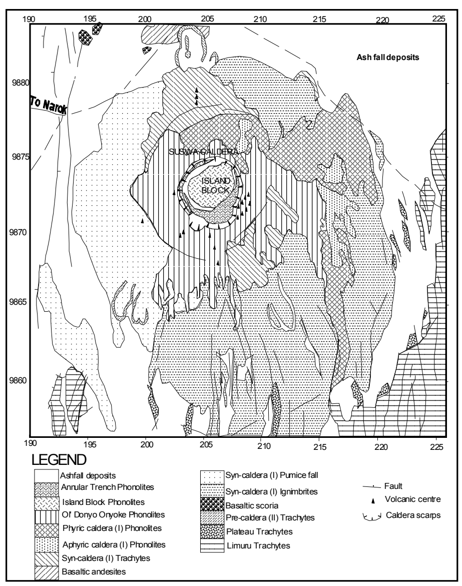


Figure 6: Geological Map of Suswa Volcano

Badlands Geothermal area

The Badlands geothermal prospect is characterized by basaltic and intermediate lava eruptions with the youngest trachyandesite flow being probably a few hundred years old. However, no age dating has been carried out. From a geological point of view, the heat source for a possible geothermal system is expected to be small and deep. Electrical surveys indicate low resistivity anomalies covering an area of about 25 km^2 within the low grounds south of Lake Elmenteita. The low resistivity could be due to a combination of high subsurface temperatures and high intensity of hydrothermal alteration of the pyroclastic deposits.

If a geothermal system exists, then resistivity indicates that the top of the reservoir would be at 1000 masl with a temperature in excess of 220^{o} C. Geochemical data indicate elevated concentrations of ionic species in water wells and warm springs indicating the contributions of thermally modified waters. Previous work in Eburru (Onacha, 1990) indicates that the geothermal system under the volcano outflows northward. The discharge from

Eburru probably contributes to the chemistry of the fluids and resistivity structure within Badlands. It can be concluded from preliminary investigations that the resource in the area is most likely of medium temperatures that would be suitable for generation using a binary system. More than 20 MW can be generated from this prospect.

Menengai Caldera

The heat source for the prospect is probably associated with a hot magmatic body that underlies the caldera structure at Menengai and a similar but probably older heat source is likely to be associated with a geothermal area to the north of Menengai. Positive magnetic anomaly that is coincident with low resistivity indicates the presence of a magmatic body at shallow depth. seismic data indicate that the magmatic body is at about 12 km depth. The interpretation of the DC resistivity data collected by Geotermica Italiana show two low resistivity areas to the northeast and southwest of the caldera. However, the northern prospect shows very high resistivity thus causing doubts about the potential of this area as a high temperature resource.

The geothermal reservoir at Menengai is hosted within fractured brittle trachytic lavas of the rift floor and welded pyroclastics that underlie the volcanic pile. At shallow levels, the paucity of the geothermal manifestations is due to the self-sealed widespread pyroclastics and layered welded pyroclastics. Although there are few surface geothermal manifestations, shallow boreholes in this area have encountered steam with gas geothermometry indicating equilibrium reservoir temperature of 170 ^{o}C to 190º C in the northern portion of the greater Menengai area.

The main recharge is associated with the adjacent eastern and western rift escarpments. These high altitude ridges often have high rainfall. The extensive fault network that is evident in the rift provides hydraulic connection and flow towards the rift floor. The rift floor in this area is at very low altitude relative to the rift scarps. Despite the low altitude and graben-like setting, permanent stream springs are rare on the rift floor around Menengai. It can, therefore, be concluded that the subsurface is very pervious and most of surface waters easily percolate downward into deep structures. The most fractured zone is probably along the Solai Axis, which may also be a major channel for ground water flow along the rift axis. Stable isotope data indicate that the water types within the prospect are dominated by meteoric water.

Based on resistivity tests, the prospect is estimated to cover an area of more than 90 km^2 which, if proven, can generate more than 200 MW. The top of the reservoir is estimated to be at 1000 masl, which is similar to the Olkaria area. The low resistivity anomaly at this depth is interpreted to represent a reservoir with temperatures in excess of 220º C.

Lake Bogoria and Arus Geothermal Prospects

Arus–Lake Bogoria is an area of volcanic rocks without any clear observable volcanic centers. The rocks largely occur as lava sheets that were probably erupted through fissures on the rift floor during the Mio-Pliocene epoch. The old age of the lava flows suggests that a magmatic body may not exist under the area. However, a large positive magnetic anomaly occurs in the area, which suggests the existence of rocks in the subsurface at high temperatures. Seismic surveys indicate shallow high activity to the east of Lake Bogoria along the Marmanet fault. The high seismic activity could either indicate high temperatures accompanied by fluid movements at shallow depth or that the activity is mainly associated with shear movement along the fault without major geothermal significance.

Geothermal manifestations are abundant in the area around Lake Bogoria and fluid geothermometry indicates moderate subsurface temperatures in the region of 145 to 245^{o}C, while those at Arus are at lower temperatures (170 to 192^{o}C). The hot springs typically have elevated boron concentrations that suggest deep circulation of fluids. The geothermal system at Bogoria–Arus area is, therefore, a product of deep circulation of meteoric water along the rift flank and rift floor faults. Deep circulating water would then gain temperature due to both deep circulation and mining of heat along the fault planes. Existence of spouting springs at Lake Bogoria indicates good hydrological connection between the recharge and up flow, which is mainly along the rift floor faults. The geothermal reservoir is expected to be small, discrete and confined to the immediate vicinity of fault zones. However, more than 20 MW can be generated from the resource using binary system technology.

Korosi Volcano

The latest volcanic activity associated with Korosi was of basaltic composition and occurred a few hundred years ago. The last silicic volcanism, however, occurred about 100,000 years ago, implying that the heat source for the geothermal system is long lived. A positive magnetic anomaly is also associated with the volcano, which suggests that temperatures more than 575^{o} C are still achievable at shallow levels. If a geothermal system occurs under Korosi, then it probably extends to the northern part of Lake Baringo as determined from low shallow seismic velocities in the region. The wide distribution of surface manifestations indicates that the geothermal area is large and extends from Lake Baringo to Korosi.

The main heat source for the geothermal system is probably located under the volcanoes of Korosi and Ol Kokwe. However, in both cases, basaltic magmatism comprises the latest activity. The hydrogeology of the prospect is probably strongly controlled by Lake Baringo, which is located to the south of Korosi. The lake water would then down flow northward as determined by the hydrological gradient. The outflow of the geothermal system is also northward. Gas geothermometry indicates that temperatures more than 250^{o} C exist in the reservoir. Therefore, it is possible that a high temperature geothermal system exists under Korosi volcano and extending southward. More than 100 MW can be generated from this prospect.

Chepchuk Geothermal Prospect

The heat source is probably associated with the old caldera at Chepchuk and some outflow from the Paka geothermal system. However, the age of the last volcanic activity dated at about 1.2 million years ago suggests that high temperatures may no longer exist in the geothermal system. Also, minimal intensity of geothermal manifestations despite major faults passing through the geothermal area signifies reduced activity in the system. Fumarole condensate chemistry, particularly high ammonium concentrations, suggests that low temperatures are associated with the geothermal system. Despite the low estimated temperatures in the reservoir, the geothermal system should be able to support a ten to 20 MW power plant utilizing binary technology.

Paka Volcano

Paka volcano is built of trachyte and basalt lavas and pyroclastic deposits that culminated to the formation of a caldera about 10,000 years ago. Younger fissure controlled basaltic and intermediate lava eruptions indicate that the magmatic system is probably still active and might have high heat stored. Positive magnetic anomaly suggests the presence of high temperatures. Seismic studies indicate shallow events directly under Paka suggesting that a hot body exists below about 2.5 to five km depth. The hot body could be the heat source for the geothermal system associated with Paka volcano.

The area covered by intense geothermal manifestations over Paka is more than 45 km^2. The large distribution suggests that the heat source could be large and probably located directly under the volcano where the hottest fumaroles occur. Fluid geothermometry indicates that temperatures in the geothermal reservoir could exceed 300^{o} C. Hydrogeology of the area is characterized by recharge mainly from the east rift shoulder and also from the south and a discharge both to the north and northwest. The highest potential area for detailed studies is within the caldera and the massif in general.

Silali Caldera

Silali caldera measures 7.5 km by five km in diameter and the formation of the caldera occurred about 7,000 years ago. The latest activity was basaltic in composition and erupted about 200 to 300 years ago. The young activity associated with the volcano indicates that the magmatic body under the volcano could still be hot and could drive a geothermal system. The presence of a positive magnetic anomaly that is coincident with the dimensions of the caldera is further proof of the presence of a hot body under the caldera. High $^{3}He/^{4}He$ suggests the proximity of the fumaroles in Silali to a shallow magmatic body. Seismic studies indicate high activity in the east and south east of the caldera floor, which could be related to a geothermal system.

Silali has some of the largest hot springs within the Kenya rift, indicating high likelihood of existence of a geothermal system under the volcano. It is estimated that Kapedo, which is one of the hot springs, associated with Silali, discharges 1000 liters per second of water at 50 to 55^{o} C. This translates into about 100 MW from this region alone. Fluid chemistry, however, indicates that the fluids are not directly from the up flow but have undergone interaction with shallow ground waters. The model for the system can be explained in terms of an up flow within the caldera with a resource area being probably more than 75 km^2. The fluid then outflows mainly to the west and north through formational contacts and faults and fractures discharging on the surface at Kapedo springs and other manifestations in the area. The resource in the prospect is estimated equal to more than 300 MW for 25 years.

Emuruangogolak Caldera

Emuruangogolak caldera measures five km by 3.5 km in diameter, and it occupies the top of a shield volcano. The latest activity was of trachytic volcanism that occurred about 100 years ago on the southern upper slopes of the volcano. The young trachytic magmatism signifies the presence of a large and hot magma body under the caldera. Positive magnetic anomaly centered on the volcano further attests to the presence of a hot body temperature of more than 575^{o} C. Geothermal manifestations, some of which are at boiling point, suggests the presence of a geothermal system which gas geothermometry indicates to be at temperatures of 200^{o} C to 350^{o} C. Abundance of fumaroles at higher temperatures on the eastern half of the caldera floor may imply a better geothermal system in that segment.

Dipping potentiometric surface to the north and recharge from east, west, and south characterize hydrogeological pattern in the area. It is anticipated that the recharge of the geothermal system is good as shown by the occurrence of hot springs on the eastern flanks of the volcano. It can be modeled that the geothermal fluid up flow within the caldera floor and immediate environs and largely outflows to the north and west. The geothermal prospect is capable of supporting more than 200 MW for 25 years.

Namarunu Geothermal Prospect

Namarunu geothermal prospect lies within an area of Plio-Pleistocene volcanic activity with the latest basaltic eruptions dated 500,000 years ago. Other basaltic scoria cones dot the Namarunu volcanic field; however, the youngest fall on north-south alignments at the western edge of the rift floor. Though the basalt lavas generally originate from great depths, they still indicate that an area could have elevated heat flows. Namarunu, therefore, has some heat that could drive a geothermal system but probably would not be as high as in other quaternary silicic complexes.

Fumaroles at temperatures ranging from 30^{o} C to 100^{o} C occur at the foot of eastern and western fault scarps. Fluid geothermometry indicates a reservoir at temperatures of more than 200^{o} C. The hottest springs occur along the eastern fault. Hydrological flow patterns indicate that recharge for the Namarunu prospect is largely from the east and south. The hot springs on the west are probably directly associated with a geothermal system in the south and south-east of Namarunu volcanic area. The area is capable of generating more than 20 MW using binary technology.

Barrier Volcanic Complex

The complex consists of three volcanoes of which Kakorinya is the most promising in terms of geothermal potential. Kakorinya is a silicic volcanic center whose caldera formation was accompanied by a collapse about 92,000 years ago, followed by resurgence activity about 58,000 years ago. A caldera association implies that the volcano developed shallow magma chamber whose heat could still drive a geothermal system. Recent basaltic activity at Teleki's volcano (100 years) is a strong indicator that new magma injections still occur, which could raise the local geothermal potential. Developing a geothermal model for the prospect is complicated by lack of geophysical data and conflicting geochemical information. Low H_2 and CH_4 in the fumaroles and springs indicate an indirect path between the discharges and the heat source suggesting that the potential for the area is low. In contrast, high gas geothermometric temperatures (218^{o} C to 328^{o} C) suggest proximity to an up flow.

It is likely that a high temperature geothermal system exists under the Kakorinya volcano. Sulphur deposits that are indicative of shallow, degassing magmas occur within the caldera, further indicating that a large heat source exists under the volcano. Preliminary indications are that the resource is capable of generating more than 100 MW.

IV. POLICIES THAT RELATE TO PRIVATE SECTOR INVESTMENT

4.1. Government Support

Since the LCPDP of 1986 to 2006, geothermal power has consistently been recommended and highlighted as a significant source of energy for generating additional capacity. As observed in Table 3 below, it comprises between 29 and 42 percent of planned net additions from 1986 to 2019 (Mwangi, 2001).

Table 3: Contributions to LCPDP

RESOURCE	CONTRIBUTION IN LCPD PLAN COVERING PERIOD			
	1986 – 2006	**1991 – 2010**	**1997 – 2017**	**2000 - 2019**
Hydro (MW) Proportion of Total (%)	299 30	204 16.5	312 17	81 6
Conventional Thermal (MW) Proportion of Total (%)	420 42	600 48.6	992 54.1	645 48.1
Imports (MW) Proportion of Total (%)	- -	- -	- -	50 3.7
Geothermal (MW) Proportion of Total (%)	280 28	431 34.9	531 28.9	567 42.2
TOTAL (MW)	**999**	**1,235**	**1,836**	**1,343**
Some Key Assumptions: Cost of geothermal plant (US$/kW) 2 x 32 MW 2 x 55 MW	2,015 1,950	2,015 1,950	2,570 -	2,794 -
Base year crude oil price (US$/bbl)	13.5	22	18.5	25
Average annual grow of demand (%)	5.5	6.1	6.2	5.5

As part of the LCPDP's concerted effort to develop geothermal as a major energy resource for Kenya's future, KenGen has instituted a program to undertake detailed surveys of all the geothermal prospects in the Kenya Rift Valley and to rank the potential of all prospects. According to KenGen, the region has a total potential of more than 2,000 MW of geothermal power generation over the long term.

To meet the geothermal component of the LCPDP in the next 20 years, detailed surveys and drilling of exploration wells must be done in many of the areas. As discussed, surface studies at Olkaria have been completed and part of the field has been developed by KenGen. The western area is being developed by an IPP.

Exploration drilling in Olkaria-Domes and Eburru Fields are complete and awaiting appraisal drilling. Surface studies have been completed in Suswa and Longonot and exploration wells sited. Detailed surface studies have not however, been done in the other prospects that include Lake Magadi, Badlands, Menengai, Arus, Lake Bogoria, Korosi, Chepchuk, Paka, Silali, Emuruangogolak, Namarunu and Barrier (see Table 4).

Table 4: Exploration status of Geothermal Prospects

Prospect	Reconnaissance	Surface Studies	Wells Sited	Wells Drilled
Olkaria Domes	Yes	Yes	3	3
Longonot	Yes	Yes	1	No
Suswa	Yes	Yes	3	No
Menengai	Yes	Partial	No	No
Badlands	Yes	Partial	No	No
Lake Magadi	Yes	No	No	No
Arus	Yes	No	No	No
Lake Bogoria	Yes	No	No	No
Korosi	Yes	No	No	No
Paka	Yes	No	No	No
Silali	Yes	No	No	No
Emuruangogolak	Yes	No	No	No
Namarunu	Yes	No	No	No
Barrier Volcano	Yes	No	No	No

4.2. Private Power Development

All four IPP projects in Kenya have been constructed through Build Own Operate (BOO) schemes. The rational for this is that the IPPs should ensure the use of high quality, reliable equipment that they believe will be dependable through the duration of the PPA. For general business-related information on Kenya, see:

"Laws of Kenya - The Foreign Investments Protection Act" at http://www.kenyalaw.com/theForeignInvestmentsProtectionAct.htm.

"Doing Business in Kenya" at http://www.mbendi.co.za/werksmns/lexaf/buske.htm

"Overview of Economic Progress: Foreign Investments and Loans in Kenya" at http://www.bisnetworld.net/bisnet/countries/kenya8.htm

4.3. Environmental and Emission Institutions and Regulations

The development of geothermal resources in Kenya is guided by legislated environmental controls contained in following main Acts: the Geothermal Resources Act, the Water Act, the Wildlife Act and the Forest Act. The new Environmental Management and Coordination Act of 1999 (EMCA), was established to harmonize the above Acts and to supersede them on matters of environment.

The new Act specifically deals with acceptable methods of handling polluting agents that arise from geothermal developments such as liquids, gas and thermal effluents; noise, toxic and hazardous waste. The new Act also spells out the requirements for an environmental impact assessment prior to any energy development activity.[13]

Although EMCA supercedes all previous Acts on matters pertaining to the environmental impact of geothermal development, the others are still in force where they are not in conflict with the former. As such, the Act

[13] Kubo, Benjamin (undated) *An Outline Of Kenya's Environmental Laws And Regulations As Applied To Geothermal Development*. Report on the Olkaria Geothermal Project. The Kenya Electricity Generating Company Ltd., Kenya.

provides legislation for sustainable use of natural resources in an environmentally-friendly manner while offering avenues for conflict resolution.

4.4. Host Country Personnel with Geothermal Experience

KenGen has 41 graduate professionals working on a full-time basis in geothermal activities. They include geologists, geophysicists, geochemists, reservoir engineers, drilling engineers and power station operation, maintenance and electrical engineers (see Table 5). Some of the personnel are trained to Master of Science or Ph.D. levels in geothermal technology. The specialized institutions at which these staff have been trained include the Geothermal Institute at the University of Auckland, New Zealand and the United Nations University Geothermal Training Program in Iceland.

Recently, KenGen has offered professional geothermal services to the IPP developing Olkaria III, including development strategy, down-hole pressure and temperature measurements, geochemical analyses and complete petrographic studies of well rock cuttings.

Table 5: KenGen's Human Resource Capacity for Geothermal Development

PHASE	ACTIVITY	TRAINED CAPACITY
Exploration	Reconnaissance Survey	Adequate
	Detailed Investigations	Adequate
	Exploration Drilling	Adequate
Appraisal	Appraisal Drilling	Adequate
	Reservoir Evaluation and Modeling	Partly Adequate
	Feasibility Study	Partly Adequate
Steam Field Development	Production Drilling	Adequate
	Well Testing	Adequate
	Preliminary Design	None
Power Plant Construction	Detailed Design	None
	Construction	None
	Commissioning	Adequate
Resource Utilization	Operation	Adequate
	Plant Maintenance	Adequate
	Reservoir Management	Partly Adequate

V. CONTACT INFORMATION

1. Local Power Company

Transmission and Distribution Company
Managing Director:
Kenya Power & Lighting Co. Ltd (KPLC)
Stima Plaza
Kolobot Road
P.O. Box 40092
Nairobi, Kenya

KenGen
Mr. Isaac Bondet
Managing Director
Kenya Electricity Generating Company
Stima Plaza,
Kolobot Road, Parklands.
P. O. Box 47936,
Nairobi, Kenya
Tel. 254-02-248833
Fax 254-02-248848

2. Ministry of Energy

Hon. Ochilo M. Ayako, M.P., Minister
Hon. Mwangi Kiunjuri, M.P., Assistant Minister
Prof. Wilfred M. Mwangi, Permanent Secretary
Nyayo House, Kenyatta Avenue
P.O. Box 30582,
Nairobi, Kenya
Tel. 254-02-333551/330048/330502

3. Ministry of Finance or Investment Authority

Hon David Mwiraria, MP, Minister
Hon John Mutua Katuku, MP. Assistant Minister
Joseph Magari, PS
Treasury Building,
P.O. Box 3007,
Nairobi, Kenya
Tel. 254-02-338111

4. Interested Bilateral Agencies

No known interest

5. US Embassy

Ambassador Johnnie Carson
P.O. Box 30137
Nairobi, Kenya
Mombasa Road Near St. James Hospital
Tel. 254-02-537800

VI. DETAILED REPORTS AND MAPS OF GEOTHERMAL AREA(S)

Geological reports and maps of the geothermal areas are available in the Ministry of Natural Resources and Environment. The topographic maps are purchased from the Survey of Kenya but approval must be given by the Department of Defense.

Figure 7: Map of Kenya's Geothermal Prospects and Grid

Table 6: Summary of Additional Planned Generation up to 2019 (KPLC, 2000)

Fiscal	Summary of Additional Generation (MW)			
Year	Hydro	Geo	Diesel	Total
2000		8		8
2001			187	187
2002		64		64
2003				
2004	60	56		116
2005				
2006			40	40
2007		64		64
2008	80.6		20	100.6
2009		64		64
2010	140			140
2011		64	20	84
2012			80	80
2013		64	20	84
2014			100	100
2015		64	20	84
2016			100	100
2017		64	40	104
2018			150	150
2019		64	60	124
Totals	**280.6**	**576**	**837**	**1693.6**

Source: Omenda, P.A., (undated) Geothermal Power Generation Potential in Kenya. KenGen.

VII. REFERENCES

Achauer, U and the KRISP Teleseismic Working Group, (1994). "New ideas based on the Kenya rift based on the inversion of the combined dataset of the 1985 and 1989/90 seismic tomography experiments." *Tectonophysics*, vol. 236, pp. 305-329.

Acres International Ltd., (1987). "Kenya National Power Development Plan 1986-2006. Executive Summary." *Report for the Ministry of Energy*, pp12-13.

Acres International Ltd., (1994). "Update of Least Cost Power Development Plan." *Report for the Ministry of Energy.* Kenya.

Acres International Ltd., (1997). "Update of Least Cost Power Development Plan 6." *Report for the Ministry of Energy*. Kenya.

Allen, D.J., Darling, W.G., and Burges, W.G., (1989). "Geothermics and hydrogeology of the southern part of the Kenyan rift valley with emphasis on the Magadi-Nakuru area." *BGS Research Report* # SD/89/1.

Clarke, M. C. G., Woodhall, D. G., Allen, D. and Darling, G., (1990). "Geology, volcanological and hydrogeological controls on the occurrence of geothermal activity in the area surrounding Lake Naivasha, Kenya." *Report of the Ministry of Energy.* Kenya.

Dunkley, P. N., Smith, M., Allen, D. J. and Darling, W. G., (1993). "The geothermal activity and geology of the northern sector of the Kenya Rift Valley." *British Geological Survey Research Report* SC/93/1.

Geotermica Italiana srl UN/GoK, (1987a). *Supplement of surface investigations within the caldera volcanoes of Longonot and Suswa*. UN/DTCD and MERD report.

Geotermica Italiana srl UN/GoK, (1987b). *Geothermal Reconnaissance Survey in the Menengai- Bogoria area of the Kenya Rift Valley,* vol. 1-5.

Geotermica Italiana (1988). *Integrated geophysical survey in the Menengai and Suswa-Longonot areas of the Kenya Rift Valley.* Final report TCD CON 7/85-KEN 82/002- Amendment 2 UN(DTCD) MOERD Report.

Green, W.V., Achauer, U., and Meyer, R.P., 1991. A three-dimensional seismic image of the crust and upper mantle beneath the Kenya rift. Nature, vol. 354, p.199-203.

Henry, W.J., Mechie, J., Maguire, P.K.H., Khan, M.A., Prodehl, C., Keller, G.R., and Patel, J., (1990). "A seismic investigation of the Kenya rift valley." *Geophysicist Journal. Int*., vol. 100, pp. 107-130.

Keller, G.R., Prodehl, C., Mechie, J., Fuchs, K., Khan, M.A., Maguire, P.K.H., Mooney, W.D., Achauer, U., Davis, P.M., Meyer, R.P., Braile, L.W., Nyambok, I.O., Thompson, G.A., (1994). "The East African rift system in the light of KRISP90." *Tectonophysics*, vol. 236, p.465-483

KenGen, (1998). "Surface scientific investigations of Longonot geothermal prospect." *KenGen Internal report*. Kenya.

KPLC, (2000). *The Least Cost Power Development Plan Update*. Prepared by The Kenya Power and Lighting Company Ltd., Final Draft, Kenya.

Mohr, C.K. and Wood, C.A., (1976). "Volcano spacing and lithospheric attenuation in the eastern rift of Africa. Earth and Planet." *Science Letters*, vol. 33, p.126-144

Mwangi, D.M., (2001). *Kenya's Least Cost Power Development Plan And Role Of Geothermal Resource*. The Kenya Power & Lighting Company Limited, Kenya.

Omenda, P. A. and Karingithi, C. W., (1993). "Hydrothermal model of Eburru geothermal field, Kenya." *Geothermal Resources Council Transactions*, vol. 17.

Omenda, P. A., (1997). *The geochemical evolution of Quaternary volcanism in the south-central of the Kenya rift*. University of Texas, USA.

Omenda, P. A., *An Update On The Status Of Geothermal Resource Exploration And Development In Kenya*. The Kenya Electricity Generating Company Ltd, Kenya.

Omenda, P.A., eds. *Ranking of the Geothermal Prospects in the Kenya Rift Valley*. KenGen Internal Report. (Report in preparation, with contributions from: J. Lagat; J. Mungania; N. Mariita; S. Onacha; S. Simiyu; K. Opondo; P. B. Kubo; P. Ouma, G. Wetangula; P. Kollikoh; and P. A. Omenda.)

Onacha, S. A., (1990). *The electric resistivity structure of Eburru prospect*. KPC report. Kenya.

Onacha, S.A., (1990). Application of Schlumberger sounding at Eburru, Kenya and TEM and MT methods at Bakki, S-Iceland. *UNU GTP Iceland*. Report 11, 52pp.

Onacha, S. A., (1998). *Transient Electromagnetic studies of Longonot*, KenGen internal report. Kenya.

Onacha, S.A., (1999). *Suswa and Longonot geothermal prospects. Comparison of surface scientific data.* KenGen internal report. Kenya.

Reed, M. J. and Renner, J. L., (1995). *Environmental compatibility of geothermal energy: in Alternative fuels and environment,* CRC Press Inc. Florida, USA, pp. 23-27.

Riaroh, D. and Okoth, W., (1994). "The geological fields of the Kenya rift," in: C. Prodehl, G.R. Keller and M.A. Khan (eds.), "Crustal and Upper mantle Structure of the Kenya Rift." *Tectonophysics*, vol. 236, pp. 117-130.

Simiyu, S. M., (1990). *The Gravity Structure of Eburru, Kenya,* UNU G.T.P. Iceland report 13, pp. 39.

Simiyu, S. M., (1996). *Integrated geophysical study of the crystal structure of the Southern Kenya Rift*. University of Texas, USA, pp. 240

DJIBOUTI COUNTRY GEOTHERMAL REPORT

Figure 1: Map of Djibouti

I. COUNTRY OVERVIEW

1.1. Geography and Climate

The French Territories of the Afars and Issas were joined in 1977 to form Djibouti. An area of approximately 23,000 km^2, Djibouti is bordered on the east by the Gulf of Aden, on the southeast by Somalia, on the south and west by Ethiopia and on the north by Eritrea. It is strategically located at the mouth of the Bab el Mandeb Strait, which links the Red Sea with the Gulf of Aden.

Djibouti consists mainly of arid plateaus, with a number of saltwater basins inland. To the north of the Gulf of Tadjourah are several mountain ranges that reach elevations of 1,500 to 2,020 m. The climate is hot. The temperature in Djibouti averages 25.6^o C in the winter (January) and 35.6^o C in the summer (July). Annual rainfall averages 127 mm in Djibouti city and about 138 mm in the mountains.

1.2. Political Structure and Social Issues

Djibouti has been a republic since 1977. Prior to that, it was a French territory for over 100 years, during which the French manner of transacting business was adopted. These practices have been modified by local custom, particularly with respect to the tribal cultures and commerce. Djibouti has a 65-member (elected) Chamber of Deputies that has legislative powers, and a new constitution adopted in 1992 that allows for multiparty political activity.

The total population is approximately 700,000, nearly two-thirds of whom live in the city of Djibouti. The two main ethnic groups are Afar and Somali. Both groups speak the Cushitic languages and are Muslim. European and Arab minorities are also present. Approximately 10,000 French civilians and 4,000 French military also reside in Djibouti. France maintains one of its largest foreign military bases in Djibouti with warships, aircraft and armored vehicles.

1.3. Economy

Djibouti's main economic asset is its strategic location. The city of Djibouti, the capital, is a major port and bunkering facility. The economy depends on the use of the port, which is linked by rail and highways to Addis Ababa, the capital of Ethiopia.

Business increased at Djibouti's port when hostilities between Eritrea and Ethiopia closed Ethiopian access to the Eritrean port of Assab. Djibouti became the only significant port for landlocked Ethiopia, handling all its imports and exports during the war. The city of Djibouti has the only paved airport in the country. Its relatively good transportation infrastructure also enables several landlocked African countries to fly in their goods for re-export. This earns Djibouti much-needed transit taxes and harbor fees.

Scant rainfall limits crop production to fruits and vegetables for local use, and most food must be imported. Djibouti has few natural resources and little industry. The nation is heavily dependent on foreign assistance to help support its balance of payments and finance development projects. External trade is marked by a deficit in the balance of payments and a surplus in services. The country imports practically all consumer and capital goods. Re-exports make up 83 percent of total exports. Imports come mainly from France, Asia, the Middle East and the Horn of Africa. Local products exported consist mainly of animal skins and hides.

Per capita consumption has dropped an estimated 35 percent over the last seven years because of recession, civil war and a high population growth rate (including immigrants and refugees). Faced with a multitude of economic difficulties, the government has fallen in arrears on long-term external debt and has been struggling to meet the requirements of foreign aid donors.

Unemployment continues to be a major problem for Djibouti's economy with the rate ranging between 40 and 50 percent. Inflation is not a concern as the Djibouti franc is a freely convertible currency that is linked to the US dollar at a fixed rate (176 francs/US$1.00 US).

II. COUNTRY ENERGY CONTEXT

2.1 Electricity Sector

Until 1999, the government of Djibouti had a monopoly in all facets of the electric utility sector. *Électricité de Djibouti* (EdD) is the state-owned electric utility and is under the jurisdiction of the Ministry of Energy and Natural Resources. EdD is responsible for the generation, transmission, distribution and sale of electricity in Djibouti and has the primary responsibility for the development of geothermal resources for power generation. In 1999, the government committed to privatizing the port, the national electricity utility, the urban water utility (in the city of Djibouti), the two national telecommunications utilities (which are to be merged) and the airport. Thus far, only the nation's port and airport have been privatized.

The *Centre de Recherche Scientifique de Djibouti* (CERD) is the national institute responsible for monitoring and carrying out scientific and technical work in Djibouti. It is a semi-autonomous government agency that reports directly to the Office of the President. CERD provides technical support to EdD for geothermal exploration and development.

2.2. Electricity Capacity and Demand

Djibouti currently has installed electricity generating capacity of 85 MW, all of which is thermal (oil-fired). The city of Djibouti is the principal power market. After the 1991-93 war with Eritrea, power demand began to recover but capacity limitations have prevented further growth. In 1998, the problem became acute when a fire occurred in the Boulaos Generating Station, destroying two units and impairing the ability to use six others for much of the year. A year later six diesel gensets capable of producing 18 MW of power were installed at critical locations throughout the city, including the airport, the marine terminal and communication centers. Recently, EdD installed four new diesel generators of six MW each at the Boulaos power station. Many private businesses and homes also installed smaller gensets.

Over the long term, electricity demand has been increasing at three to five percent per year. Projection of peak demand in Djibouti is complicated by the problems of recent years, including the Boulaos fire of 1998. Historically, base load demand has been on the order of 40 to 50 percent of peak demand. Simple linear regression applied to the historical data from 1971 through 1990 suggests that peak demand has grown at an average of 1.55 MW per year, with standard deviation of ±1.14 MW. Based on work carried out by Geothermal Development Associates, conservative estimates of peak and base loads of 60 and 30 MW, respectively, were projected for the year 2003, under normal circumstances.

The average cost of electricity for domestic consumers is about US$0.20 per kWh with commercial customers paying approximately US$0.28 per kWh. This high cost is due to: (a) deteriorating power generation equipment; (b) use of expensive diesel fuel; and (c) high transmission and distribution losses. All diesel fuel is imported and thus represents a severe drain on foreign exchange.

2.3 Dependency on Foreign Oil

Alternative sources of energy for conversion to electricity on a commercial basis are lacking in the country. There is no indigenous coal, oil or gas; no vegetation for biomass nor surface waters appropriate for hydropower. Interconnection to the Ethiopian power grid was studied in 1989 and was not considered a viable option. As recently as late 1999, Djibouti and Ethiopia revisited the possibility of a transmission line interconnection. If sufficient power capacity were to become available in Djibouti, interconnection with Ethiopia–and eventually with an Eastern Africa grid–may be feasible and become a source of hard currency for the Djiboutian government.

There is currently no upstream (exploration or production) oil activity in Djibouti. The downstream oil sector is an important aspect of Djibouti's economy. The city of Djibouti is a significant regional bunkering and refueling facility. Three companies, ExxonMobil, Shell and Total FinaElf, handle refueling at Djibouti's port. These companies, along with Chevron/Texaco, also distribute and market petroleum products in the country. Two-thirds of the port’s trade comes from Ethiopia, which stopped using Assab in Eritrea when the two countries went to war in 1998. Ethiopian oil imports through Djibouti nearly doubled in 1999 following the outbreak of war.

III. GEOTHERMAL RESOURCES

3.1. Country Geology

Djibouti lies at the junction of three active, major coastal spreading centers: (a) the Eastern Africa Rift zone, which extends south-southwestward from Djibouti through Kenya to Tanzania and north-northwestward through Eritrea to the Red Sea; (b) the Red Sea Rift, which extends northward beneath the Red Sea, the Gulf of Aqaba, and the Dead Sea and terminates in northern Syria; and (c) the Gulf of Aden and its westward extensions into Djibouti–the Gulf of Tadjourah and the Ghoubbet el Kharâb (see Fig.2). This structural junction is unique, being the focal point of very high heat flux. Although direct measurements are unavailable, it is undoubtedly among the highest heat fluxes on earth (ENEL/DPT (1990). The rift zone is still expanding by about one mm per year. The last volcanic eruption occurred in 1978 when the Ardoukoba volcano erupted.

3.2. Geothermal Resources

According to a recent study by the Geothermal Energy Association (Reed, 1999), the geothermal potential in Djibouti is between 230 MW and 860 MW from a number of prospects including the:

- **Lake Abbe** area on the border between Djibouti and Ethiopia
- **Hanle** plain near Yoboki town
- **Gaggade** plain about 20 km northeast of Hanle on the other side of the Baba Alou Mountains

- **Assal** area between Lake Assal and Tadjourah Bay on the active rift zone extending northwest through the Alol depressions
- **Arta** area north of Arta Mountain
- **Tadjourah** area on the northern shore of Tadjourah Bay
- **Obock** area near Obock town
- **Dorra** area in the mountains about 40 km north of Lake Assal

Little or no exploration has been done in the last four areas. The status of exploration in the other areas is as follows:

The Assal Area

The most important geothermal prospect in Djibouti, the Assal prospect, is on an active rift zone that extends from the Ghoubbet al Kharab through Lake Assal, into the mountain range northwest of the lake and up through the Alol plains. The rift is also active on the northern shore of Ghoubbet al Kharab. As Lake Assal is the lowest place in Africa, 154 m below sea level, there is a steady flow of sea water from the sea through the ten km wide volcanic area between the Ghoubbet al Kharab and Lake Assal. This flow goes mainly through the northern part of the area where tectonic movement is still active. The inflow has been estimated to be of the order of 20 m^3 per second. In spite of this inflow, there are many fumaroles in the area and it is likely that the temperature below the cold inflow is very high.

The first concerted effort to assess and explore Djibouti's geothermal resources took place in the Assal area from 1970 to 1983 and was funded by the French government. The work consisted principally of geological surveys and studies and the drilling of two wells—Assal 1 (A1), a potential producer, and Assal 2 (A2). Drilling and testing results discovered a moderate to deep, highly saline reservoir, where scaling was recognized to be a significant problem. A potential shallow reservoir was also identified, but was never flow-tested.

The next phase, from 1984 to 1992, funded by the Italian government, Africa Development Bank (AfDB), Organization of Petroleum Exporting Countries (OPEC) Fund, United Nations Development Program (UNDP), and World Bank, initially turned to the Hanlé-Gaggade geothermal area 35 km to the southwest, but after testing only low enthalpy fluids, attention returned to Assal. During this phase, funding supported the drilling of wells Assal 3 (A3), a potential producer, Assal 4 (A4) and Assal 5 (A5), all of which encountered high temperatures. At that point, prior to adequate testing of promising zones, most of the available funds had been expended. Although the results of drilling were highly encouraging, follow-on funding was contingent upon one additional production well. The last well, Assal 6 (A6), located near producers A1 and A3, was funded by the Djiboutian government. In spite of mechanical difficulties during drilling operations, this well was deemed to be a producer.

In October 1989, Virkir-Orkint, an Icelandic consulting company funded by the government of Italy, initiated a limited scaling and corrosion study of the deeper brine. The last phase of work at Assal, funded by the government of Italy and the World Bank, focused solely on the development and production of the deeper Assal resource. Although an ambitious plan for further work was generally agreed to, key questions with respect to priorities and implementation, including study and mitigation of the scaling, were never resolved between the funding participants. The next phase of development never proceeded. No new exploration or development activities of any material consequence have taken place at Assal since 1993.

The Abbe Area

The Abbe area is on the border between Djibouti and Ethiopia. Surface exploration has been done on both sides of the border, mostly by Italian scientists. This area is believed to have a low salinity reservoir with an estimated formation temperature of between 120° C and 175° C. No holes have been drilled in this area to measure the temperature.

The Hanle Area

The Hanle area has been explored by Italian scientists and was selected as the site for the first large scale geothermal exploration project in Djibouti. Three gradient holes were drilled, one in 1982 supervised by the Italians and two in 1984 as the first phase of the geothermal project. Four wells from 1500 m to 2000 m deep were drilled between 1985 and 1986 in Hanle and possibly in Gaggade if the first deep wells in Hanle showed poor results. The highest temperature measured in Hanle is 129° C at 445 m in the well Garrabays-1, drilled in 1982 close to fumaroles on the mountainside. The other wells showed lower temperatures. All three wells were about 450 m deep. The thermal gradient in the three wells was very low, only 1.3° C to 3.0° C per 100 m. The reservoir temperature in Hanle has been estimated to be from 160° C to 250° C.

The Gaggade Area

The Gaggade area is parallel to the Hanle area and also has been explored by Italian agencies. A supplementary surface exploration program was planned to start in February 1985 to select the sites for the first deep wells (2000 m) to be drilled in 1986 if drilling in Hanle failed to give the expected results. The reservoir temperature in Gaggade has been estimated as a little higher than in Hanle, about 210° C to 275 °C. No wells have been drilled in the Gaggade area.

The Arta Area

Arta is a small area with some fumaroles north of Arta Mountain. Only preliminary exploration has been done in this area. This is especially interesting because it is very close to the existing power line from Djibouti to Arta. A small power station could be economical in this area.

3.3. Thirty-MW Geothermal Power Plant in the Lake Assal Region

EdD and CERD have been the country's principal advocates for geothermal energy for power generation. In October 1997, the Director of EdD came to the United States to solicit the interest of US geothermal power companies to developing the Assal field. Two years later EdD and US-based Geothermal Development Associates (GDA) signed a Memorandum of Understanding (MOU). In August 2000, GDA completed a feasibility study on the development of a 30 MW geothermal power plant in the Lake Assal region west of the cit of Djibouti that established the commercial viability of the proposed generating facility. Access to Djibouti's port facilities will enhance geothermal development equipment supply and activities. A paved road exists up to the Assal geothermal prospect, about 100 km from the capital (and existing grid).

The US$85 million project could potentially be constructed on a build-own-operate (BOO) financing scheme. In 2000, the Global Environmental Facility (GEF) approved a US$287,000 grant through UNDP to enable the government and GDA to negotiate the principle agreements required for the project. To date, UNDP has not disbursed the funds. Additional donor funding has been offered that will bring the total available for this phase of the project to approximately US$600,000.

The President of the Republic, the Minister of Energy and Natural Resources and others in the present government of Djibouti have expressed strong support for the development of the Assal project, and support for GDA's work. A project is anticipated to move forward with the cooperation of EdD and GDA in 2003.

3.4. Sub-Contract Opportunities

As the project progresses, it is likely that equipment and services will be required by GDA to carry out the following operations: resource exploration; drilling and completion (cementing and casing); well testing; reservoir assessment; steam gathering systems; power plant design and construction; power plant operation and maintenance; project financing; environmental studies and mitigation; machinery parts; maintenance and repair; mineral extraction; transmission line construction; and water purification.

3.5. Environmental and Emission Institutions and Regulations

Presently, there are no laws or regulations that apply to environmental issues for the Assal geothermal project development. This is likely to change soon. It is only within the past two years that responsibility for the environment has been given to a government ministry. Since May 12, 1999, this responsibility has fallen under the Minister of Urban Planning, Housing, Environment, National and Regional Development. Draft guidelines for the environment were developed under the *Plan d'Action National pour l'Environnement* for the Republic of Djibouti (Third Version), in July 1999.

Should the project move forward as such, GDA plans to work in cooperation with this ministry and will follow the basic environmental guidelines and practices presently recognized for geothermal power plant projects in the United States. The affected environment, environmental consequences and potential mitigation measures will each be adequately addressed in a timely manner to the satisfaction of the government, GDA and funding sources.

IV. POLICIES THAT RELATE TO PRIVATE SECTOR INVESTMENT

4.1. Foreign Investments

There are no restrictions on the transfer of funds into or out of Djibouti and individuals may open foreign currency accounts. Djibouti has joined the New York Convention of International Arbitration.

The Investment Code was created under Law No. 58/94/3rd L of October 16, 1994 and was amended by Law No. 88/year/1 RE L of February 13, 1984. It details the guarantees and tax benefits available to private sector individual or corporate investors for various types and sizes of projects. A geothermal power project qualifies under Investment Code, Scheme A: (i) as a mining operation; and (ii) for its creation, utilization, modernization or extension of the electrical industry; and (iii) where conditions require, a minimum investment of 5,000,000 DF (US$28,134) and the creation of permanent jobs. There is: (a) exemption from payment of license fees for the years during which the installations concerned are put into operation and for the following five (5) years; and (b) exemption from Internal Consumption Tax and import taxes as regards to construction materials and all the other equipment necessary to complete the investment program.

The National Investment Board has been set up to enforce the Investment Code. The composition and function of the Board are laid down by decree of the Council of Ministers. Upon filing of a completed application to the Board, there is a one-month period for the Board to ask for further information or formulate objections to the applicant. Beyond this deadline, and in the absence of a response from the Commission (Investment Code Commission, Ministry of Trade and Tourism), the investment is considered registered. General legal guarantees under the Investment Code include rights for foreigners and Djiboutians: (a) to invest in specific projects; (b) freedom of movement, communication and residence for the operation of an enterprise; and (c) indemnification in the event of expropriation (as well as other basic commercial rights).

4.2. Guarantees

The government of Djibouti has not provided a sovereign guarantee to a privately-financed project in the past. The Republic of Djibouti is not yet a member of the Multilateral Investment Guarantee Agency (MIGA) convention of the World Bank.

Djibouti is a member of Inter-Arab Guarantee Investment Company (IGIC). IGIC provides insurance for inter-Arab investments and for export credits against non-commercial risks in case of investments and non-commercial risks of export credits. The non-commercial risks include nationalization, currency inconvertibility, war, civil disturbances, cancellation of the import license and prevention of the entry of goods or their transit into the country. The commercial risks include insolvency of the debtor, bankruptcy, as well as default and abrogation or termination of the export contract.

The IGIC also undertakes the promotion of the flow of investments within the Arab countries by carrying out activities that are ancillary to its main purpose and in particular, those relating to the identification of investment opportunities and the study of the conditions that govern the flow of investments in said countries.

4.3. Host Country Personnel with Geothermal Experience

CERD employs geothermal-experienced engineers and geotechnical and support personnel who are available to offer assistance on behalf of the host-country. These professionals can assist in all phases of the resource and wellfield development. Their engineering and technical understanding of geothermal energy can significantly advance resource confirmation and wellfield development tasks.

The Chief of Geothermal Services for EdD Abdou Mohammed Houmed is a geologist who was formerly with ISERST, the predecessor of CERD and who has geothermal experience at the Assal geothermal site.

4.4. Employment of Foreigners and Locals

Regulation of foreign workers is covered by the *Ministere du Travail* (Ministry of Workers), *Decret No. 81-103/PR/TR*, *Portant Reglementation du Travail des Etrangers.* Regulation of Djiboutian workers are covered by the *Conditions Générales d'Emploi Des Travailleurs du Commerce, du Bâtiment* and *des Ateliers* of the *Territoire Francais des Afars et des Issas*; *Arrete No. 66/24/SPCG du 29 Mars 1966*; *Réglement des Conditions Générales d'Emploi des Travailleurs du Commerce, du Bâtiment et des Ateliers de la Côte Francaise des Somalis; Modifiés par les arrêtés No. 1944/SG/CG du 26 décembre 1969; 72-329/SG/CG du 1er mars 1972; 74-339/SG/CG du 7 février 1974*.

Local wage rates for typical office and skilled field employees are in the neighborhood of (a) 55,000 DF (US$309) per month for office employee (requirements will include: bi- or tri-lingual secretary, office manager, clerk, messenger and security); and (b) 65,000 DF (US$365) per month for skilled worker (requirements will include: laborers, mechanics, welders, heavy equipment operators and roughnecks).

Employees benefit from a social protection system. In case of illness or accident, they receive family allowances and a retirement pension at the end of their career. To finance these regulations, the National Insurance Benefits Fund collects contributions based on the wages, with 15.7 percent payable by the employer and four percent by the employee. Salary and wages reach a maximum of 300,000 DF (US$1,685) per month for calculation of contribution.

Table 1: Salary Contribution for Social Protection System

	%
Retreat	7.0
Family allowance	5.5
Industrial injuries	1.0
Inter-Company Medical Service	3.5 of salaries
	2.7 of family
Total	**19.7**

4.5. Taxes

Industrial, Commercial or Company Profits

A tax of 25 percent is collected annually on industrial taxable profits (such as those that will be generated by a private geothermal project). A company is subject to a one percent flat rate minimum tax on revenues that cannot be deducted from taxable net profit.

Exemptions

Tax exemptions exist for equipment, industrial and commercial profits and land taxes are exonerated for up to ten years. Exempted from the Domestic Consumer Tax are goods imported for the execution of projects benefiting from foreign funding, except for lubricants, fuel oils, pneumatics and spare parts. Companies that carry out a project benefiting from foreign funding are exempted from the Importer's License Tax.

Tax is computed on a monthly basis as follows:

Table 2:General Tax on Salaries and Wages

Monthly Income (DF)	Monthly Income (US$)	Income Tax Rate (%)
25,000 – 30,000	140 – 169	2
30,000 – 100,000	169 – 561	6
100,000 – 200,000	561 – 1,123	10
200,000 – 400,000	1,123 – 2,247	14
400,000 – 600,000	2,247 – 3,370	19
600,000 – 800,000	3,370 – 4,494	25
800,000 +	4,494 +	32

Table 3:Tax on Fringe Benefits

Monthly Income (DF)	Monthly Income (US$)	Income Tax Rate (%)
Under 30,000	Under 169	0
30,000 – 100,000	169 – 561	4
100,000 – 150,000	561 – 841	5
250,000 – 250,000	841 – 1,402	6
350,000 – 350,000	1,402 – 1,936	7
350,000 – 450,000	1,936 – 2,524	8
450,000 – 550,000	2,524 – 3,085	9
550,000 +	3,085 +	10

Petroleum Products

The government of Djibouti levies a tax on imported petroleum products consisting of a 28 percent domestic consumption tax on the CIF price, plus a petroleum surtax of 2100 DF (US$11.82) per barrel. This increases the final cost of the fuel oil used in the Djibouti diesel fuel by 32.8 percent.

V. CONTACT INFORMATION

1. Local Power Company

Mr. Djama Ali Guelleh
Director
Électricité de Djibouti
Bd. de la République
B.P. 175
République de Djibouti
Tel: 253-35-2851
Fax: 253-35-4396

2. Ministry of Energy

Mr. Mohamed Ali Mohamed
Minister of Energy and Natural Resources
Tel: 253-35-8673 (Mobile)

Mr. Abdi Farah Chideh
Secretary-General
Ministry of Energy and Natural Resources
P.O. Box 10010
Djibouti, Republic of Djibouti
Tel. 253-35-0137, 35-0340
Fax 253-35-4396
Email energie@intnet.dj

3. Geological Survey

Mr. Jalludin Mohammed, Director
Centre de Recherche Scientifique de Djibouti (CERD)
B.P. 486 Djibouti
Tel: 253-35-2795
Fax: 253-35-4812

4. Ministry of Finance

Mr. Yacin Elmi Bouh
Minister of Economy, Finance and Privatization
Le Ministre de L'Economie des Finances et de la Planification Chargé de la Privatisation
Tel. 253-35-0297, 35-1809
Fax 253-35-6501

5. Interested Multilateral Agencies

Resident Representative
United Nations Development Programme
P.O. Box 2001
Djibouti
Tel: 253-35-1361 (General Office)
253-80-2506 (Mobile)
253-35-3371, 35-3372 (Reception)
Fax 253-35-0587
Email afaf.abu-hasabo@undp.org

6. Interested Bilateral Agencies

Group Agence Francaise de Developpement
Philippe Mahé, Senior Project Officer
Agence Régionale de Djibouti
Rue Franchet D'Esperey - BP 1937 - Djibouti
Tel. 253-35-2297
Fax 253-35-4809
Email: afd@intnet.dj

7. US Embassy

Mr. Donald Yamamoto
Ambassador
American Embassy
Tel: 253-35-3995
Fax: 253-35-3940

VI. MAPS OF COUNTRY GEOTHERMAL PROSPECTS AND GRID

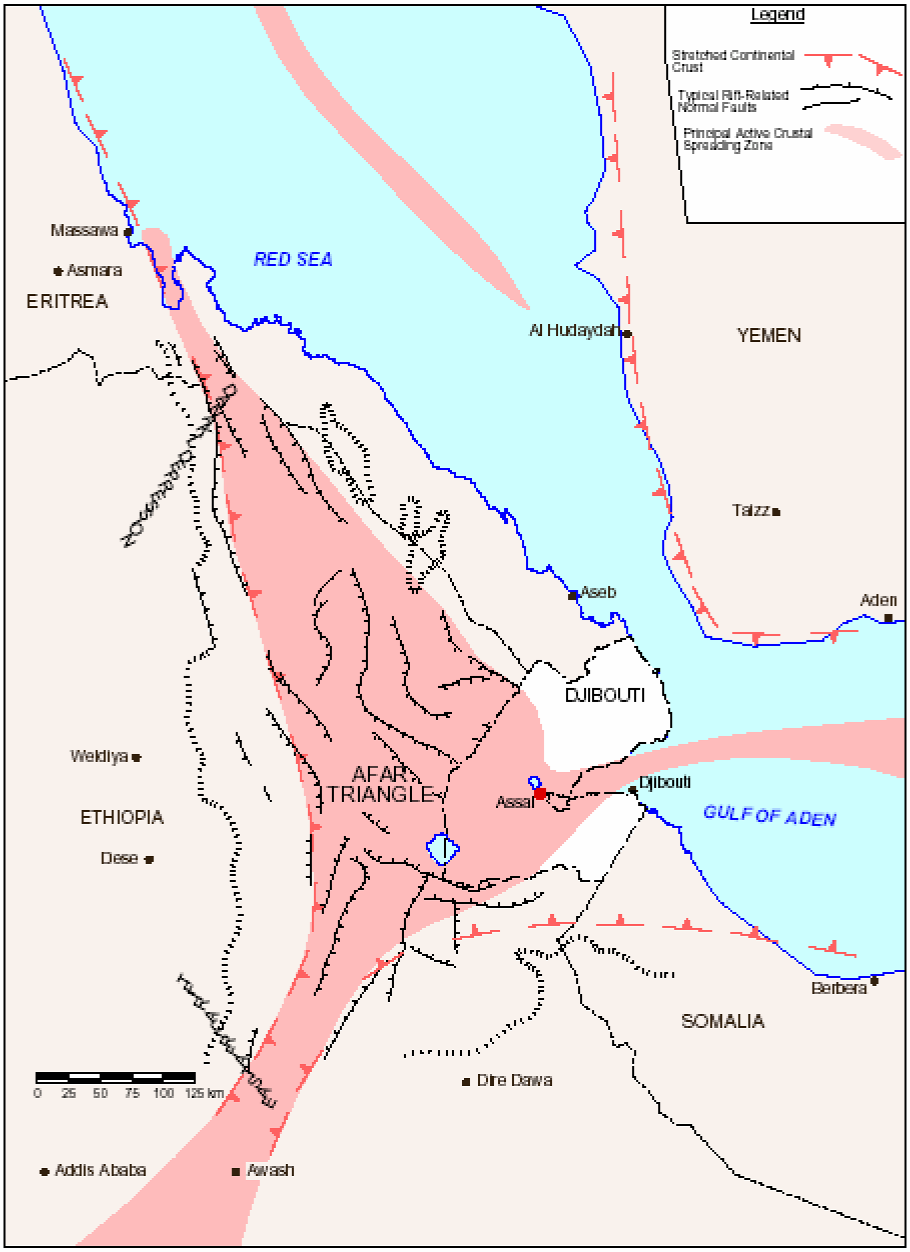


Figure 4.1.1. Afar Triangle and Assal Geothermal Area
Regional Thermo-Structural Relationship

GEOTHERMAL DEVELOPMENT ASSOCIATES

Figure 2: Afar Triangle and Assal Geothermal Area Regional Thermo-Structural Relationship

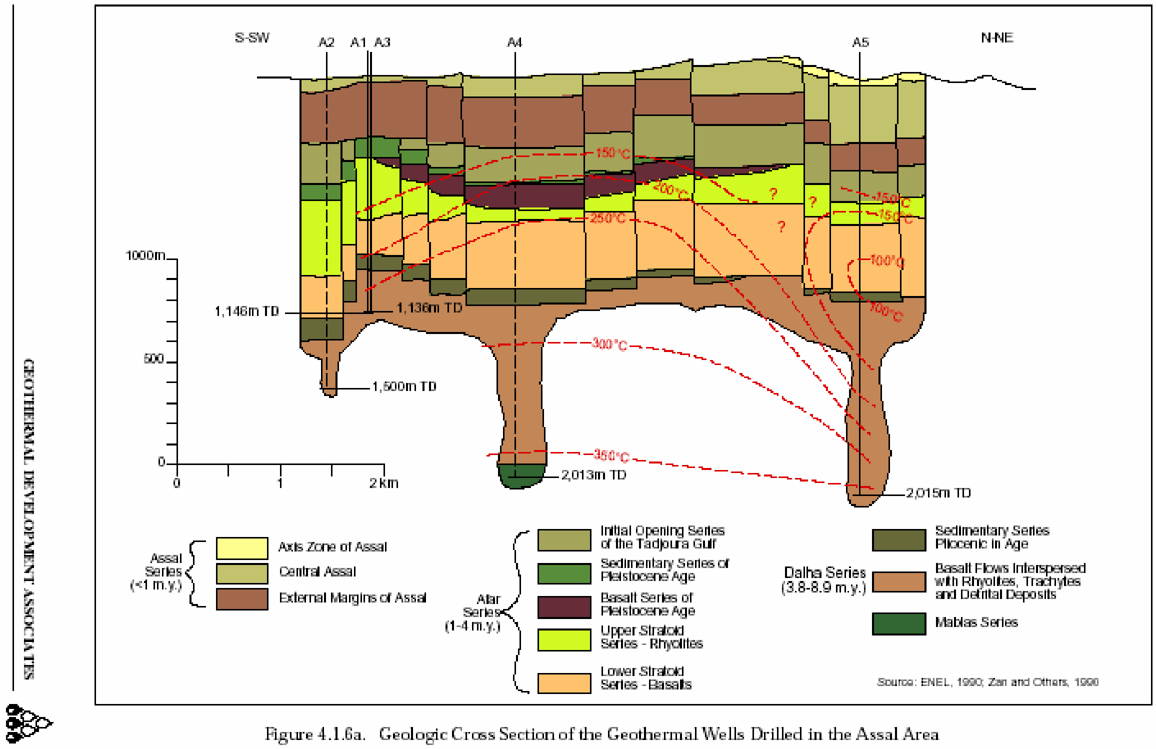


Figure 4.1.6a. Geologic Cross Section of the Geothermal Wells Drilled in the Assal Area

Figure 3: Geologic Cross Section of the Geothermal Wells Drilled in the Assal Area

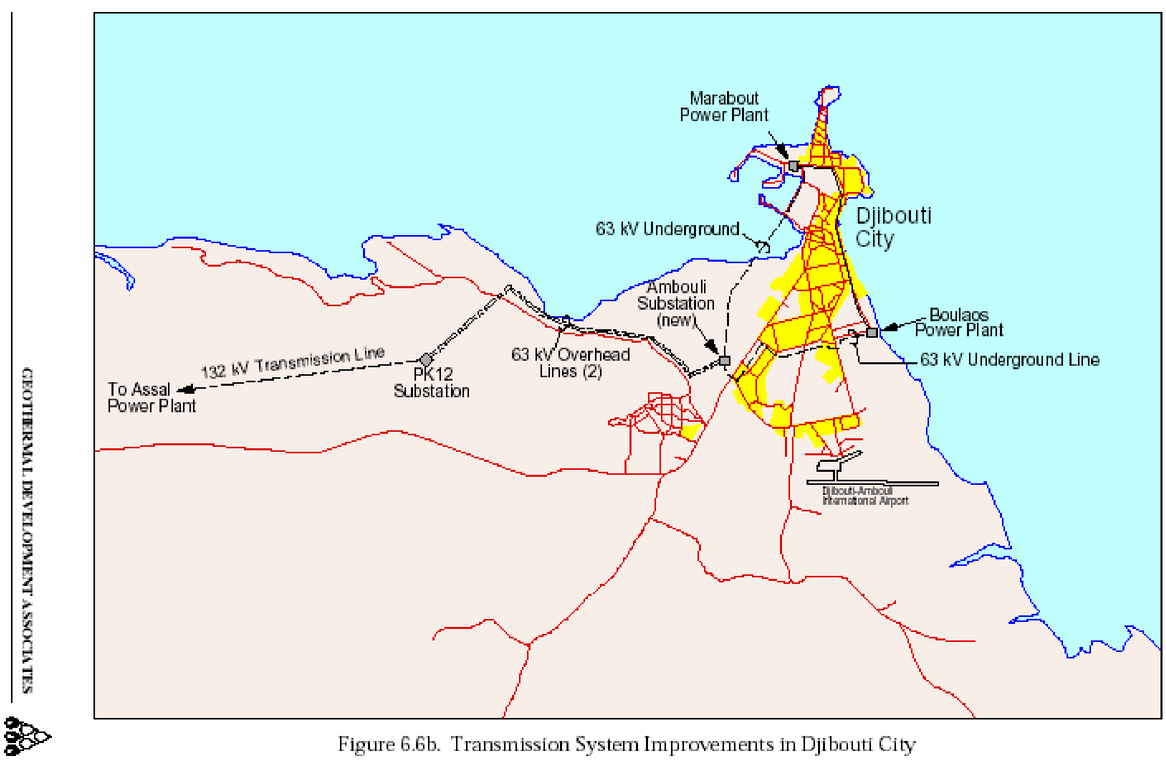


Figure 6.6b. Transmission System Improvements in Djibouti City

Figure 4: Transmission System Improvements in the city of Djibouti

Figure 5: Transmission Line

VII. DETAILED REPORTS AND MAPS OF GEOTHERMAL AREA(S)

CERD maintains a cartographic center where copies of many geologic and topographic maps of the region can be purchased. A list of some of the available maps is below.

Instit Géographique Nationale – France, 1992, Djibouti Carte Générale á l:200,000: Les Spéciales de L'IGN Pays et Villes du Monde, 3615 IGN, Édition 1, Paris.

Djibouti map, index, 8/5 x 11", color shaded relief, index map w/provinces.

Plan de Djibouti, Djibouti Ambouli, and Location of Places, 5 p.

Instit Geographique National, 1962, Carte de la Cote Francaise des Somalis au 1/100,000 Territoire Francais des Afars et des Issas – Tadjoura: Feuille NC-38-XIX-4, eschelle 1:100,000.

Instit Geographique National, No Date, Carte de la Cote Francaise des Somalis au 1/100,000 Territoire Francais des Afars et des Issas – Assal: Feuille NC-38-XIX-3, eschelle 1:100,000.

Instit Geographique National, 1961, Carte de la Cote Francaise des Somalis au 1/100,000 Territoire Francais des Afars et des Issas – Ali Sabih: Feuille NC-38-XIX-2, eschelle 1:100,000.

The reports listed below are also available at CERD.

VIII. REFERENCES

Abdou Mohamed Houmed, (1984). "Geothermal Prospects in the Djibouti Republic", *Proceedings of the 6th Geothermal Workshop,* Geothermal Institute, University of Auckland.

Aquater, (1988), *Djibouti Geothermal Exploration Project, Republic of Djibouti, Assal 3 Well Chemistry*, Commessa 339400, GEOT A3158, June 1988.

Aquater, (1982). *Technical - Economic Study of Geothermal Pre-Feasibility, General Conclusions*, March 1982.

Battistelli, A., Rivera, J., & Ferragina, (1991). "Reservoir Engineering Studies at the Assal Field: Republic of Djibouti", *Geothermal Resources Council Bulletin*, November 1991.

Compagnie Francaise Pour le Developpement de la Geothermie et des Energies Nouvelles, (1990). *Projet Geothermique d'Asal, Analyse des Donnees de l'Exploration*, September 1990.

ENEL-D.P.T., *Djibouti Geothermal Project, Economic Evaluation*.

ENEL-D.P.T., (1991). *Djibouti Geothermal Project, Report on the State of Mining Knowledge*. R.2.AM.XB.00.101.0.

ENEL-D.P.T., (1990). *Djibouti Geothermal Project, - Report on the State of Mining Knowledge of the Assal Zone, Proposals and Recommendations*.

ENEL-D.P.T., (1991). *Djibouti Geothermal Project Feasibility Study for the Exploitation of Assal-3 Well,* Italian Ministry of Foreign Affairs/Electricite de Djibouti, Pisa.

Fabriol, R. & Varet, J., (1983). *Discussion sur la Faisabilite Technique de l'Exploitation du Fluide Mis en Evidence Par le Forage Assal 1 Pour la Production d'Electricite a la Lumiere de l'Experience des Champs de Cerro Prieto et Salton Sea*, Bureau de Recherches Geologiques et Minieres 83 SGN 021 GTH, Republique de Djibouti.

Jaludin, M., et al., (1992). *Reservoir Geothermique Superficiel Assal - Note de Synthese Finale*, ISERST.

Koenig, J.B., Geothermex Inc., (1987) *Assessment of Results of Drilling Hanle 1 and 2 and Evaluation of the Assal Depression for Geothermal Drilling and Resource Development*. World Bank, Republic of Djibouti.

Reed, et al., (1999). *Geothermal Energy, the Potential for Clean Power from the Earth*. Preliminary Report, Geothermal Energy Association.

Patou, Michel, (1992). *Reevaluation Economique du Projet de Developpement de la Geothermie et de sa Place dans le Systeme de Production d'Electricite.* World Bank, Washington, DC.

ETHIOPIA COUNTRY GEOTHERMAL REPORT

Figure 1: Map of Ethiopia

I. COUNTRY OVERVIEW

1.1. Geography, History and Politics

Ethiopia is located in northeastern Africa between 3.5° and 15° northern latitudes, 33 and 48° eastern longitudes, and has an area of 1.1 million km^2. Ethiopia is bordered by Eritrea, Sudan, Kenya, Somalia and Djibouti and is the tenth largest country in Africa (about twice the size of France). The country has an estimated population of 63.5 million that is growing at 2.9 percent per annum. Eighty-five percent of the population lives in rural areas. Approximately 2.2 million people live in the capital, Addis Ababa.

Ethiopia is the oldest independent country in Africa. Except during the Italian occupation of 1936-41, Ethiopia maintained its freedom from colonial rule. In 1974, a military junta, known as the Derg, deposed Emperor Haile Selassie I, who had ruled the country since 1930 and established a socialist state. The Derg was in power for 17 years and was eventually toppled by a coalition of rebel forces, the Ethiopian People's Revolutionary Democratic Front (EPRDF), in 1991. A constitution was adopted in 1994, and Ethiopia's first multiparty elections were held in 1995. A two-year border war with Eritrea ended when a peace treaty was signed in December 2000.

Ethiopia is a democratic federation comprised of nine regions, governed by a bicameral legislature with 656 combined representatives, a Prime Minister and a President. The ruling coalition (EPRDF) has been in power since 1991. However, six other major parties and some 50 smaller parties also participate in the political system. National elections were held in May 2000, and the ruling EPRDF coalition was re-elected.

The country is made up of four main ethnic groups: Oromo (35 percent), Amhara (30 percent), Tigre (six to eight percent) and Somalis (six percent). The religious breakdown of the country's population is 40 percent Muslim, 45 to 50 percent Ethiopian Orthodox and Christian, five percent Protestant and an additional five percent different indigenous beliefs. The main languages spoken in Ethiopia include Amharic (the official language), Tigrinya, Oromifa, English and Somali.

1.2. Economy

Ethiopia's economy is primarily agrarian, with the agricultural sector accounting for 45 percent of GDP and 80 percent of the workforce. Coffee, Ethiopia's primary export crop, accounted for 58 percent of exports in 1999 and has averaged two-thirds of all export earnings over the last 20 years. Other agricultural exports include khat, a mild stimulant from the leaves of the Catha Edulis shrub, pulses, oilseeds, live animals, hides and skins. Ethiopia's GDP growth averaged five percent from 1996 to 2000 and was estimated at 7.3 percent for 2001.

Continued donor support is an important element in Ethiopia's economic reform and poverty reduction strategies. In 1997, the IMF approved a US$200 million loan for Ethiopia's energy sector to: (a) increase the efficiency and sustainability of Ethiopia's power sector; (b) to increase electricity use for economic growth and improved quality of life; and (c) to improve utilization efficiency of rural renewable energy. Following the outbreak of hostilities with Eritrea the IMF, World Bank and other donors suspended new lending to Ethiopia. The suspension was lifted after the signing of the peace accord in December 2000.

II. COUNTRY ENERGY CONTEXT

2.1. Electricity Sector

Until recently, power generation was monopolized by the Ethiopian Electric Power Corporation (EEPCO). With the adoption of a new electricity law in 1997 (Electricity Proclamation No. 86/1997) and subsequent regulation in 1999 (Regulation No. 49/1999), EEPCO was converted to an autonomous parastatal agency responsible for the transmission and distribution of electricity and the Ethiopian Electricity Agency (EEA) was formed to regulate the activities of the electricity sector and promote and develop efficient, reliable and cost-effective electricity services. The role of the EEA is to:

- Supervise the generation, transmission, distribution and sales of electricity
- Determine the appropriate quality and standards for electricity services
- Issue, suspend and revoke licenses
- Issue professional competence certificates
- Study and provide recommendations for tariff structures

Under the new energy law, EEPCO's board of directors answers directly to the Office of the Prime Minister and is responsible for the transmission and distribution of electricity and the development and construction of power generation plants. Power generation, however, has recently been opened to the private sector. At present, EEPCO operates two systems, the grid (known as the Interconnected System) that serves larger urban centers and the self-contained system that provides power for areas beyond the grid. EEPCO's Interconnected System distributes electrical power to 365 towns, which consume 92 percent of the total energy produced. The remaining small power generation facilities were installed by the previous Rural Infrastructure Development Department of the Ministry of Agriculture.

2.2. Electricity Market

Ethiopia has 714 MW of installed generating capacity, of which 184 MW was completed during 2002. Per capita electricity consumption in Ethiopia is among the lowest in Africa averaging 21.5 kWh per annum. Currently, less than half of Ethiopia's towns and four percent of the population have access to electricity.

The vast majority of Ethiopia's existing capacity (94 percent) is hydroelectric and accounts for 97.5 percent of electricity produced. Diesel generators contribute most of the remainder (five percent) of capacity and geothermal one percent. The Interconnected System run by EEPCO has an installed capacity of 665 MW with 11 hydropower stations and two diesel stations that formerly contributed 6.5 MW, both of which are now retired. In 1999, a pilot geothermal plant with a generating capacity of 7.3 MW was added. The total energy output capacity of the Interconnected System is about 1600 GW per year. The system now supplies demand centers within an approximate radius of 500 km around Addis Ababa. Supply in the self-contained system is dominated by diesel generators although there is one five-MW and two smaller hydropower stations. The current generating capacity of the self-contained-system is 42 MW from 41 diesel plants.

During recent drought conditions only 170 MW of power was generated. Power rationing took place including outages of 13 to 14 hours every third day for both residential and industrial customers. Some industries (i.e., cement) shut down entirely. Load shading started again in January 2003 due to inadequate rainfall during the preceding year.

Official statistics for the year 2000 show that 1.69 GWh electricity was produced and 1.38 GWh was sold. Industry accounted for about 38 percent of consumption and 39 percent of sales revenue, while domestic consumption was 37 percent and 28 percent of sales revenue. A cross-subsidy of the domestic tariff category by the commercial tariff category (24 percent of consumption and 32 percent of revenue) exists. Production costs are reported to be 2.3 cents US per kWh for hydro and 24 cents US per kWh for diesel. Electricity is sold countrywide for an average price of 5.5 cents US per kWh.

Projected energy requirements from the year 1990 through 2040 indicate that power generation capacity needs will increase more than 14 times by 2020 and about 25 times by 2040. See Table 1 for a forecast of energy demand.

Table 1: Forecast of Energy Demand

Year	**2000**	**2002**	**2005**	**2010**	**2015**	**2020**	**2025**
Power Sales, GWh	1.38	1.65	2.01	2.64	3.37	4.29	5.47
Net Generation, GWh	1.69	2.01	2.46	3.25	4.17	5.31	6.79
Peak Load, MW	331	396	484	639	819	1,044	1,333

2.3. Competing Resource Options

Ethiopia is endowed with a variety of energy resources including hydro, coal, biomass, solar, geothermal and natural gas. The country is not a large consumer of petroleum fuels.

Hydropower

Ethiopia claims to have a total of 650 TWh per year of hydro generation potential, the second largest in Africa. A more practical potential has been calculated at 260 TWh per year, of which ten percent represents the potential for small-scale hydro installations. Two new hydro plants came on line from 2000 to 2002 (Tis Abay, 75 MW and Gilgel Gibe. 184 MW). The government financed the Tis Abay plant while the African Development Bank and World Bank financed the Gilgel Gibe plant. EEPCO has started to build Ethiopia's largest (300 MW) hydro generating facility at Tekeze, in northern Ethiopia. Germany's Lahmeyer has been commissioned to conduct feasibility studies on three potential hydroelectric sites: a 195-MW plant at Beles, a 370-MW facility at Halele-Werabesa and a 440-MW plant at Chemoga-Yeda.

In 2001, EEPCO and Italy's ENERCO signed an MOU for the construction of three power plants, two of which will be hydro and the third, a coal fired plant. The first of the hydro projects is the Awash 4 hydroelectric facility that will generate 40 MW. The second and the largest facility will be the 162-MW Genale hydroelectric facility located on the border between the Oromiya Region and the Southern Nations, Nationalities and Peoples Regional State. The plants will be Build-Operate-Transfer (BOT) contracts under which ENERCO will operate the facilities for 30 years (renewable for another 30 years).

Natural Gas

Current natural gas reserves are estimated to be 24 m^3. There is no commercial production of hydrocarbons in Ethiopia. In December 1999, the government and Sicor (Texas) signed a preliminary agreement to produce natural gas and associated liquids. The Gazoil Ethiopia Project (GEP) acquired two MW concessions in the Calub and Hilala areas of the Ogaden basin and the construction of a 600 km, 24-inch pipeline to channel gas and associated liquids to Awash, 220 km east of Addis Ababa.

Petroleum Exploration

The Ethiopian government has selected a number of potential petroleum exploration areas for private investment, in addition to the development of the natural gas reserves at Calub and Hilala in the Ogaden. In order to exploit its reserves, the government established the Calub Gas Share Company (CGSC) with most of the shares initially belonging to the government. With a renewed focus on increasing private investment, the government recently decided to sell its shares in CGSC. In the Ogaden Basin, Ethiopia Hunt Oil, a local branch of the Texan-Canadian Hunt Oil Company, had acquired rights to the Genale River concession. The rights were relinquished a few years ago, due to financing problems, although exploration data identified some encouraging structures.

Coal

In June 2001, EEPCO and Italy's ENERCO signed an MOU for the construction of the Delbi Moye 75-MW coal-fired plant that will use local coal deposits at the site the Ethiopia Geological Survey discovered during the mid-1980s. Like ENERCO's two hydro-electric plants, the coal plant will be a BOT contract under which ENERCO will operate the facility for 30 years (renewable for another 30 years).

Energy for Export

In April 2001, Ethiopia signed agreements to export electricity to neighboring Djibouti and Sudan. It is unclear when this will begin as it requires the construction of some 300 km of transmission lines to connect both countries electric grids.

2.4. Rural Electrification

The government of Ethiopia has plans to decentralize the electricity distribution structure and is preparing to launch a rural electricity program in which the private sector is expected to play a key role. By 2012, electricity is planned to reach 20 percent of the population, doubling the number of people who have access to electric power. The World Bank International Development Association (IDA) is providing US$200 million under the Second Energy Project (P000736) that includes decentralization of EEPCO's management and accounting and billing systems. It also strengthens rural energy capability by adapting technologies to Ethiopia's needs and trains research personnel overseas in various energy fields.

III. GEOTHERMAL RESOURCES AND DEVELOPMENT

3.1. Overview

Ethiopia's geothermal resources are located in the Ethiopian Rift valley and in the Afar Depression, which are both part of the Great East African Rift System (See Fig. 2).

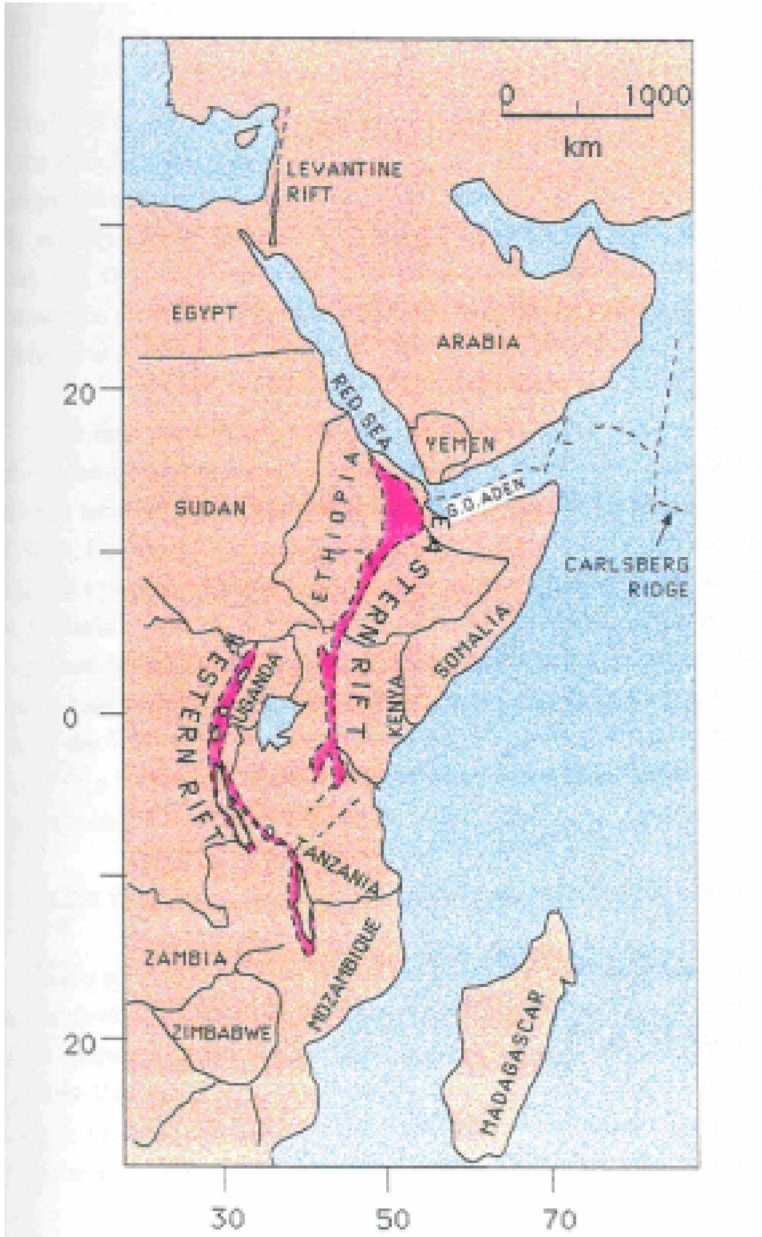


Figure 2: Great East African Rift System

The Ethiopian Rift System extends over 1000 km in a north-northeast direction and is divided into four main areas: Main Ethiopian Rift; Afar Depression; Lake Turkana and Lake Chew Bahir Rifts.

Main Ethiopian Rift

The Main Ethiopian Rift extends approximately 400 km from the southwest to the northeast from 6^{o} north (near Lake Chamo) to 9^{o} north where it funnels out into the Afar Depression in the north-eastern part of the country and meets the Afar triple junction. It is dominated by acid volcanic rocks, mainly consisting of rhyolite volcanoes and domes as well as thick ignimbrite sheets and other loose pyroclastics. The width of the Main Ethiopian Rift is determined by two parallel faults; the distance between which varies from 35 to 80 km and averages 70 km. The relative displacement of the Rift floor below the uplifted plateau varies as much as 2,000 m. The Wenji Fault Belt is a zone of recent crustal extension that was active during the Quaternary period. Pantelleritic volcanoes and large calderas are located between the offsets of the Wenji fault belt among which is the Aluto volcano.

Afar Region

The Gulf of Aden and Red Sea trend rifts also enter the Afar Triple Junction from the south-southeast and north-northwest. The focal point may be thought of as being located in the vicinity of 10.5° north and 41.5° east. The Afar rift floor is also dotted by a large number of rhyolitic volcanoes in the south and often basaltic edifices in the north. In the southern Afar, the rift floor is comprised of extensive ignimbrite sheets. In the northern part of the Afar, in the zone of the Red Sea, the terrain is made mostly of trend rifting, basalt sheets of late tertiary to recent age. In addition to zones of continental sedimentation, at least two occasions of marine transgression of the northern Afar rift during the last quarter of a million years have left large thicknesses of mainly evaporate sediments.

Thermal Springs

Many thermal springs exist in the highland areas of Ethiopia, especially in areas affected by tertiary tectonics within the rift. The city of Addis Ababa, located on a westward embayment of the Main Ethiopian Rift, started around the Finfine thermal springs where there are international class hotels and a public bath. Most of the surface geothermal manifestations and the more vigorous discharges in Ethiopia are located within the Ethiopian rift system. A large number exist in the Main Ethiopian Rift due to more favorable hydrologic conditions. The drier Afar region has more concentrated manifestations but exhibits greater overall heat flow. The high concentration of thermal manifestations in the rift system is due to the high regional heat flow there is an underlying zone of upper mantle intrusion beneath the thinned crust. In the Afar region, the depth to the upper mantle ranges between five and 20 km giving rise to the highest heat flow anywhere along the length of the Eastern Africa Rift.

3.2. Geothermal Exploration, Potential and Use

Exploration

Geothermal exploration began in Ethiopia in 1969 with a regional geological-volcanological mapping and hydrothermal manifestation inventory that covered most of the Ethiopian Rift. With financial and technical assistance from United Nations Development Program (UNDP), the Ethiopian government conducted a systematic campaign of geothermal exploration along the Main Ethiopian Rift and the Afar Depression from 1969 to 1973. On the basis of several years of exploration activities involving geological, geochemical and geophysical investigation, 18 geothermal prospecting areas were selected for further studies (See Fig. 3). These include:

- **Lakes District** – Aluto-Langano, Corbetti, and Abaya
- **Southern Afar** – Tulu-Moye, Gedemsa, Dofan, Fantale, Meteka, Teo, Danab
- **Northern Afar** – Tendaho and Dallol (Danakil Depression)

Geothermal Potential

Total geothermal resource potential in Ethiopia is estimated to be over 1000 MW, approximately 700 MW in excess of its annual requirement of 400 MW. Of this, at least 170 MW is from sites in the Lakes District, 260 MW from sites in the Central Afar, 120 MW from sites in the Southern Afar and 150 MW from sites in the Danakil Depression. Among these prospects, exploration has centered on two main areas, the Aluto-Langano (Lakes District) the site of a 8.52 MW (gross) pilot geothermal power plant and the Tendaho geothermal fields (Northern Afar) where plans are underway for the development of a five to 20 MW geothermal plant.

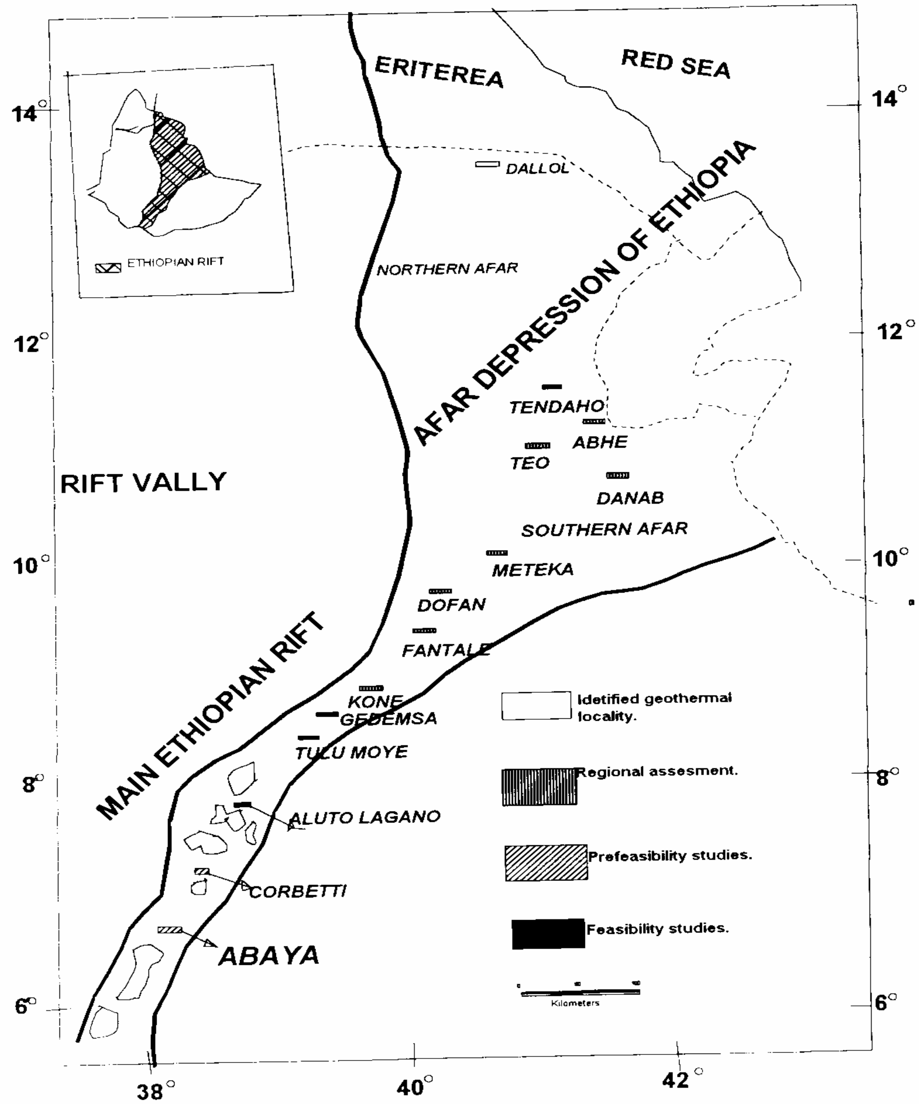


Fig. 1 Location Map of the Geothermal Prospect Areas within the Ethiopian Rift Valley

Figure 3: Map of Geothermal Prospect Areas Within the Ethiopian Rift Valley

Geothermal Use

Until 1998 the only utilization of geothermal energy in Ethiopia was for leisure and therapeutic purposes. More than a dozen facilities ranging between large hotels in Addis Ababa (Sheraton, Hilton, Gyon, Filweha hotels) and resort hotels, swimming pools and public baths elsewhere exploited geothermal waters on commercial bases. Three mineral water bottling plants (including the producer of the long renowned brand "Ambo") exploit other resource areas. Hundreds of other areas serve as traditional sites for public bathing, both hot water and steam, with little or no commercial development.

3.3. The Aluto-Langano Geothermal Field and Pilot Power Plant

Geothermal Exploration

With support from UNDP and the European Economic Community, a geothermal feasibility study began in the Aluto-Langano area in 1981. As part of the study, eight exploration wells were drilled at the site from 1981 to 1985 ranging between 1,100 and 2,500 m in depth. The LA1 well, about 1,100 m in depth, was cold. The LA2 was drilled on the western flank of the volcano, and the subsurface horizons penetrated were found to be completely sealed by secondary hydrothermal mineral deposition and isolated from the main underground fluid circulation system. The underground temperature was low. An assessment of chloride ion variation in recently drilled shallow wells helped to site LA3 along a young fault on top of the volcano. This well was the discovery well: 315° C fluid at 1,700 m depth. The LA4, 5 and 8 wells were productive and had temperatures ranging from 280° C to 335° C with moderate permeability. The LA5 well was abandoned after an extended fishing job at about 1,600 m depth and was later observed to heat up to greater than 250° C. Another well, LA7, showed extensive cold water inflow above a high temperature zone. LA7 could be stimulated to discharge but was later relegated for use as a re-injection well.

Construction of Five-MW Geothermal Plant

In 1994, GENZL (New Zealand) and the Ethiopian Electric Light and Power Authority (EELPA) carried out a review of the work at Aluto Langano in order to: (a) confirm the geothermal resource in the area (which had been estimated at 30 MW); (b) recommend a strategy for the development and use of the resource; and (c) facilitate the design of a five MW pilot geothermal plant using steam from the existing wells to provide electricity to feed into the grid. Well testing and reservoir engineering studies were carried out until 1996, at which time the Ethiopian Institute of Geological Survys (EIGS) ceded responsibility for the wells to EEPCO (EELPA's successor) for development of the geothermal plant. A turn-key contract for the construction of the pilot power plant was awarded to ORMAT International on August 9, 1996.

The Aluto-Langano Geothermal Pilot Power Plant is the first geothermal power plant to generate electricity in Ethiopia. The designed power output of the pilot plant is 8.52 MW (gross) and 7.28 MW (net). Nevertheless, due to various problems described below, the current power output is less than two MW. The pilot power plant is supplied with steam and brine from four production wells (LA3, LA4, LA6 and LA8) at between 2000 m and 2500 m depth. There is one re-injection well (LA7), which is an original field exploration well. The working fluid in the binary units is iso-pentane. Ambient air is the cooling media for the condenser in both units.

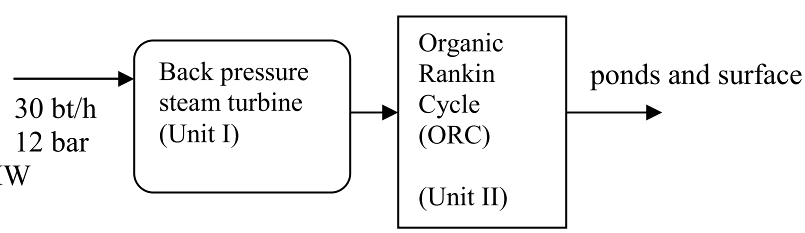
The Aluto Langano plant is composed of two separate units. The first unit, the Geothermal Combined Cycle Unit (GCCU), is comprised of two subsystems, a back pressure steam turbine using geothermal steam and a binary type unit with pentane as its working fluid. After the steam expands in the backpressure turbine, the remaining heat is fed into the binary unit that creates additional power. The GCCU uses the higher-pressure outputs from wells LA3 and LA6. The second unit, known as the ORMAT Energy Conversion unit, is a binary type unit that uses the output from the lower pressure wells LA4 and LA8.

Schematic of Aluto Langano Plant

- Total design gross power: 8.52 MW
- Total design net output: 7.280 MW
- Actual net output: ~2.0 MW

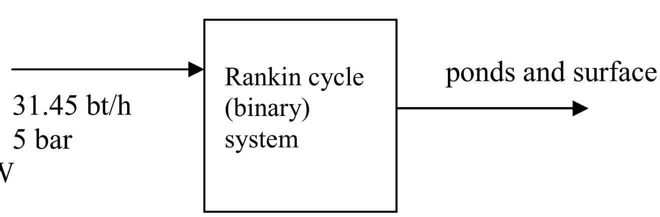
Unit A - Geothermal Combined Cycle Unit (GCCU)

Wells LA3 and LA6
Steam flow rate: 30 bt/h
Design pressure: 12 bar
Design output: 5.02 MW



Unit B - ORMAT Energy Converter Unit

Wells LA4 and LA8
Steam flow rate: 31.45 bt/h
Design pressure: 5 bar
Design output: 3.5 MW



Technical and Maintenance Issues

During the commissioning of the Aluto-Langano plant, the capacity of the wellhead pressure decreased to a level of approximately 4.5 MW. Following the commissioning of the plant, the generating capacity declined even further. In December 1999, one of the units was shut down due to a pentane leak and has not been repaired. A May 2000 EEPCO report notes that a test protocol was not used for either the generating equipment or protective devices at the time of the commissioning of the plant. The EEPCO study made a number of other findings:

The actual pressures of the four operating wells are below the design pressures as follows:

Well	LA3	LA4	LA6	LA8
Design pressure (bar)	12.5	6.4	13.35	8.4
Actual pressure (bar)	5	3.2	6.2	3

It is not clear if the decreasing pressures are the result of down-hole scaling, low permeability or both.

- Well LA8 continues to flow but is reported to be discharging mud.

- Wells LA3 and LA6 are connected at a T-junction. However, the parallel production of these wells has been hampered by backflow from LA6 into LA3.

- In December 1999, the ORMAT Energy Conversion unit (3.5 MW) ceased operating due to the pentane leak. As a result, the dependable capacity of the plant (from the GCCU) decreased to approximately one MW.

- Wellhead valves reportedly cannot be easily opened or closed, and there is leakage. This could be the result of scaling (which has been noted in other parts of the plant), lack of maintenance on the valves (insufficient lubrication or packing) or the age of the valves (some of which are more than 15 years old). Also, spare valves and maintenance equipment (grease gun, safety pressure releasing tool, hydraulic packing gun, etc.) are not available and EEPCO technicians require training in valve maintenance and repair procedures.

- The plant uses air-cooling and has a total of 36 cooling fans. However, according to EEPCO sources, many of these fans are out of operation due to misalignment between the motor and fan shaft and, consequently, have prematurely worn fan belts.

- Scaling and blockages have occurred within the pre-heaters. EEPCO has considered cleaning the pre-heaters with wire brushes but is wary of damaging the pre-heater tubes.

- Brine from wells LA6 and LA8 is discharged into the atmosphere (as flashed steam) and into the ponds before being used for power generation.

- Insulation is missing from certain wellhead valves, steam and brine lines.

- Although three shallow injection test wells were drilled and limited re-injection trials were conducted in LA7, approximately 500 m from the wells brine from LA4 and LA8 has been discharged into the ground. Local people have been observed bathing and collecting water from the ponds for domestic use. Cattle have been observed drinking the pool water. This represents both environmental and health hazards.

- Deposits of amorphous silica with small amounts of calcium carbonates and calcium sulfates have been noted in surface equipment and at surface discharge areas. Scaling rates in the production wells and in brine lines have not been studied. However, reaming of calcite and silica deposits in the well casings and subsequent use of inhibitors have been suggested.

- Problems are reported in relation to the operation of the 15-kV transmission line that runs northwest from the plant to the town of Adame-Tulu, located on the main road to Addis Ababa.

- Spare parts and maintenance equipment are lacking. Although the Geological Survey of Ethiopia (GSE) prepared a list of spare parts and maintenance equipment for EEPCO, the items have not yet been ordered.

During construction of the plant, ORMAT trained a number of Ethiopian nationals as part of its responsibilities under the turnkey contract with EELPA. Following commissioning of the plant, ORMAT submitted two proposals to EEPCO, to: (a) provide spare parts for the plant; (b) send a field engineer to repair the pentane leak; and (c) provide ongoing plant maintenance. ORMAT also offered to carry out additional training of Ethiopian nationals at no cost to EELPA. ORMAT has indicated, if requested by EEPCO, it would still be willing to provide additional training to Ethiopian nationals at no cost and conduct an assessment of the corrective measures required to bring the plant back to its designed level of performance.

Plant Refurbishment

The problematic operation of the Aluto-Langano plant has discouraged Ethiopian leaders from considering the construction of additional geothermal plants despite the identification of a number of high potential prospects. Refurbishment of the Aluto-Langano geothermal plant would require and assessment and analysis of:

- The potential and performance of the geothermal resource that is being tapped by the existing boreholes
- The causes of the scaling and decreased wellhead pressures that have occurred (both down-hole and on the surface), their impact on the operation of the plant, and the measures that can be taken to mitigate their impact and their respective costs
- The design of the plant, including interconnections between the existing boreholes
- The current level of local expertise to maintain and ensure the upkeep of the plant and the resource and additional training that may be required
- The availability of spare parts and tools to ensure proper maintenance and repair of the plant and boreholes

An industry team would need to be sent to Ethiopia for a period of seven to ten days to work with EEPCO and EIGS to complete a full evaluation of the elements listed above. The recommendations of the team would include a plan to ensure the long-term viability of the Aluto-Langano plant so it serves as a positive example of the use of geothermal energy in the Rift Valley region.

3.4. The Tendaho Geothermal Field and Plans for a Five to 20 MW Plant

Between 1979 and 1980, geothermal exploration work was carried out in the Tendaho area (Gebregzaibher, 1994). In 1993, three deep and three shallow exploratory wells were drilled to a maximum depth of 2100 m that found a maximum temperature of 260° C. The drilling operation in the Tendaho geothermal field was financed jointly by the Italian and Ethiopian governments. A production test and feasibility study indicated that the four productive wells (out of six drilled) could supply enough steam to operate a pilot power plant of about five MW (Aquater, 1996).

The Ministry of Mines is now in the process of developing plans to open the Tendaho field to private sector development for the installation of a five-to-20 MW geothermal power plant. The recent upgrade of a tarmac highway through the Tendaho area will help facilitate such exploration. In addition, the Ethiopian government plans to extend the country's main 230 kV-transmission line to Semera, which is within ten km of the Tendaho area.

3.5. Additional Geothermal Prospects and Exploration Plans

There are a number of other geothermal prospects in Ethiopia that the GSE is considering exploring. The following is a list of prospects in order of priority:

- High Priority: Tulu-Moye, Gedemsa and Corbetti (advanced exploration stage)
- Medium-High Priority: Abaya
- Medium Priority: Dofan - Fantale and Meteka (detailed investigation-ongoing)
- Medium-Low Priority: Teo and Danab (reconnaissance)

Tulu-Moye and Gedemsa Geothermal Prospect Area

In the Tulu-Moye and Gedemsa geothermal prospect (see Fig. 3) there exists a high concentration of recent (0.8 - 0.08 million years ago) and historical eruption (Bora, Berecha and Giano, of peralkaline felsic lava and related tensional and transverse tectonic features (0.1 - 1.2 million years ago) with abundant silicic peralkaline volcanic products (Di-Paola, 1976). The latter suggests the existence of a deep-seated magma chamber with a long residence time (ELC, 1987). The area is highly affected by hydrothermal activity with the main hydrothermal manifestation being weak fumaroles, active steaming grounds (60 to 80° C) and altered grounds.

In 1998, the Geological Survey of Ethiopia (GSE) began carrying out geophysical, geo-chemical testing at Tulu Moye (in the Lakes District). Integrated geological, geochemical and geophysical studies included shallow temperature gradient wells (150 - 200 m in depth). The analysis confirmed the existence of potential geothermal reservoirs and delineated target areas for further deep exploration wells (Ayele et al, 2002).

Corbetti and Lake Abaya Geothermal Prospect

The Corbetti geothermal prospect area (Fig. 3) is within a 12 km-wide caldera that contains widespread thermal activity such as fumaroles and steam vents. Detailed geological, geochemical and geophysical investigations indicated the presence of potential geothermal reservoirs. Six temperature gradient wells have been drilled to depths ranging from 93 m to178 m (Kebede, 1986) and recorded a maximum temperature of 94° C. Many hot springs, fumaroles and altered grounds also exist in Lake Abaya prospect (See Fig. 3). In 2001 integrated geological, geochemical and geophysical studies identified the existence of a geothermal resource in the prospect (Ayele et al., 2002) and drilling of shallow temperature gradient wells have been recommended.

Dofan Geothermal Prospect Area

Geological, geochemical and geophysical investigations in the Dofan geothermal prospect (Figure 3) show the area to be characterized by a complex volcanic edifice which erupted considerable volume of pantelleritic lava from numerous eruptive centers between 0.5 and 0.2 million years ago (Cherinet and Gebreegziabheir, 1983; ELC, 1987). There is evidence of active tensional tectonics responsible for the graben structure, which cuts the central part of the edifice. The presence of several hydrothermal manifestations (fumaroles and hot springs) within the graben, together with an impervious cap, indicate the need for further detailed exploration. The EGS is carrying out detail geological, geochemical and geophysical investigations to delineate and select areas for deep exploration wells.

Fantale Geothermal Prospect Area

The Fantale geothermal prospect is characterized by recent summit caldera collapse, felsic lava extrusions in the caldera floor and widespread fumarole activity, suggesting a shallow magmatic chamber (ELC, 1987; Mamo et al., 2002). Active tensional tectonics form fissures up to two m wide near the volcanic complex. Ground water discharge to the system is assured by the proximity of the area to the western escarpment. The results of an integrated interpretation of previous data suggest the area has potential for future detailed geothermal resource investigation. EIGS is carrying out detailed geological, geochemical and geophysical investigations in order to delineate and select target areas for deep exploration wells.

IAEA Cooperative

In 1993, the GSE initiated a technical cooperation program through the Ethiopian Science and Technology Commission (ESTC), with the International Atomic Energy Agency (IAEA). As part of this program, water samples from the entire Ethiopian Rift Valley and its escarpments are being analyzed at the isotope hydrology laboratory of the IAEA in Vienna, Austria. On going geothermal activities of the GSE include:

- Monitoring (geochemical and reservoir engineering) of the Aluto-Langano and Tendaho geothermal fields
- Detailed geological mapping, geochemical and geophysical studies of the Southern Afar area (e.g. Dofan and Fantale etc.)
- Collection of water samples for isotope, chemical and gas analysis from surface geothermal manifestations around Main Ethiopian Rift, Southern Afar and Northern Afar regions

3.6. Geothermal Drilling and Testing Equipment

The GSE owns two drilling rigs: (1) a Kremco-K600 (purchased with funding from the European Economic Commission) that has a drilling capacity of 2.5 km and a 250,000 lb hook-load capacity; and (2) a Massarenti (bought with funding from the government of Italy) that is located at Dubti (near Tendaho in Afar Region) and has a 300,000 lb hook-load capacity with the capability of drilling two to five km (with different diameter of pipes). The Survey also has a Central Geological Laboratory where surface and core samples as well as geothermal fluids can be analyzed.

IV. POLICIES THAT RELATE TO PRIVATE SECTOR INVESTMENT

4.1. Foreign Investment

The government of Ethiopia is committed to ensuring that private capital plays a significant role in the economy. In recent years, Ethiopia has eliminated tax, credit and foreign trade laws that discriminate against the private sector, simplified administrative procedures and established consistent rules regulating business activities.

The Ethiopian Investment Authority is the country's one-stop-shop for private investors. The Authority receives investment applications, approves and issues investment permits, provides registration services to newly incorporated business organizations, provides work permits to foreign employees, issues trade and operating licenses to approved foreign investors and facilitates access to land by foreign investors in accordance with federal and regional laws.

4.2. Private Participation in Energy Exploration and Production

Geothermal Resource Exploration and Development

A developer interested in geothermal exploration is required to be licensed by the Ministry of Mines. The Mining Proclamation 52/1993, Mining Income Tax Proclamation 53/1993, Mining Operations Regulation 182/1994, Proclamation 22/1996, Proclamation 23/1996 and the Investment Proclamation of June 1996 form the legal basis for mining and geothermal exploration in Ethiopia.

A project developer can obtain separate licenses for prospecting (one year), exploration (three to five years) and development (duration as projected in the feasibility study). Land is available under leasing arrangements (common for similar investment purposes worldwide). Moderate license and lease fees apply. Terms vary to favor investment in less advantaged areas, such as the Afar Region (where many of the geothermal prospects are located).

Private Sector Power Generation

Power purchase agreements are negotiated with the state utility company, EEPCO. Legislation governing investment in electric power generation includes benefits from the incentives allowed under general investment legislation. It is, however, administered by the Ethiopian Electricity Agency and subject to the terms of

Electricity Proclamation No. 86/1997 and Regulation No. 49/1999. Current legislation seeks to promote domestic and foreign private investment in power generation for sale to the grid and for distribution and sale through mini-grids in areas where the national grid does not reach.

For larger scale power generation, licenses may be acquired with validity extending over project life or 40 years for generation plants, 50 years for transmission, distribution and power sales licenses and ten years for power export or import licenses.

Incentives for private power generation include:

- Exemption from profit tax for a minimum period of three years, and up to five years depending on the type and location of the investment, with provisions for additional exemptions of one to two years for investments in existing enterprises
- Carrying forward of losses incurred during the tax-exempt period for three to five years after expiry
- Duty-free imports of spare parts of up to 15 percent of the value of capital goods imported for investment purposes

The employment of foreign nationals is allowed if a foreign investor is unable to find qualified staff locally.

The Investment Code of 1996 provides investment guarantees and ensures the protection of private property. Ethiopia is a member of the Multilateral Investment Guarantee Agency (MIGA), the World Bank affiliate that issues guarantees against non-commercial risks that may be faced by enterprises in member countries.

4.3. Environmental and Emission Institutions and Regulations

All projects must have authorization from the Environmental Protection Authority or the relevant regional environmental agency and provide an Environmental Impact Study (EIS). The EIS requires that developers consult with the communities likely to be affected by a project. The approval of an EIS or the granting of authorization does not exonerate the developer/investor from liability for environmental damages. Investors are required to ensure that an EIS meets all the requirements specified under the directives issued by the Ethiopian Environmental Protection Authority. An EIS for a geothermal project must include:

- The nature of the project, including the technology and processes to be used
- The content and amount of liquid, gas or solid emission that will be released during implementation and operation
- Source and amount of energy required for operation
- Information on likely trans-regional impacts
- Characteristics and duration of all the estimated direct or indirect, positive or negative impacts
- Measures proposed to eliminate, minimize or mitigate negative impacts
- Plans for reducing environmental management problems
- Contingency plan in case of accident
- Procedures for self-auditing and monitoring during implementation and operation

4.4. Host Country Personnel with Geothermal Experience

The GSE executes its scientific and technical activities through a geothermal team, which is under the Hydrogeology, Engineering Geology and Geothermal Department. The GSE also has a drilling department that carries out core, water well and geothermal deep well drilling and associated geotechnical works. The staff of the geothermal team includes geologists, geochemists, geophysicists and reservoir engineers with geothermal-specific training and hands-on experience at Langano and Tendaho.

The Geothermal Group at the Geological Survey of Ethiopia comprises the following professional staff:

Name	Designation	Specific area of expertise
Meseret Teklemariam, Dr.	Senior Geologist/Geochemist	Geochemistry, alteration mineralogy
Birhanu Gizaw, Dr.	Senior Geochemist	Fluid geochemistry

Name	Designation	Specific area of expertise
Kibret Beyene	Senior Geochemist	Fluid geochemistry
Asfaw Teklu	Senior Geochemist	Fluid geochemistry
Salahadin Ali	Senior Geochemist	Fluid geochemistry
Tafesse Gizaw	Senior Geochemist	Fluid geochemistry
Tadewos Chernet, Dr.	Senior Geologist	Volcanology, mapping, well site geology
Solomon Kebede	Senior Geologist	Volcanology, mapping, well site geology
Tadesse Mamo	Senior Geologist	Volcanology, mapping, well site geology
Endalkachew Getaneh	Geologist	Volcanology, mapping
Yiheyis Kebede	Senior Geophysicist	Geothermal exploration
Yohannes Demissie	Senior Geophysicist	Geothermal exploration
Yiheyis Amdebirhan	Senior Geothermal Engineer	Reservoir, steam field engineering, testing
Akalwold Wahid	Physicist	Reservoir Engineering
Yohannes Lema	Physicist	Reservoir Engineering

In addition to the above GSE staff, a number of senior management professionals, geologists, drilling engineers, drillers and drilling mechanics operate in related professional fields in the private sector. Key private sector-based professionals include:

Name	Designation	Areas of Expertise
Getahun Demissie	Geologist	Exploration management, policy/ legislation/ negotiation
Molla Belaineh	Geologist	Exploration management
Teshome Abera	Drilling Engineer	Drilling management
Negussie Mekuria	Geochemist	Exploration geochemistry
Abebe Ayele	Geophysicist	Exploration geophysics

Foreign mining companies that paid on the order of US$1000 monthly salary for higher level professional employees and were competitive. Drivers with knowledge of English were paid approximately US$150 per month. Other employee salaries are in between these amounts except for top management staff who were paid higher wages. Ethiopians currently living overseas can also be attracted.

V. CONTACT INFORMATION

1. Local Power Company

Mr. Mihret Debebe
General Manager,
Ethiopian Electric Power Corporation
Tel: 251-1-56-0041
Email: eepco@telecom.net.et

Mr. Solomon Taddesse,
Ethiopian Electric Power Corporation,
Power Systems Department,
ICS Generation Division,
Tel: 251-1-15-2710

Mr. Getachew Betemariam,
Head, EEPCO Aluto Langano Geothermal Project,
Mexico Square, Room 14/15.
Tel: 251-1-15-3659, res. 71-7240

2. Ethiopian Electric Agency

Mr. Getahun Kifle,
General Manager,
P.O. Box 2554 Addis Ababa
Tel.: 251-1-507733/35/57
Fax: 251-1-507734
Email: electric_agency@telecom.net.et

3. Geothermal Resource Development Licensing

Ministry of Mines
HE Ambassador Mohammed Dirir, Minister
P.O. Box 486, Addis Ababa, Ethiopia.
Tel. 251-1-46-33-57
Fax: 251-1-46-33-64

HE Mrs. Sinknesh Ejibu, Minister of State
P.O.Box 486, Addis Ababa, Ethiopia.
Tel: 251-1-61 51 39, res: 65 04 56
Mobile: 09-20-32-87
Fax: 251-1-61 51 30
Email: Sink.mme@Telecom.net.et

Officer directly responsible for licensing:
Mr. Getachew Tesfaye,
Head, Mining Operations Department,
Tel. 251-1-61-4573

4. Ministry of Infrastructure Development

Dr. Kasu Yelala, Minister

5. Geological Survey of Ethiopia

Geological Survey of Ethiopia, Makanissa Campus
P.O. Box 40069, Addis Ababa.
Tel: 251-1-20 28 51, 20 28 58, res. 61 18 50
Email: geology-institute@telecom.net.et

Dr. Meseret Teklemariam, Geologist/Geochemist
Mr. Yiheyis Amdebirhan, Reservoir Engineer
Dr. Tadewos Chernet, Geologist

6. Private Ethiopian Consultant

Geothermal exploration management
Policy/legislation/ licensing/government relations:

Mr. Getahun Demissie,
General Manager, GeoMET Plc,
P.O. Box 578/1110, Addis Ababa.
Tel: 251-1-62 05 11, 62 04 11, 61 50 59, res. 18 92 04
Email: geomet@telecom.net.et

7. Ethiopian Investment Authority

Ethiopian Investment Authority
P.O. Box: 2313 Addis Ababa,
Ethiopia
Tel: 251-1 510033
Fax: 251-1 514396
Email: ethiopian.invest@telecom.net.et

8. US Embassy

Ms. Aurelia E. Brazeal
US Ambassador
US Embassy
P.O. Box 1014
Addis Ababa, Ethiopia
Tel: 251-1-550 666
Fax: 251-1-550 342

Mr. Dan Balzer
Regional Environmental Hub Officer
US Embassy
Addis Ababa
Tel: 251-1-55-06-66, ext. 283.
Email: balzerdk@state.gov

Mr. Moges Worku
Assistant to the Regional Environment Officer
US Embassy
Addis Ababa
Tel: 251-1-55-06-66, ext. 283
Email: workum@state.gov

VI. DETAILED REPORTS AND MAPS OF GEOTHERMAL AREA(S)

Reports exist for the general reconnaissance that was carried out during the early 1970's and more detailed geological, geochemical, geophysical and drilling reports for the areas that had been subjected to detailed investigation: Langano, Tendaho, Corbetti, Abaya and Tulu Moye. A report of the semi-regional survey of the Central and Southern Afar is also available. Private sector generated studies and reports are also held by private proprietors.

The country has full coverage by 1: 2,000,000, 1:500,000 and 1:250,000 scale topographic maps of good quality. Several of the larger scale sheets are periodically updated. Much of the country has also been covered by a continuing program of 1:50,000 scale topographic mapping. All but a few geothermal prospect areas located south of 12^{o} north latitude have good quality 1:50,000 topographic maps. The country is also covered by a series of

1:50,000 nominal scale aerial photographs of very good quality covering 130 km^2 per frame. Topographic maps and aerial photographs are sold at the Ethiopian Mapping Authority.

Geologic map coverage at 1:500,000 scale maps is available for all of the rift system. Some areas are covered by the standard 1:250,000 scale regional mapping program of the Geological Survey of Ethiopia. Area specific geological maps at various scales exist for many areas, in the forms of unpublished working maps. Published maps are available for sale at the Geological Survey of Ethiopia. Copies of unpublished maps may be acquired by prospective licensees upon application.

There are good human, institutional and infrastructural capacities for photogeologic interpretation and geological map production within the country for use in quickly generating maps for any area.

Prices of topographic maps are generally less than US$2 per sheet. Geologic maps cost US$8-10 per sheet. Aerial photographs cost about US$1.50 per frame. When ordering for stereoscopic viewing, calculate at 20 to 25 km^2 effective coverage per frame. Photogeologic interpretation is contracted at between US$1.50-2.50 per km^2 depending on whether field verification is involved and if only non-publication quality blue print (working) maps are required.

VII. REFERENCES

Aquater, (1982). "Technico-Economic Study for Tendaho Geothermal Resources Development - Economic Report," Comm. 318700, IDRO a/1123, Ethiopian Institute of Geological Surveys, Geothermal Exploration Project, 1982.

Aquater, (1996). "Tendaho geothermal project, final report." MME, EIGS- Government of Italy, Ministry of Foreign Affairs, San Lorenzo in Campo**.**

Ayele, A., Teklemariam, M., Cherinet, T., and Amdeberhan, Y. (1999). "Promotion Document." Geothermal Team, September 1999.

Ayele, A., Teklemariam, M. and Kebede, S. (2002). "Geothermal Resources Exploration in the Abaya and Tulu Moye- Gedemsa Geothermal Prospects, Main Ethiopian rift." Compiled Report.

B. Gizaw, (1993). "Aluto-Langano Geothermal Field, Ethiopian Rift Valley: Physical Characteristics and the Effects of Gas on Well Performance", *Geothermics*, Vol. 22, No. 2, pp. 101-116.

Cherinet, T. and Gebreegziabhier, Z., (1983). "Geothermal geology of the Dofan and Fantale area (northern Ethiopian rift.)" Geothermal Exploration Project, EIGS.

Di Paola, M., (1976). "Geological Map of the Tullu Moye active volcanic area 1: 75, 0000 (Arussi: Ethiopian Rift Valley)." CNR, Pisa.

Di Paola, G.M., *The Role of the United Nations in the Field of Geothermal Resources Exploration in Developing Countries*, United Nations Department of Technical Cooperation for Development, New York.

Demissie, Getahun, (1998). "Notes on Some Geothermal Prospects in Ethiopia", personal communication, January 16, 1998.

Electroconsult (ELC), (1986). *Geothermal Exploration Project- Ethiopian Lakes District, Exploitation of Langano-Aluto Geothermal Resources, feasibility report*. ELC, Milano, Italy. pp 150.

Electroconsult (ELC), Geotermica Italiana, (1987). *Geothermal Reconnaissance Study of Selected Sites of the Ethiopian Rift system*. EIGS Lib. No. 840-051-04. I.

Endeshaw, Abebaw, (1988). "Current Status of Geothermal Exploration in Ethiopia," *Geothermics,* vol. 17, No. 2/3, pp. 477-488.

Ethiopian Institute of Geological Surveys, (1987). *Geothermal Reconnaissance Study of Selected Sites of the Ethiopian Rift System - Final Report*. Addis Ababa, Ethiopia. ELC, Milan, Italy.

Gebregzabher, Zewde, (1986). "Hydrothermal Alteration Minerals in Aluto Langano Geothermal Fields, Ethiopia." *Geothermics*, vol. 15, No. 5/6, pp. 735-740.

Gebregzabher, Zewde, (1994). "Geothermal Country Report of Ethiopia," *Geothermal Research Report,* Kyusha University, No. 3, pp. 19-23, October 1994.

Hutter. G.W., (1995). *The Status of World Geothermal Production (1990-1994)*. Proceedings of WGC, 1995, vol. 1, pp 3-14.

Kebede, S., (1986). *Results of temperature gradient survey and geophysical review of Corbetti geothermal prospect. ,* EIGS, 1986.

Ministry of Mines and Energy, (1986). *Geothermal Exploration Project Ethiopian Lakes District Rift - Exploitation of Langano-Aluto Geothermal Resources Feasibility Report*, Addis Ababa, Ethiopia; ELC, Milan, Italy.

National Meteorological Services Agency, (1996). *Ethio-US Country Study Project-Technical Report*, Addis Ababa, August 1996.

Meseret Teklemariam and Kibret Beyene. *Geochemical Monitoring of The Aluto-Langano Geothermal Field, Ethiopia*, Geological Survey of Ethiopia, Addis Ababa, Ethiopia.

Mamo, T. Getaneh. E. and Berhanu, D., (2002). The *Geology and Surface Alteration Mapping of Fantale Area (1: 50,0000).* Geothermal Team, GSE.

Mckenzie, D.P., Davis, D. and Molnar, P., (1970). "Plate tectonics of the Red Sea and East Africa." *Nature*, vol. 226, pp 243-248.

Mohr, P. A., (1962). "The Ethiopian Rift System." *Bulletin of Geophysics. Obs.,* Addis Ababa, pp. 33-62

Mohr, P. A., (1971). *The Geology of Ethiopia*. Haile Sellassie I University Press. Addis Ababa.

Teklemariam, M., (1996). *Water Rock interaction Processes in the Aluto-Langano Geothermal Field, Ethiopia*. Department of Earth Sciences, University of Pisa, Italy.

Teklemariam, M. Amdeberhan, Y. Beyene, K. and Gebreegziabheir, Z., (2000). "Geothermal Exploration and Development in Ethiopia." Proceedings in the World Geothermal Congress, WGC 2000, Kyushu, Tohoku, Japan.

UNDP, (1973). *Geology, geochemistry and hydrology of hot springs of the East African Rift System within Ethiopia.* Rec. Rep. DDSF/ON/116, United Nation, New York.

ERITREA COUNTRY GEOTHERMAL REPORT

Figure 1: Map of Eritrea

I. COUNTRY OVERVIEW

1.1. Geography, History and Climate

Eritrea is located in the Horn of Africa and is bordered by the Red Sea, Sudan, Ethiopia and Djibouti. The country has a high central plateau that varies from 1,800 to 3,000 m above sea level. The remainder of the country is comprised of coastal plain, western lowlands and some 300 islands. The climate is temperate in the mountains and hot in the lowlands. Asmara, the capital, is about 2,300 m above sea level. Maximum temperature is 26^{o} C (80^{o} F). The weather is usually sunny and dry, with a short rainy season occurring during February to April and a longer rainy season beginning in late June and ending in mid September.

Eritrea did not achieve full independence from Ethiopia until 1993. In 1890, Eritrea's boundaries were set by the Italians, who ruled the country for over 50 years until 1941 when they were defeated by the British during World War II. Britain subsequently administered Eritrea until 1952 when the United Nations federated Eritrea to Ethiopia with limited autonomy. In 1961, an armed struggle for independence began and ended 30 years later in May 1991. The Eritrean People's Liberation Front (EPLF) had assumed control of Asmara and established the Provisional Government of Eritrea (PGE). Eritrea was officially declared independent from Ethiopia on May 24, 1993. Although Eritrea and Ethiopia separated amicably, several border issues remained unresolved, and in 1998 fighting broke out between the two countries over the disputed Badme region. In 2000, both sides accepted an Organization of African Unity (OAU) peace proposal and signed a formal treaty ending the war.

1.2. Political Structure and Social Issues

The country possesses a high degree of social and political stability. The government is comprised of separate legislative, executive and judicial branches. The judicial body operates independently of both the legislative and executive branches and has a court system at the village, district, regional and national levels. The National

Assembly outlines the internal and external policies of the government, regulates their implementation and approves the budget. The assembly has 150 members. The president nominates officials to head the various ministries, commissions and offices. The cabinet's comprised of 16 members and is chaired by the president. Eritrea's 3.5 million citizens belong to nine major ethnic groups and are part of three distinct linguistic families: the Cushitic (or Hamitic), the Semitic and the Nilotic languages.

1.3. Economy

The Eritrean economy has been severely hampered in recent years by the border war with Ethiopia. The country's economy is based primarily on agriculture with the main export crops consisting of coffee, cotton, fruit, hides and meat. The government also exports fish from the Red Sea to markets in Europe and elsewhere. The port at Massawa was recently rehabilitated.

While agriculture employs nearly 80 percent of the population, it only contributes 22 percent to the nation's GDP. By contrast, worker remittances from abroad accounts for an estimated 60 percent of the GDP. Farmers remain largely dependent on rain-fed agriculture and growth in this and other sectors is hampered by lack of a dependable water supply. A number of mining companies have licenses to prospect and explore in the country, including Sub Sahara Corporation, Sanu Resources, Inc., Nevsun Resources Ltd. and Eritrean Minerals Co., but no commercial mineral deposits have been found to date.

Major American investors in Eritrea include Mobil Oil, Coca Cola (Red Sea Bottlers) and Sub Sahara Corporation in collaboration with the Phelps Dodge Exploration Corporation. The South Korean Company Keangnam Construction Company (a subsidiary of Daewoo) and the China State Construction and Engineering Corporation (CSCEC) have significant representation in Eritrea and are heavily involved in housing, office and hospital construction in Asmara and Massawa. Keangnam built the Tokker Dam outside of Asmara (US$29 million) and the Hirgigo Power Plant in the lowlands (US$110 million) and is planning to build its African headquarters in the suburbs of Asmara. CSCEC is also building a large pharmaceutical plant in Keren.

With the cessation of hostilities with Ethiopia, GDP growth is expected to return to approximately five percent annually. Donor development funding, nevertheless, is seen as crucial to the improvement of the country's economy.

II. COUNTRY ENERGY CONTEXT

2.1. Electricity Sector

Prior to 1975, Eritrea's electricity supply was owned and operated by the private sector. However, in 1975, the utility company (now the Eritrea Electric Authority (EEA)) was nationalized. EEA, which operates under the Ministry of Energy and Mines (MEM) is responsible for generation, transmission and distribution of electricity.

To date, no private power generation or transmission line agreements have been established in Eritrea. To extend the supply of electricity to more locations and customers throughout the country, the government is actively seeking private sector participation in its electricity sector. Private companies are allowed to generate and sell power to EEA.

2.2. Current and Projected Electricity Demand

Approximately 21 percent of Eritrea's population has access to electricity, but that drops to only two percent for rural populations. Per capita electricity consumption has improved from as low as 16 kWh in 1991 to 59 kWh in 2001 (see Table 1). In 2001, the total energy consumed in the country was estimated at 683,000 tons of oil equivalent, 66.7 percent of which was consumed by the household sector, 16.4 percent by the public and commercial sectors, 14.1 percent by transport and 2.7 percent by industry.

In 2001, EEA had approximately 50 MW of diesel-fired generating capacity excluding a new 84 MW power plant in Hirgigo, just outside of Massawa. This will be commissioned soon and will increase the country's total generating capacity to approximately 130 MW. The government paid US$158 million for the Hirgigo diesel power station using soft loans (one to 1.5 percent interest over 30 years). The Hirgigo Power and Transmission Expansion Project will increase the transmission capacity to 80 km of 132 kV line connecting Hirgigo and Asmara and over 200 km of 66 kV lines integrating Asmara with market centers at Keren, Mendefera and Dekemhare as well as Massawa with Gindae. The length of the medium voltage distribution network (15 and 5.5 kV), which was around 860 km in 1998, grew to 1400 km in 2001, including recent rural electrification projects.

Table 1: Profile of Electricity Services from the EEA Systems, 1992-2001.

Year	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**
Generation (GWh)	110.3	119.9	130.2	144.7	161	180	186	205	201.4	224.4
Consumption (GWh)	93	93.4	105.8	123.2	127.6	143.7	145.2	158.5	159.7	185.7
Loss (%)	15.7	22.1	18.7	14.9	20.7	20.2	21,1	22.7	20.7	17.3
Customers (000)	69.5	68.9	74.4	78.0	85.3	91.1	94.4	95.7	96.2	102.4
Firm cap. (MW)	30	40.8	39.1	55.7	56.8	54.4	54.2	53.8	49.8	134
Per capita (kWh)	36	35	38.4	43.5	43.7	48	46.8	48	47.2	59
Pop. (mil)	2.59	2.67	2.75	2.83	2.92	3.01	3.1	3.19	3.29	3.38

High demand for geothermal-based energy in the central-eastern part of the country is anticipated for:

- Better refrigeration, illumination, air quality, access to information and telecommunications as well as business development.
- The establishment of manufacturing plants (cement, fish, refrigeration, water distillation and reverse osmosis desalination).
- Tourism (the gulf of Zula has a high potential for tourism including historical remains, animal parks, diving and fishing, hot springs and fumaroles.
- Coastal development in line with the newly constructed Massawa-Assab road.

2.3. Electricity Rates

In order to encourage energy efficiency and private sector energy development, the Eritrean government charges users the real cost of energy. Energy subsidies are generally avoided unless they reflect real economic savings from the use of a specific resource. Present electricity rates are ten US cents per kWh for industrial customers and 14 US cents per kWh for residential and commercial customers. The cost of small scale diesel generation in the rural areas is in the 20 to 30 US cent per kWh range. There are a number of mini-grids in the rural areas that use diesel power and provide electricity for a few hours each day. EEA income from electricity sales alone was US$21.3 million in 2001, which translates to and average of 11.5 US cents per kWh.

2.4. Oil Exploration

Hydrocarbon exploration, primarily offshore in the Red Sea, began in the 1960's when Eritrea was still federated with Ethiopia – with mixed results. In 1995, Eritrea signed a production sharing contract (PSC) with US-based Anadarko Petroleum for offshore drilling rights, but Anadarko's three exploration wells, the Zula and Edd Blocks, came up dry. The company and its partners ceased activities and relinquished their exploration rights. In May 2001, US-based CMS Energy signed a PSC with the Government of Eritrea. The contract granted CMS Energy exploration, development and production rights on the nearly 14,000 km^2 (onshore and offshore) Difnin Block in northern Eritrea. However, in late 2002, CMS transferred its rights and obligations in Eritrea to Perenco, a French-based oil company.

Many areas of the Eritrean Red Sea basin remain open for licensing under production sharing contracts. The Ministry of Energy recently announced an invitation to all interested international oil companies to apply for PSCs on the remaining acreage in the country. Recently, the government reduced the income tax rates from 50 percent to 35 percent to provide an incentive for petroleum exploration activities.

2.5. Rural Electrification

The electrification of the densely populated Zobas in highland Eritrea is being done through grid extension. With capital assistance from SIDA, the MEMWA and EEA have embarked on extending the grid to many of the villages around large cities, major roads, transmission and distribution lines.

The following two tables reflect the recent achievements and immediate plans for the future.

Table 2: Rural Electrification Completed, 1999-2001

Project area	Number of villages/towns	Project cost (US$)
Aditekelezan	11 Villages, 1 Town	297,189
Dibarwa	10 Villages, 1 Town	403,131
Elabered	2 Villages, 1 Town	142,737
Hagaz	1 Village, 1 Town	193,043
Teseney	3 Villages	413,900
TOTAL	**27 Villages, 4 Towns**	**1,450,000**

Based on the above, over 14,000 households have benefited from the recently completed electrification program. An additional 46,200 households are expected to benefit from this electrification program from 2002 to 2004. (See Table 3).

Table 3: Planned Electrification of Rural Villages and Towns, 2002-2004

Project Area	Number of Villages/towns	Project cost (US$)	Implementation Status
Himbrti	17 Villages	319,029	In progress
Mekerka	12 Villages	484,175	In progress
Mendfera	13 Villages	399,903	In progress
Keren	14 Villages	2,256,923	Fund soliciting in progress
Barentu	7 Villages	2,381,748	"
Dekemhare	40 Villages	2,668,252	"
Adikeyih	26 Villages	1,398,932	"
Nakfa	1 Town	324,660	"
Afabet	1 Town	324,660	"
Omehajer	1 Town	242,718	"
Tsorona	1 Town	242,718	"
Tio	1 Town	324,660	"
TOTAL	**129 Villages, 5 Towns**	**11,367,378**	"

Source: Ministry of Energy and Mines, Eritrea Electric Authority 2002-2004 budget (EEA,2001).

The policy being implemented by the MEMWA for rural electrification includes the following: Medium voltage distribution from the nearest source to the center of a village is the responsibility of the government (and its development partners). Reticulation within the village, including a 15 kV/400V transformer, is the responsibility of the village communities. EEA owns the infrastructure and is generally responsible for repair and maintenance of the system. The private sector has not participated in the extending the grid to rural areas, but there are many off-grid gensets installed by the private sector in semi-urban and rural agricultural areas. Without outside support, rural electrification has proceeded slowly. The World Bank, however, has a US$25 million power distribution project it has proposed that includes a rural electrification component.

III. GEOTHERMAL RESOURCES AND DEVELOPMENT

3.1. The Alid Volcanic Center

In 1973, a United Nations Development Programme (UNDP) study identified a potentially significant exploitable geothermal resource in Eritrea. In order to help Eritrea decrease its dependence on imported oil, the US Agency for International Development (USAID) in 1995 financed a follow-up study by the USGS on the possible use of geothermal resources for power generation in Eritrea, building upon previous work by the late professor G. Marinelli and the staff of the MEMWR.

To plan the study, a USGS representative visited Eritrea in June 1995 to observe the extent of surface expressions of hydrothermal activity in the region, assess the logistical problems that would be encountered in carrying out field work and meet with members of MEMWR to formulate a strategy for carrying out the investigations. The USGS agreed that the project would focus on high enthalpy geothermal resources for the production of electricity, and that the best target would be to carry out detailed geologic and geochemical investigations at the Alid volcanic center. The field work was carried out during January and February 1996 by a five-person USGS team with MEMWR counterparts.

3.2. Alid Geological Conditions

The Alid volcanic area is located about 120 km south of Massawa. Alid has been identified as a potential high enthalpy geothermal resource for some time due to evidence of geologically young rhyolitic volcanism within the context of spreading-related basaltic volcanism. It is also the site of many fumaroles (UNDP, 1973; Beyth, 1994).

Alid rises about 700 m above the floor of the Danakil Depression, a crustal spreading center that traverses the eastern lowlands of Eritrea. The mountain is a structural dome that formed as a result of local intrusion(s) of silicic magma into the upper crust. The sediments are fine-grained deposits typical of a shallow inter-tidal environment. Some contain marine fossils. The lava flows include basalt, andesite and rhyolite. Some basalt is pillowed, indicative of emplacement underwater, but most of the lavas are emplaced in a subaerial environment.

Basalt lava from within the sedimentary sequence of Alid contains considerable non-radiogenic argon, which results in a very poorly constrained age in the probable range of 200,000 to 300,000 years old. The stratigraphically oldest hyalite yields an age of about 212,000 years while the stratigraphically youngest hyalite lava is 24,000 years.

At least 11 geothermal areas have been identified on Alid. Fumaroles and thermal pools are found on the northern half of Alid suggesting that a hydrothermal system underlies most of the volcanic center. An area of 10 km^2 has been identified as having a high heat flow. Gas geothermometry has indicated most temperatures are between 190° C and 350° C with a median temperature of approximately 270° C.

The USGS study also collected groundwater samples from the surrounding lowlands and adjacent highlands in Alid to determine regional stable isotope and chemical variations that might provide clues to sources of recharge for the Alid hydrothermal system.

3.3. USGS Findings

Results of the USGS studies strongly suggested the presence of a hot upper crustal magmatic or plutonic body beneath the Alid Mountain. The geologic structure and tectonic environment of Alid were considered highly favorable for producing and maintaining substantial fracture permeability beneath the mountain that may extend north and south from the mountainous base. USGS determined that the overall temperature and permeability conditions of the area were sufficiently favorable for the existence of an electrical grade geothermal resource and recommended exploring drilling to depths of 1.5 to 2 km. To select the most appropriate drilling sites and targets, the USGS team first recommended that a number of tasks be undertaken, including:

- Obtaining new aerial photographs of Alid and surroundings at a scale of about 1:25,000.
- Preparing a new topographic map of the area at a scale of 1:25,000 with a contour interval of 5 m in relatively flat terrain and 10 m on the steep flanks of Alid.
- Preparing a fracture pattern map, using the new aerial photographs as a primary source of information.
- Completing an electrical resistivity survey of Alid and surroundings within Alid graben.
- Drilling 10 to 15 wells to provide information on temperature gradients and depth to the water table. Nominal target depths in the range of 100 to 200 m were recommended using slim-hole diamond-core drilling technology.
- Completing a study of carbon dioxide and radon in soil gas to help locate zones of high permeability through which these gases seep from their subsurface hydrothermal sources.

The USGS/MEMWR study represents Eritrea's first attempt to evaluate and promote the use of a geothermal resource. The Alid report can be obtained through the USGS (jlwnstrn@usgs.gov) or MEM.

3.4. Proposed Alid Geothermal Exploration Project

Since the geothermal resource at Alid is not confirmed, further exploration and analysis (as indicated above) is required. These activities would be hosted by the MEM and require the participation of outside private sector geothermal exploration companies and international donor support. The following is an illustrative program and budget of what is needed.

The objectives of the Eritrea/Alid Geothermal Exploration Project include:

- Upgrading of geologic, geochemical and geophysical information for the assessment of the spatial extent of geothermal prospects in the Alid region using this information to establish a geothermal model and identifying high-probability borehole targets for drilling.
- Identifying and testing geothermal resources in one or more of the identified target areas through drilling at selected sites.
- Preparing of technical and financial/investment plans for the installation of an appropriately-sized geothermal power plant that will meet a portion of the increasing power demand in the country. Also, studying the feasibility of direct use of the same geothermal resources in industry and agriculture.
- Increasing the number of Eritreans within both the public and private sectors with experience in geothermal resource testing, evaluation, project design and financing. Public sector trainees would come from within MEM.

Phase One

The Eritrea geothermal exploration project will consist of two phases. The first phase will be to provide additional information on the likely spatial extent and structure of the reservoir as well as to select the sites of the first boreholes. The first phase will also include due diligence with regard to demand, legal and tax aspects of private power development. The evaluation of the geologic, geochemical and geophysical data and the feasibility study will proceed concurrently.

The first phase includes two components:

1) <u>Evaluation of geologic, geochemical and geophysical data</u>

- Evaluation of existing data.
- Field checking existing data, interpretation and planning for drilling.

2) <u>Feasibility study</u>

- Electrical demand in Eritrea that can be met by geothermal energy.
- Process heat (agricultural) demand in the Alid region.
- Legal, tax and other aspects related to private-power development.

Phase Two

The second phase will depend on the results of the first phase. If the first phase is successful, the second phase will consist of exploratory drilling, well testing and the preparation of a plan for the installation of a commercially-sized geothermal power plant that will help meet power demand in the country.

Expected Outputs

Expected outputs of the Geothermal Exploration Program include:

- A feasibility study including legal and tax constraints and other requirements for a private power agreement.
- A demand study, including electricity generation and process heat.
- An evaluation of geothermal resources in the Alid region of Eritrea based on geology, geochemistry and geophysics.
- An evaluation of geothermal resources in the Alid region based on drilling.
- A viable geothermal energy resource exploration and development capacity will be established within the Geological Survey of Eritrea.

Budget

In the first phase, only the Alid geothermal prospect will be considered. If the results of preliminary work indicate that more than one area warrants detailed analysis, the budget for first phase should be increased by approximately US$300,000 per prospect. The second phase budget assumes either four slimholes or two production-sized holes would be drilled in the Alid geothermal prospect.

The approximate costs and time requirements for the Eritrea Geothermal Exploration Program are:

- Phase One US$500,000 18 months
- Phase Two US$4,000,000 18 months

3.5. Additional Geothermal Prospects

Asmara-Massawa Highway Springs

Aside from Alid, geological, geochemical and hydrothermal studies done in the eastern lowland have documented the existence of other thermal springs along the Asmara-Massawa highway, near the Gulf of Zula and in the Henab area 170 km north of Massawa. The thermal springs along the Asmara-Massawa highway are on a section of the middle to lower levels of the western escarpment of the Red Sea graben. Surface temperature and chemical analyses have been carried out at the Ali Hasa, Dongolo Basso, Sabarguma and Ailet spring areas. The hydrothermal features at these areas are classified as warm and hot springs (defined based on their temperatures being lower or higher than 50° C). They issue near-neutral waters with low chemical contents. All of the springs are of low energy exhibiting quiet flow, no steam separation and no gas evolution.

Red Sea Coast

Similar analyses have been carried out at Gelti, Zula, Acfat and Ua-a thermal springs along the Red Sea coast south of Massawa. Gelti is located on the southern end of the Gulf of Zula. The Gelti group consists of a large number of thermal springs located on the sea coast and low pressure steam vents located within about 200 m of the shore.

Gulf of Zula

There are a number of less significant hydrothermal areas near the Gulf of Zula area outside the Gelti system. A large diameter dug well located in Arafali village is 10 m deep and produces water at a temperature of 36° C and a pH of 7.0. Another well that was dug in Zula town is 20 m deep and produces thermal water with a temperature of 36° C and a pH of 7.0.

Acfat Group

The Acfat group of thermal springs is located about 4 km north of Zula town and about 1.5 km from the sea. The main spring has a temperature of 43° C, a large discharge and a pH of 7.0. The springs occur on the edge of a swamp. Ua-a thermal spring is located about 20 km north-west of Foro village located to the north of Zula town. It occurs in an area covered by fluvial deposits. It has a large discharge, a temperature of 36° C and a pH of 7.5.

IV. POLICIES THAT RELATE TO PRIVATE SECTOR INVESTMENT

4.1. Foreign Investment

In recent years, Eritrea has updated its laws in an effort to attract foreign investment. In 1998, the National Bank of Eritrea adopted a free-floating exchange rate for the nation's currency, the Nakfa, which has remained stable due largely to Eritrea's low debt load (only seven percent of GDP). In 1994, Eritrea adopted a new Investment Proclamation that eliminated pre-existing joint venture prerequisites, opened most sectors of the economy to foreign investment (except for domestic retail and wholesale trade and product importation), reduced taxes on profits and minimized customs duties on selected import items, including imports of capital equipment. Although Eritrean law does not allow land to be bought or sold, investors and real estate developers may obtain rights to lease land for periods of up to 99 years.

Official approval for private projects is vested with the Eritrean Investment Center. The Office of International Cooperation within the Office of the President also must sign off on national development projects. The Investment Center is required to act upon investor certification applications within a ten-day period. Large-scale projects are usually reviewed and approved by the appropriate minister or the Office of the President. Successful Korean, Chinese and US companies have been able to make high-level contacts at the early stages of their projects. While projects are permitted to be wholly-owned by private foreign companies, they are examined to ensure that they include training of Eritrean staff to replace expatriate workers, and that those projects will not negatively impact the environment or local conditions.

Taxes on corporate profits range from 25 percent to 35 percent. Declared dividends are not taxed. Corporate profits set-aside for reinvestment are taxed at 20 percent. Losses incurred during the first two years of operation may be carried forward for three consecutive years. The Investment Proclamation also maintains that investments are protected from nationalization, confiscation, seizure or expropriation. Foreign investors are offered further protection as a result of the Government of Eritrea actively seeking appropriate bilateral and multilateral investment protections through the Multilateral Investment Guarantee Agency (MIGA) and the International Center for the Settlement of Investment Disputes (ICSID).

The government is actively looking for foreign investors to explore under utilized resources in energy, minerals, fisheries and tourism, as well as in rebuilding its infrastructure.

4.2. Private Power Development

Eritrea is emerging from the centrally planned economy mode of the Ethiopian Derg government. The government is committed to a market economy and privatization, and has made development and economic recovery its two top priorities. Significant investments, including the above-mentioned US$25 million World Bank project and an European Union-funded project for power sector upgrades in Masawa and Goun, are being arranged by the government to improve the national electric power supply system.

The potential for industrial development in Eritrea is excellent and the new 80 MW diesel plant at Hirgigo will be a short-term fix to the Country's energy needs. An all-weather road from Massawa to Assab is almost complete. The road to Alid, about 40 km from the main Massawa-Asab road, is flat and unpaved but easily passable. The distance from Alid to the existing electric grid is about 110 km. Adding geothermal power to the national grid would require the construction of a transmission line over this distance. The market for additional electric power is expected to expand rapidly, especially using resources that do not require the expenditure of hard currency.

To better enable the private sector to enter the market, the government is drafting an Electricity Proclamation that will establish an Electricity Regulatory Board and a system operator with whom independent power producers (IPPs) and the independent power distributors (IPDs) will interact.

IPPs will have the option to generate power from a variety of sources, including geothermal. Importation or exportation of electricity is allowed, subject to government approval. National companies and electric membership co-operatives are encouraged to participate in rural electrification by extending the national grid or through a self-contained system of generation and distribution. A geothermal project can be structured as a joint venture with the MEM, the EEA or another Eritrean entity.

4.3. Mining Law

Geothermal resources are governed under the Mining Law, specifically section III, Article 18(3) of Proclamation No.68/1995. All mineral resources in Eritrea are public property and the State is charged with the conservation and sustainable development of all natural resources for the benefit of the people. A license is required for any geothermal exploration. When a private company receives a license to explore a region for mineral resources, it automatically receives a license to develop the resource.

The Mining Law recognizes the risky nature of mining investments and allows write-offs of exploration expenditure incurred anywhere in the country, a reinvestment deduction (five percent of gross income), no dividend tax and nominal rate of import duty (0.5 percent) on all inputs necessary for mining operations. The incentives given to mining companies also apply to geothermal development companies.

4.4. Environmental and Emission Institutions and Regulations

Eritrean Mining Law chapter 11(30) legal notice No.19/1995 requires an environmental impact assessment that documents the factors considered by the applicant in the formulation of the geothermal exploration and development projects.

4.5. Government Support

If a private developer were to build a geothermal plant at Alid, the MEM would be the signatory of the private power agreement (PPA) on behalf of the Eritrean government, and the EEA would be responsible for installing the transmission line from Alid to the existing grid. The Eritrean government has indicated that it would prefer purely private sector-based development of its geothermal resources without the involvement of either bilateral or multilateral donor agencies. However, in view of the high up-front costs, help from such agencies might be required. The financing scheme could be either through build-own-operate (BOO) or build-own-transfer (BOT) arrangements. The government is ready to consider both options. If the Eritrean government were to issue a geothermal-based PPA it also indicates that it would also be willing to sign a guarantee of payment.

MEM has expressed its interest to USAID in promoting the development of geothermal energy and would also be willing to contact the World Bank, UNDP, African Development Bank and others. The World Bank representative in Eritrea indicated the Bank could become involved in one or more of the following ways:

Technical Assistance

Provision of technical assistance to the government in relation to identifying, understanding and addressing the legal and technical issues that will arise as they prepare to negotiate a geothermal-based private power agreement.

Soft Loans

Provision of a soft loan to the government to enable it to contract with a company to carry out the drilling of the exploratory boreholes. A World Bank soft loan includes a ten-year grace period, zero percent interest, repayable over 40 years and a 0.75 percent user fee on loan funds actually drawn down and used. The government could receive a World Bank soft loan and then contract with a private power developer to repay the loan on its behalf.

4.6. Host Country Personnel with Geothermal Experience

Eritreans realize they lack the human resources to fully develop their country and consider the training of host country nationals a high priority. Eritrea has an ample supply of artisans and semi-skilled craftsmen, although technical experts, highly skilled professionals and managers are in short supply. The government and international donor agencies are trying to remedy the situation with domestic and external training courses. As the government improves infrastructure and as foreign investment increases, skilled professionals of the Eritrean diaspora are likely to return home in greater numbers.

Eritrean law requires contractors to preference to the employment of Eritrean nationals to the fullest extent possible, provided such nationals have the qualifications and experience. If an Eritrean national cannot be found with qualifications and skills suitable to fill a position the licensee may employ a qualified foreign national (Mining Law, Article 29(1)). Eritrea adheres to International Labor Organization conventions regarding minimum working conditions and terms of employment. Trained reservoir engineers, geophysicists, geologists, mining engineers and mining surveyors are available.

It is likely that training for Eritrean nationals would be needed in the following fields:

- Borehole geology
- Chemistry of thermal fluids
- Geothermal utilization
- Drilling technology

V. CONTACT INFORMATION

1. Ministry of Energy

Ministry of Energy and Mines
H.E. Minister Tesfai Gebreselassie
P. O. Box 5285; Asmara, Eritrea
Tel. 291-1 11-68-72 or 12-79-44
Fax: 291-1 12-76-52

2. Department of Mines

Alem Kibreab
Director General,
Department of Mines
Ministry of Energy and Mines
P.O. Box 272,Asmara, Eritrea,
Tel. 291-1-202843/202844
Fax 291-1-124509
Email: akibreab@yahoo.com

3. Department of Energy

Samuel Baire
Director General,
Department of Energy
Ministry of Energy and Mines
P. O. Box 5285; Asmara, Eritrea
Tel.: 291-1 11-68-72 or 12-79-44
Fax: 291-1 12-76-52
Email: samuelbaire@yahoo.com

4. Geological Survey
Michael Abraha
Head of Regional Mapping
Geological Survey of Eritrea
Ministry of Energy and Mines
P.O. Box 272,Asmara, Eritrea
Tel. 291-1-202843/202844
Fax 291-1-124509
Email: m_abraha2002@yahoo.com

5. Local Power Company

Abraham Woldemichael
Manager
Eritrean Electric Authority
P.O. Box 911
Asmara, Eritrea
Tel. 291-1-122228
Fax. 291-1-121468
Email: eeahrg@eol.com.er

6. Macro-Policy and Economic Cooperation

Dr. Woldai Futur
Head of International Cooperation
Macro-Policy and Economic Cooperation
Office of the President
Government of the State of Eritrea

7. Eritrean Investment Center

Abdelahi Yassin
Director
P. O. Box 921,
Asmara, Eritrea
Tel.: 291-1-118822 or 126684 or 118124
Fax: 291-1-124293
Email: erinvest@eol.com.er

9. US Embassy

Ambassador Donald J. McConnell
Franklin D. Roosevelt Street,
P.O. Box 211, Asmara, Eritrea
Tel. 291-1-120004
Fax: 291-1-127584

VI. MAP OF COUNTRY GEOTHERMAL PROSPECTS

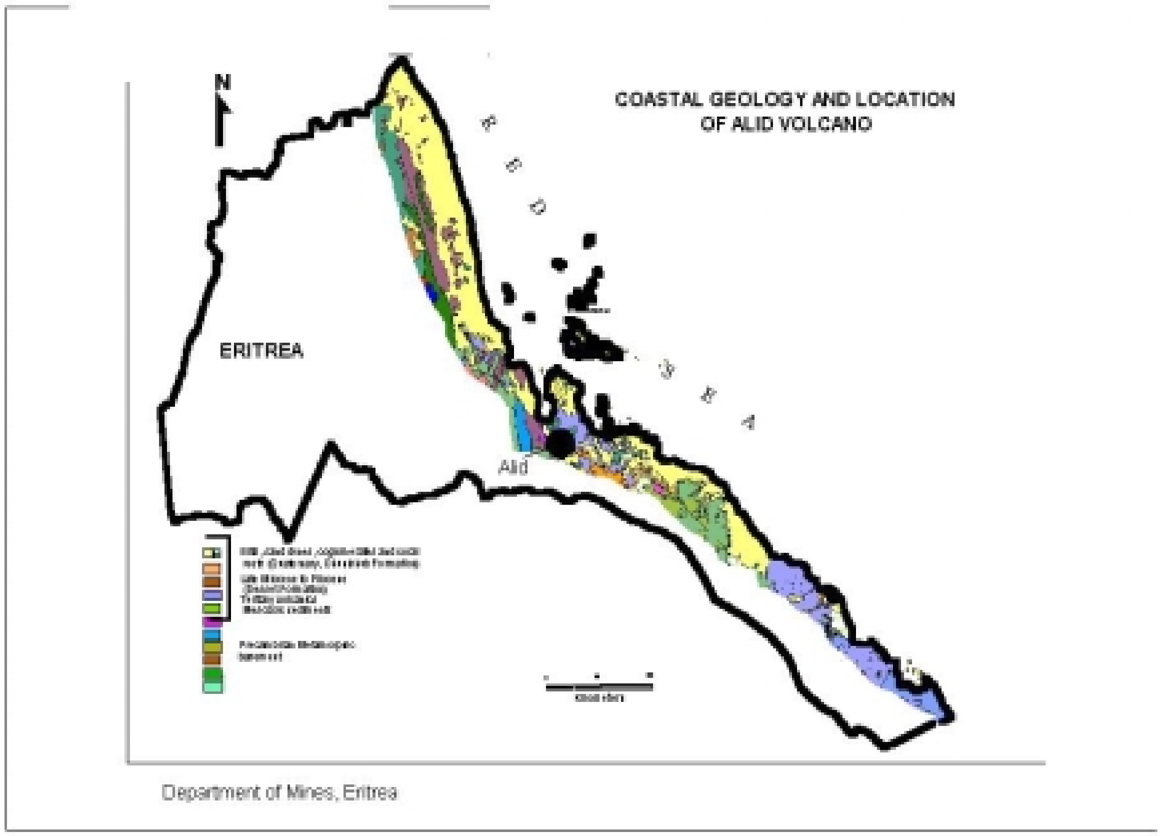


Figure 2: Coastal Geology and Location of Alid Volcano

VII. DETAILED REPORTS AND MAPS OF GEOTHERMAL AREA(S)

The following maps are available of geothermal area(s):

- topographic maps of 1:100,000 and 1:200 000 scale.
- aerial photographs of 1:20 000, 1:30,000 and 1:60,000 scale.
- geological map of Alid at 1:60 000 scale.

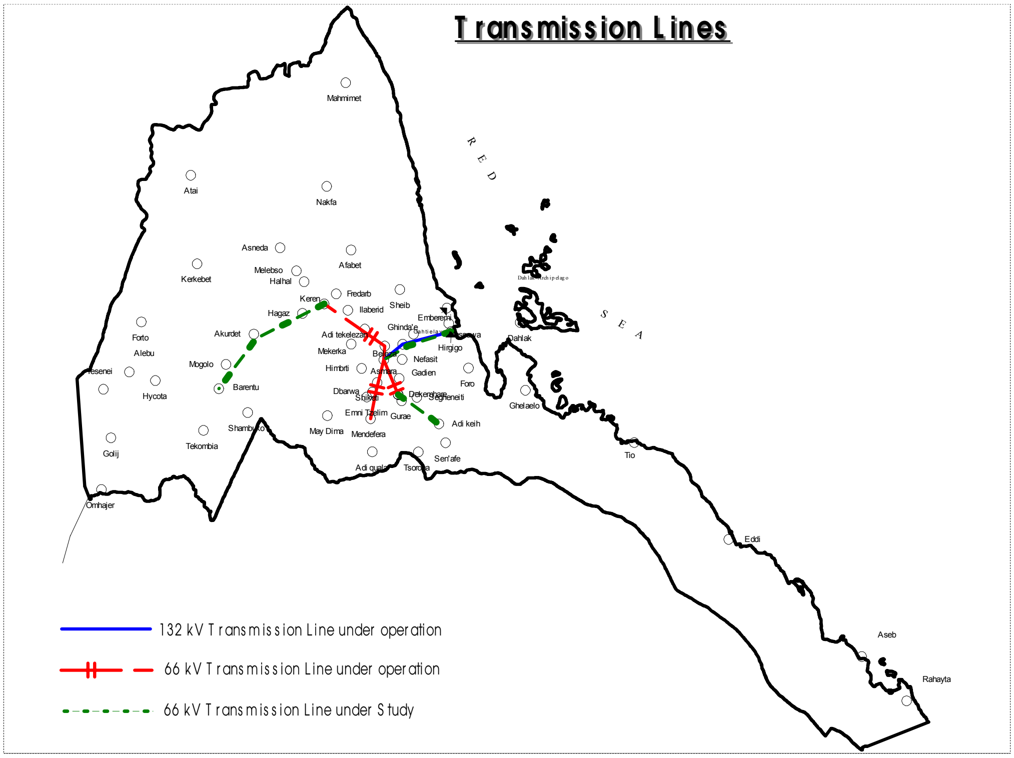


Figure 3: Transmission Lines

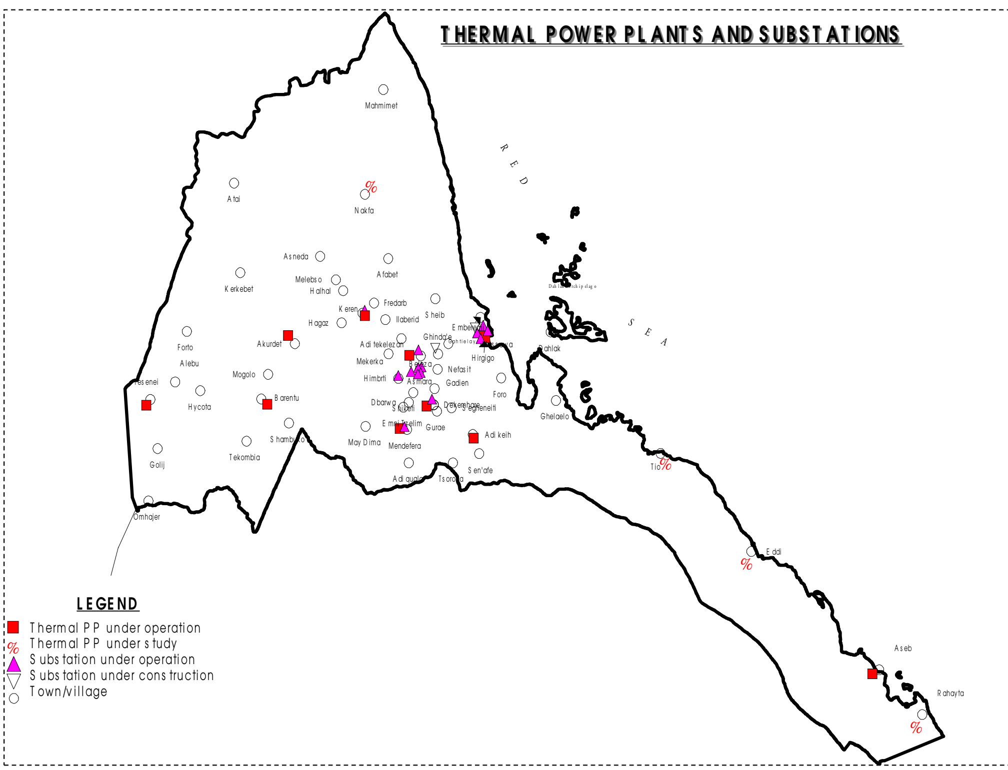


Figure 4: Thermal Power Plants and Substations

Table 4: Power Plant Capacity

Power Plants Capacity			
System	Power Plants	Installed Capacity kW	Firm Capacity kW
Interconnected	Hirgigo	88,000	88,000
	Gerar	12,700	3,000
	Gejjeret	2,800	2,400
	Beleza	33,900	27,000
	Mendefera	1,780	1,200
	Dekemhare	1,620	1,400
	Keren	2,280	2,000
Self Contained	Assab	9,700	5,600
	Adi Keih	1,390	900
	Agordet	655	600
	Barentu	850	580
	Tesseney	655	600

Table 5: Substations

Substations					
No	Name	Voltage Range kV		Transformer Capacity MVA	
		Under Operation	Under Construction	Under Operation	Under Construction
1	Hirgigo	132/66/15/10.5		114.0	-
2	Gerar	50/5.5	66/15	12.0	24.0
3	Forto Vittoro	50/15	66/15	1.5	12.0
4	Gurgusum	50/5.5	66/15	12.0	12.0
5	Cement Factory	50/5.5	-	2.0	-
6	Dogali	50/5.5	66/15	0.5	3.0
7	Ghinda	50/15	132/66/15	3.0	24.0
8	Asmara East	132/66/15	-	120.0	-
9	Asmara Center	66/15/5.5	-	12.5	-
10	Gjjeret	66/15/5.5	-	12.5	-
11	Denden	66/15/5.5	-	6.0	-
12	Beleza	66/15/5.5	-	41.0	-
13	Tsa-Ada Kristian	66/15	-	6.0	-
14	Mai - Nefhi	66/15	-	6.0	-
15	Keren	66/15	-	6.0	-
16	Mendefera	66/15	-	6.0	-
17	Dekemhare	66/15	-	6.0	-

VIII. REFERENCES

Wendell A. Duffield, Michael A. Clynne, and Thomas D. Bullin, et al. (1997). *Geothermal Potential of the Alid Volcanic Center, Danakil Depression, Eritrea.* USGS Poen-File Report 97-291, 62 pp.

UGANDA COUNTRY GEOTHERMAL REPORT

Figure 1: Map of Uganda

I. COUNTRY OVERVIEW

1.1. History, Population and Government Structure

Uganda has an area of approximately 241,000 km^2 and a population of about 24.6 million people with an annual growth rate of 2.5 percent. Uganda has borders with the Democratic Republic of the Congo (765 km), Kenya (933 km), Rwanda (169 km), Sudan (435 km) and Tanzania (396 km). Uganda achieved independence from the United Kingdom in 1962. During the 1990s, the government held non-party presidential and legislative elections. In 1995, the government restored its legal system back to an English-based common and customary laws that accepts compulsory International Court of Justice (ICJ) jurisdiction with reservations.

1.2. Economy

Agriculture accounts for over 50 percent of the country's GDP. Over 85 percent of the population is rural and relies on subsistence agriculture for livelihood. Nevertheless, an increasing proportion of the population is beginning to practice commercial agriculture for local consumption and export. The country's main agricultural products are: (a) cash crops – coffee, tea, sugarcane, tobacco, cotton, cocoa and palm oil; (b) food crops – maize, wheat, millet, sorghum, cassava, potatoes and rice; (c) oil seed crops – ground nuts, coconuts, castor oil, sunflower and simsim; (d) horticultural crops – pineapples, mangoes, bananas, papaw, passion fruits, avocados, vegetables and flowers; and (e) livestock products – dairy products, beef, pork, poultry, skins and hides and fish.

II. COUNTRY ENERGY CONTEXT

2.1. Electricity Sector

Until the passage of Uganda's Electricity Act in 1999, the Uganda Electricity Board had a complete monopoly over the generation, transmission and distribution of electrical power. Under the 1999 Act, a new independent Electricity Regulatory Authority was established to regulate the industry. The Authority reviewed a number of alternative models for restructuring the power sector and decided on a system with a single transmission entity (the Uganda Electricity Transmission Company) along with a number of separate generating and distribution companies. The Act still allows the Electricity Board to generate power from existing installations. However, all new generating capacity will be provided competitively by the private sector through a process organized by the Uganda Electricity Transmission Company. The process will be monitored by the Electricity Regulatory Authority.

As part of its plans to expand access to energy services, the Ugandan government policy is to promote competitive private sector participation in the development of conventional and renewable energy resources. The much-anticipated Bujagali hydro electric dam will be Uganda's first private power project. Another key government policy objective is to maximize the export potential of power to neighboring countries once internal demand is met.

2.2. Electricity Demand and Distribution

The country has a total installed generation capacity of 300 MW, the majority of which comes from the Owen Falls Dam at Jinja in southeastern Uganda and includes 80 MW that was recently added. Even with the recent increase, electricity demand continues to exceed capacity, requiring load shedding at least once a week.

The electricity grid extends across the southern part of the country covering Masaka, Kampala and Jinja to the west of Owen Falls Dam; Tororo to the east, where it connects with the Kenyan power grid; and to the northern line running up to Lira (see Fig. 3). The long distance distribution of electricity is through 132 kV and 66 kV power lines while the towns are served by 33 kV and 11 kV transmission lines.

Although 40 percent of the country's population lives in the area covered by the Uganda Electricity Board's power system, only six percent of Ugandans have access to electricity, five percent in urban areas and one percent in rural areas. In smaller remote urban centers, electricity is produced primarily using diesel or oil generators. Some small hydro is also in use. The remaining 94 percent of the population represents a potential market for increased electric power generation, transmission and distribution. Domestic power demand is estimated to be growing at two percent per month.

The Ugandan government is rehabilitating the existing power generation and distribution installations and exploring ways to meet the increase in energy demand from other indigenous energy sources. As part of this effort, the government is formulating a long-term integrated least-cost "Alternative Energy Resources Development Programme." While the development of the country's hydropower has been a top priority in recent years, geothermal energy is being looked at more closely and has considerable potential, particularly for five to ten MW mini-grid applications.

2.3. Hydropower

The country is endowed with considerable hydropower resources with the potential capacity on the Nile to be estimated in excess of 2,000 MW. There are currently five different independent hydropower projects proposed in Uganda with the Bujagali project being the most advanced.

Table 1: Proposed Independent Hydropower Projects

Project	Sponsors	Capacity (MW)	Earliest Commissioning Date
Bujagali	AES Nile Power	290	2005
Kalagala	Arabian International Construction	450	NA

Project	Sponsors	Capacity (MW)	Earliest Commissioning Date
Karuma Falls	NORPAK	100 stage 1 100 stage 2	2002 NA
Muzizi	CDC	Up to 13	NA

Source: United Nations Conference on Trade and Development (2000). Investment Policy Review: Uganda

The Bujagali hydro project has the potential to be the single largest private investment in East Africa's history. At the request of the Government of Uganda, AES Corporation, through its privately owned subsidiary, AES Nile Power, is planning to build and operate a US$500 million, 290 MW run-of-the-river power plant on a Build-Own-Operate-Transfer (BOOT) basis, at Bujagali Falls on the Victoria Nile, near Jinja in southeastern Uganda. AES is also due to construct 100 km of 220 kV and 132 kV transmission lines and two substations. The electricity generated from the project will be sold by AES Nile Power to the Uganda Electricity Transmission Company under a 30-year power purchase agreement (PPA). There are questions surrounding the financing of this project. The project is presently on hold pending resolution of issues related to corruption, environmental management and AES' ability to finance the project. Apart from Bujagali, a 200 MW hydropower station, known as Karuma, is being negotiated with the government of Uganda by NORPAK.

2.4. Rural Electrification

Uganda is pursuing a three-pronged rural electrification strategy. The first is an Energy for Rural Transformation (ERT) program that is being undertaken with support from the World Bank to increase access to modern, clean and affordable energy in rural areas from one to ten percent by 2012 (equal to an additional 500,000 customers). The ERT program seeks to achieve this growth through the use of renewable energy and traditional fuels. The World Bank has committed US$375 million over a ten-year period, which is being implemented by a range of ministries (the Ministry of Energy and Mineral Development (MEMD) serves as the main coordinating body). The activities being pursued include:

- Rural electrification, promotion and dissemination of information
- Renewable energy capacity building, assessment and database development
- Development and implementation of renewable energy and rural electrification master plans that will form the basis for selection and sequencing of priority rural electrification projects

Development of the country's geothermal resources is also contemplated under the ERT program with surface exploration activities due to begin in the second half of 2003. The Ugandan government will seek private investors to participate in the follow-on feasibility study and drilling phases.

The second part of the government's efforts to increase rural energy includes a three-year pilot program to connect 2,000 customers in remote areas with solar electric power. The third prong of Uganda's strategy is to increase low-cost hydro generation. Power from the proposed Bujagali project will meet the core demand for Uganda's energy needs and support the government's rural electrification strategy. Mini-hydro projects, further away from the grid, are also being developed with investments from the private sector to reach distant local markets. The International Finance Corporation (IFC) is providing the Uganda Rural Electrification Company, Ltd. with financing for mini-hydro projects in Bushenyi and Mbarara.

III. GEOTHERMAL RESOURCES AND DEVELOPMENT

3.1. Overview

The western branch of the East African Rift System runs along the border of Uganda with the Democratic Republic of Congo (DRC). Young faulting, often accompanied by volcanism and geothermal surface manifestations, marks the Rift Valley. Based on research carried out at the hot springs in the western region of the country around the shores of Lake Albert, the potential for geothermal power is estimated at 450 MW (McNitt, 1982).

3.2. Geothermal Energy Exploration Project I

Between 1993 and 1994, with assistance from UNDP, the OPEC Fund and the government of Iceland, the Ugandan government initiated the first phase of the Geothermal Energy Exploration project (known as GEEP I). Three geothermal prospects located within the western branch of the Eastern Africa Rift System were investigated (Stefansson, 1987): (a) the Katwe volcanic field in the south; (b) the Buranga field on the eastern side of the rift zone adjacent to the foothills of the Rwenzori Mountains; and (c) the Kibiro field in the northern part of the Western Rift Valley near Lake Albert.

Katwe Geothermal Prospect

The Katwe field is located within the Katwe-Kikorongo Volcanic Field, south of the Rwenzori massif and is bordered to the south by Lake Edward and Kazinga Channel, in the Kasese district. The Katwe geothermal prospect, which is located 35 km from the terminus of a 132 kV transmission line at Kasese, lends itself to a number of industrial applications, including fish and crop processing and salt mining.

The unique compositions of the volcanoes as well as the salt deposits at Lake Katwe have attracted scientific attention since the early 1900's. The Katwe geothermal prospect is known for its explosive craters and saline lakes. The studies carried out under GEEP I centered on the geology and geochemistry of the hot, saline and cold springs. The highest surface temperature was measured at 70° C. The Katwe resource has proven difficult to evaluate from spatial and temperature perspectives, but chemical studies indicate the subsurface temperature may be above 200° C.

The Kazinga Channel connects Lake Edward and Lake George, freshwater lakes that produce a considerable amount of fish. The districts of Kasese, Bushenyi, Kamwenge, Kyenjojo and Kabarole have a total population of 2,277,006 and are in close proximity to the Katwe geothermal prospect. The districts are agricultural areas that produce cotton, tea, coffee and tobacco as the principal cash crops. Other crops include bananas, maize, wheat, millet, sorghum, cassava and potatoes. Horticultural crops are also grown in the area, and livestock is raised. Kasese is the only district in the area with an irrigation project. Plans underway to expand this project will increase the demand for dependable electric power.

Salt production using artisan methods is ongoing in the Lake Katwe crater, and many crater lakes in the area have highly saline waters. Further investigation is needed in this area to determine the source of the geothermal brines and the possibility of commercial salt/chemical recovery. A geothermal power plant could supply energy for salt mining at Katwe.

Buranga Geothermal Prospect

The Buranga geothermal prospect lies at the foot of the escarpment northeast of the Rwenzori Massif in Bundibugyo District, approximately 50 km from Fort Portal along the Fort Portal – Bundibugyo road. The Buranga area has the most impressive geothermal surface manifestations of the three prospects, the highest natural flow and the largest confirmed areal extent. It is the only geothermal field in Uganda where prospecting has been initiated as a result of a number of boreholes drilled in the early 1950's (the project, however, was never completed). A total of 37 hot springs have been located and mapped, with temperatures of up to 98.3° C. Subsurface temperatures, however, are estimated to be in the range of only 120° C to 150° C (Bahati and Armannsson, 1995).

The Bundibugyo District has a population of 211,616 (population census, 2002) and is an agricultural area with fertile soil where coffee, cotton, palm oil, cocoa and tobacco are grown. There is fishing activity on the Semliki River and in Lake Albert near the prospect. Remotely located, the Bundibugyo District could greatly benefit from the use of geothermal resources for both power generation and direct uses, including agricultural and fish processing.

Kibiro Geothermal Prospect

The Kibiro geothermal prospect is situated in the Hoima district on the eastern shore of Lake Albert at the foot of the eastern escarpment of the Rift Valley and has a limited area of surface manifestations. Prior to the GEEP I study of 1993-1994, the geology of the Kibiro area had not been looked at in the same detail as the other two prospects. The GEEP I study located and mapped 15 hot or warm springs and measured surface temperatures up to 86.4° C. Although an aeromagnetic survey done in 1983 detected magnetic anomalies in the vicinity of the Buranga and Kibiro prospects, the heat sources of the two areas remain uncertain (EDICON, 1984). Nevertheless, subsurface temperatures of 200° C and above were determined with the greatest confidence using geothermometry at the Kibiro prospect, which is the highest of the three areas (Bahati and Armannsson, 1995).

The Kibiro prospect is also characterized by an ancient salt industry that utilizes the saline water percolating through the sediment. The prospect comprises the Hoima and Masindi districts, which have a total population of 809,246 and is close to a 32 kV grid connection at Kigorobia. There is fishing activity on Lake Albert, and the surrounding area is one of the leading tobacco growing regions of the country. In addition to electricity production, geothermal heat could be used in salt, fish and tobacco processing.

Additional geothermal prospects may be associated with the 46 hot and mineralized springs that were identified throughout Uganda (Wayland, 1935). Some of these locations consist of a single spring or a few springs, whereas others are larger areas with a number of hot springs. Some of the springs may have industrial use possibilities and should be investigated.

3.3. Ongoing Resource Assessments

Due to limited funding under the GEEP I, only geological and geochemical surveys were carried out at the Katwe, Buranga and Kibiro geothermal prospects. The GEEP I hydrological studies were not detailed and left many unanswered questions about the origin of the geothermal fluids, their residence time, connection with surface and/or cold groundwater and recharge areas of the fields.

With funding from the International Atomic Energy Agency (IAEA) and the Ugandan government, a new hydrological project (Isotope Hydrology for Exploring Geothermal Resources, UGA/8/003) was initiated to delineate the flow characteristics of surface, ground and geothermal waters in the Katwe, Buranga and Kibiro geothermal prospects. In 2000, the Isotope Hydrology project was integrated into the Uganda Alternative Energy Resources Assessment and Utilization Study (UAERAUS), a project between the African Development Bank (AfDB) and the Ugandan government to formulate a long-term integrated energy resource development program for the country focusing on the use of geothermal, biomass, wind, peat, solar and mini-and micro-hydro resources. The study will be carried out in three phases:

- *Phase I:* Formulation of a strategic program for the development and utilization of alternative energy resources.
- *Phase II:* Preparation of feasibility studies of priority projects for selected highly energy-deficient rural areas and towns.
- *Phase III:* Preparation of detailed designs and tender documents.

Additional geophysical surveys will fall under Phase I of the UAERAUS project which, when completed, will upgrade the geothermal exploration at the Katwe and Buranga prospects to pre-feasibility status. The government of Iceland has also offered to provide support to carry out similar studies at Kibiro's third geothermal prospect, starting in June 2003. The Icelandic program will also synthesize the information from all three of the prospects (Katwe, Buranga and Kibiro) and prepare its recommendations. The results of the geophysical surveys, together with the model already established from the GEEP I geological and geochemical studies, will provide the information needed to site the first exploration wells. The UAERAUS and Icelandic studies are scheduled to be completed and analyzed by the end of 2003.

3.4. Geothermal Energy Exploration Project II (GEEP II)

Once the UAERAUS and Icelandic studies have been completed, the second phase of the Uganda Geothermal Energy Exploration Project (GEEP II) can begin. GEEP II will entail a full feasibility study that, if successful, would pave the way for the construction of a geothermal power plant by an IPP. GEEP II will consist of two phases: a due diligence and feasibility stage and an exploratory drilling phase.

Feasibility Phase

The first stage of GEEF II will entail a full feasibility study of one or more of the three prospects. The study will:

- Integrate the results of the UAERAUS and Icelandic geological, geochemical and geophysical studies
- Assess the demand for electricity in western Uganda near the geothermal prospects
- Evaluate the market and demand for process heat (agricultural) in western Uganda
- Analyze the legal, tax and other aspects relating to private power development

The evaluation of the geologic, geochemical and geophysical data and the market, demand, legal and tax analysis will proceed concurrently. It will take approximately six months to complete the feasibility study at an estimated cost of US$150,000.

Exploratory Drilling

If the results of feasibility study are successful, the next phase will entail drilling three exploratory boreholes and testing at one of the geothermal prospects. At the same time a plan for the installation of a commercially-sized geothermal power plant commensurate with the resource and power demand in the region will also be prepared. The exploratory drilling phase takes approximately 12 months and costs approximately US$5 million.

Expected Outputs

Expected outputs of the GEEP II will include:

- A feasibility study with the legal and tax constraints and other requirements for a private power agreement
- A demand study, including electricity generation and process heat
- An evaluation of geothermal resources at one of the three Ugandan prospects based on test well results

The training of Ugandans from the public and private sector in geothermal resource analysis, development and management which will help improve the geothermal energy resource exploration and development capacity of the Geological Survey and Mines Department within the Ugandan Ministry of Energy and Mineral Development.

The total budget for both the feasibility and exploratory drilling and study phases will be US$5.15 million and require approximately 18 months to complete.

3.5. Support from the Ministry of Energy and Mineral Development

External funding from the public or private sectors will be needed to implement the GEEP II. The Geological Survey and Mines Department of the Ugandan Ministry of Energy and Mineral Development has indicated that it will provide in-country support services such as office space, use of fax, telephone, email and host country counterpart personnel as necessary to the private company or public sector-financed entity that undertakes the project.

3.6. Potential Geothermal Uses

In addition to power generation, there are a number of other ways that Uganda's geothermal resources can be put to commercial use. Geothermal heat could be used as a substitute for increasingly scarce wood for drying fish, salt, tea and crops, curing tobacco and processing sugar. This would create possibilities for more valuable uses of the wood, and protect the environment. Most of the hot spring waters are currently used for healing (skin diseases and rheumatics) and their utilization by the growing tourist industry should also be studied. Other potential uses include domestic, agricultural and industrial heating. Some of the waters in these areas also contain low total dissolved solids and could be used as mineral water (Bahati, 1996).

3.7 Commercial Geothermal Opportunities

The government of Uganda is interested in discussing potential partnership relationships with one or more geothermal IPPs. In such a relationship, both parties would collaborate to obtain grant or "partial risk guarantee" funds[15] for geothermal exploration.

Government officials recognize they do not have sufficient geothermal data to negotiate binding PPAs with geothermal developers but would welcome negotiating preliminary "non-financial PPAs" with one or more interested private geothermal companies. This would constitute a short list, and enable interested companies to partner with the Ministry of Energy and Mineral Development to identify funding for geothermal exploration under the GEEP II and further project development.

Including the GEEP II project, near-term goods and services likely will be required for the following:

- Project feasibility study
- Project development
- Exploration program design and analysis
- Drilling and completion
- Well testing
- Reservoir assessment
- Power plant design
- Financing
- Environmental studies
- Planning and design for possible direct uses

IV. POLICIES THAT RELATE TO PRIVATE SECTOR INVESTMENT

4.1. Foreign Investment

Uganda has a fully liberalized foreign exchange regime with no restrictions on the movement of capital. Uganda's constitution guarantees the right to property, and foreign investors are permitted to retain 100 percent ownership in local businesses.

In 1992, Uganda became a member of the Multilateral Investment Guarantee Agency (MIGA) which allows foreign investors to insure their investments in Uganda against a wide range of non-commercial risks including expropriation, currency transfers, breach of contract and civil strife. Foreign investors can apply for MIGA insurance through the Uganda Investment Authority (UIA). US and UK companies investing in Uganda may also apply for political risk insurance through the Overseas Private Investment Corporation (OPIC) (US) or the Overseas Investment Insurance Scheme (UK).

4.2. Uganda Investment Authority

UIA is the government body that promotes and facilitates investment in Uganda. The UIA helps investors:

- Obtain necessary information on investment in Uganda
- Implement project ideas through professional advice and assistance in locating relevant project support services

[15] "Partial risk guarantee" funds may be made available under a program being discussed to cover loans for part of the cost of high-risk exploratory drilling. The loans must be repaid from electricity revenues if the exploratory drilling is successful. The guarantee funds will repay the portion of the loan guaranteed if the exploratory drilling is not successful.

- Issue the necessary investment license and help investors secure secondary licenses and approvals (e.g., work permits, trading licenses)
- Arrange contacts for investors and organize itineraries for visiting foreign missions within the country
- Help investors seek joint venture partners and linking with possible funding agencies

4.3. Fiscal Incentives

In order to attract foreign investment, Uganda has adopted a number of fiscal incentives that provide generous capital recovery terms, particularly for projects that entail significant investment in plant and machinery and for investments that are medium-or long-term. These incentives are divided into three categories: (a) investment allowances; (b) deductible annual allowances; and (c) annual depreciation allowances.

Category 1 – Initial investment allowances that are deductible once from the company's income. Initial allowances are based on the value of plant and machinery (Table 2).

Table 2:

	Percent (%)
Kampala, Entebbe, Namanve, Jinja and Njeru areas	**50**
Outside Kampala, Entebbe, Namanve and Jinja area	**75**
Start-up costs	**25**
Scientific research expenditure	**100**
Training expenditure	**100**
Industrial buildings	**20**

Category 2 – Deductible Annual Allowances – Depreciable assets are specified in four classes under a declining balance method (Table 3).

Table 3:

		Percent (%)
Class 1	Computers and data handling equipment	**45**
Class 2	Automobiles, construction and earth moving equipment	**35**
Class 3	Buses, goods vehicles, tractors, trailers, plant and machinery for farming, manufacturing and mining	**30**
Class 4	Cars, locomotives, vessels, office furniture, fixtures etc.	**20**

Category 3 – Other Annual Depreciation Allowances (Table 4).

Table 4:

	Percent (%)
Industrial buildings, hotels and hospitals	**5**

4.4. Tax Incentives

Assessed losses arising out of company operations, including losses from investment allowances, can be carried forward indefinitely. In addition, Uganda's corporate tax rate of 30 percent is one of the lowest in Africa. All imported plant equipment and machinery is duty and tax-free. Investors who register as VAT traders are allowed VAT refunds on all construction materials used on their projects within a four-year project implementation period.

4.5. Environmental and Emission Institutions and Regulations

The National Environment Management Authority (NEMA) is the principal agency responsible for the management of the environment in Uganda. It coordinates, monitors and supervises all activities in this field.

While NEMA is responsible for oversight, implementation is the responsibility of all the relevant ministries. Each ministry has an environment liaison unit responsible for integrating environmental concerns into sectoral plans and implementing environmental activities within the ministry's mandate. For more information, see http://www.nemaug.org.

4.6. Host Country Personnel with Geothermal Experience

The Geological Survey and Mines Department within the Ministry of Energy is responsible for all surface geothermal exploration in Uganda and has a geothermal team capable of carrying out surface geothermal exploration. The Ugandans in this group have received training at the United Nations University in Reykjavik, Iceland and other institutions in New Zealand, Austria, China and the Philippines. A close working relationship exists between Ugandan geothermal experts and their counterparts in Iceland. See Table 5 below for staff descriptions.

Table 5: Geological Survey and Mines Department Geothermal Personnel

Name	Date	Relevant qualifications	Institution
Godfrey Bahati (Chemist)	1986-1989	BSc. (Honors) in Chemistry	Makerere University Kampala, Uganda
	1993-1993	Certificate in Geochemistry (Chemistry of Thermal Fluids)	United Nations University, Iceland.
	1993-1993	On-job training. Geothermal exploration and utilization methods	Olkaria Project, Naivasha, Kenya
	1997-1997	Certificate in Hydrogeology and Geothermics (Groundwater Tracing Techniques)	Institute of Hydrogeology and Geothermics, Austria
	1999-1999	On-job training. Conceptual Modeling and Production Geochemistry	PNOC Geothermal Institute, Manila, Philippines
	2000–2000	Certificate in Project Planning and Management	Uganda Management Institute, Kampala
Edward Isabirye (Geologist)	1987-1990	BSc. (Honors) in Chemistry and Geology	Makerere University Kampala, Uganda
	1994-1994	Certificate in Borehole Geology in Geothermal Energy	United Nations University, Iceland
	2002-2002	Certificate in Groundwater Isotope Hydrology	Institute of Hydrogeology and Geothermics, Austria
	2002-2002	On-job training. Isotope Hydrology	IAEA Vienna, Austria
Fred Tugume (Geophysicist)	1991-1994	BSc. (Honors), in Math and Physics	Makerere University Kampala, Uganda
	1995-1995	Certificate in Geophysical Exploration for Geothermal Energy	United Nations University, Iceland
	1996-1998	Master of Science in Seismology	University of Bergen, Norway
Vicent Kato (Geologist)	1988-1991	BSc. (Honors) in Geology and chemistry	Makerere University Kampala, Uganda
	1995-1997	MSc. in Geological Survey.	International Institute of Aerospace Survey and Earth Sciences –ITC, The Netherlands
	2000-2000	Certificate in Geochemistry (Isotope Hydrology)	United Nations University, Iceland
	2002-2002	Diploma in Geothermal Technology	University of Auckland, New Zealand

Name	Date	Relevant qualifications	Institution
Agnes Alaba (Geologist)	1990-1993	BSc. (Honors) in Geology and chemistry	Makerere University Kampala, Uganda
	1995-1996	Certificate in (Geological Application of Remote Sensing 1996 and Database Management Systems-(GARS-DBM))	The Royal Museum for Central Africa (RMCA) – Belgium.
	1997-1998	MSc. in Geoinformatics	International Institute of Aerospace Survey and Earth Sciences –ITC, The Netherlands
	2001	Certificate in groundwater tracing techniques	Institute of Hydrogeology and Geothermics, Graz, Austria
Gabriel Data (Geochemist)	1991-1994	BSc. (Honors) in Geology and Chemistry	Makerere University Kampala, Uganda
	1997-1997	Certificate in computer science (Database and GIS)	SEAMIC, Dar-es-Salaam, Tanzania.
	2002-2002	On job training in Groundwater Hydrology for Geothermal exploration	East China Geological Institute, Funzhou, Jianxi province in China.
Andrew Katumwehe (Geophysicist)	1992-1995	BSc. (Honors) in Geology and chemistry	Makerere University Kampala, Uganda
	1999-2000	MSc. in Exploration Geophysics	International Institute of Aerospace Survey and Earth Sciences –ITC, The Netherlands

V. CONTACT INFORMATION

1. Local Power Company

Uganda Electricity Board
Amber House
29/33 Kampala Rd.
P.O. Box 7059
Tel. 256-41-254071
Fax 256-41-235119/250132
http://www.ueb.co.ug

Uganda Electricity Transmission Company Ltd.
Mr. Kiyemba Eriasi, Managing Director
P.O. Box 7625, Plot 29/33 Amber House
Kampala, Uganda
Tel. 256-41-233 972/ 250-677
Fax 256-41-341789
Cell 256-77-221 266
Res. 256-71-232706
Email e.kiyemba@uetelc.com

Mr. Gerald Muganga, Manager, Engineering
Tel. 256-41-233 433, ext. 2217
Email muganga@ueb.co.ug

Mr. Herman Ssenyondwa, Principal Planning Engineer
Tel. 256-41-233 433
Res. 256-41-259 996
Email ssenyondwa@ueb.co.ug

2. Ministry of Energy

Ministry of Energy and Mineral Development
Mr. Fred Kabagambe-Kaliisa, Permanent Secretary
Amber House
Plot No. 29/33 Kampala Road
P.O. Box 7270
Kampala/Uganda
Tel. 256-41-234733
Fax 256-41-234732
Email psmemd@energy.go.ug

3. Electricity Regulatory Authority

Engineer Dr. F.B. Sebbowa
Chief Executive Officer
Plot 1, Colville Street
8th Floor, Communication House
P. O. Box 10332, Kampala
Tel. 341852,341646, 341624
Email era@africaonline.co.ug

4. Geological Survey

Mr. Joshua Tuhumwiire, Commissioner
Mr. Godfrey Bahati, Coordinator Geothermal Exploration
Geological Survey and Mines Dept.
P.O. Box 9, Entebbe, Uganda
Tel. 256-41-320656/320559/320118
Fax 256-41-320364
Email gsurvey@starcom.co.ug

5. Ministry of Finance or Investment Authority

Ministry of Finance, Planning and Economic Development
Appollo Kaggwa Rd, Plot 2/4,
P.O. Box 8147, Kampala, Uganda
Tel. 256-41-234700/9, 235051/4
Fax 256-41-230163
Email rmuwanga@swiftuganda.com or efmp@imul.com

Mr. Amos Lugolobi, Director
Investment Promotion Division
Uganda Investment Authority
Plot 28 Kampala Road
P.O. Box 7418, Kampala
Tel. 256-41-251561-5/234105
Fax 256-41-342903
Email alugolobi@ugandainvest.com
www.ugandainvest.com

6. Interested Multilateral Agencies

The World Bank
P.O. Box 4463
Kampala, Uganda
Tel. 256-41-230-094, 232-533
Fax 256-41-230-092

7. Interested Bilateral Agencies

US Agency for International Development (USAID)
42, Nakasero Road
P.O. Box 7856
Kampala, Uganda
Tel: 256-41-235879
Fax: 256-41-233417
www.usaid.or.ug

8. US Embassy

Economic and Commercial Officer
U.S. Embassy – Plot 1577 Gaba Road
Tel: 256-41-259791/259792/259793
Fax: 256-41-259794

VI. DETAILED REPORTS AND MAPS OF GEOTHERMAL AREA(S)

Uganda Department of Geological Survey and Mines – List of Available Maps and Data

Small Scale Geological Maps

1:1,500,000	Uganda Geology with text (Uganda Atlas edition)
1:1,250,000	Geology of Uganda (Edition, 1960)
1:1,250,000	Geology of Uganda with Bouguer Contours and Gravity Stations (Edition 1, 1960)
1:500,000	Geological Map of Central Uganda
1:2,000,000	Geological Map of East Africa

1:250,000 Geological Maps

Arua, Pakwach, Fort-Portal, Mbarara, Kabale

1:250,000 Geological Maps with Bouguer contours and Gravity Stations:

Arua, Pakwach, Moroto, Fort-Portal, Kampala, Mbarara, Masaka, Kabale

1:250,000 Topographical Maps with Bouguer Contours and Gravity Stations:

Hoima, Masindi

1:100,000 Geological Maps:

Arua, Paidha, Kiboga, Lake Wamala, Buhwezu, Rukungiri, Bushenyi, Kabale, Rwentobo

Provisional Geological map of part of the Kafu Basin

Geological map of part of Bunyoro

Geochemical Maps

1:2,000,000/1:4,000,000 Geochemical Atlas of Uganda – both soft and hard cover
Geochemical moving average maps of sheets 9 and 17

Geophysical Maps:

1:1,500,000 Uganda Geophysical with text
(Uganda Atlas addition)
1:1,500,000 Geophysical and Seismological with text (Uganda Atlas edition)

Computer Aided Data

Topographic maps (scale 1:50,000)
Geology maps (scale 1:50,000)
Geology map (A4 size)
Topographic map (A4 size)
Geology map (A3 size)
Topographic map (A3 size)

Digital

Geophysical digital data ¼ ° sheet or part of it
Airborne Geophysical digital data of Southern Uganda (Radiometric)
Airborne Geophysical digital data of Southern Uganda (Magnetic)
Airborne Geophysical digital data of Southern Uganda
Geochemical digital data ¼ ° sheet or part of it

6.4. Topographic Maps

Topographical maps covering the entire country are available.

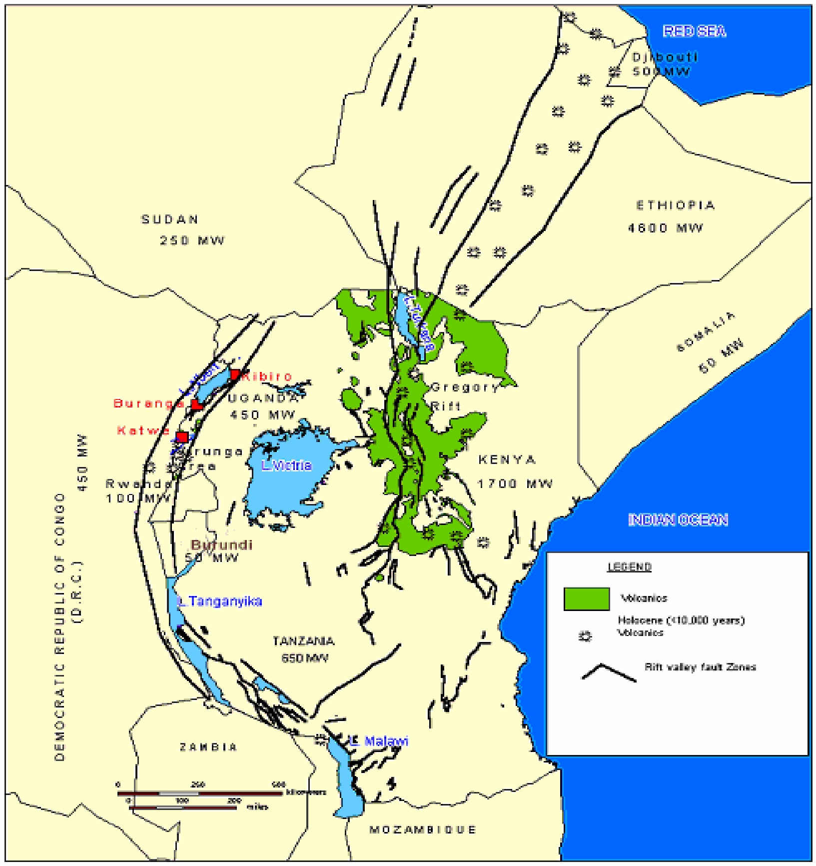


Figure 2: Location of the three main geothermal prospects of Uganda and the Estimated geothermal potential of East Africa.

Figure 2: Location of the Three Main Geothermal Prospects of Uganda

VII. MAPS OF COUNTRY GEOTHERMAL PROSPECTS AND GRID

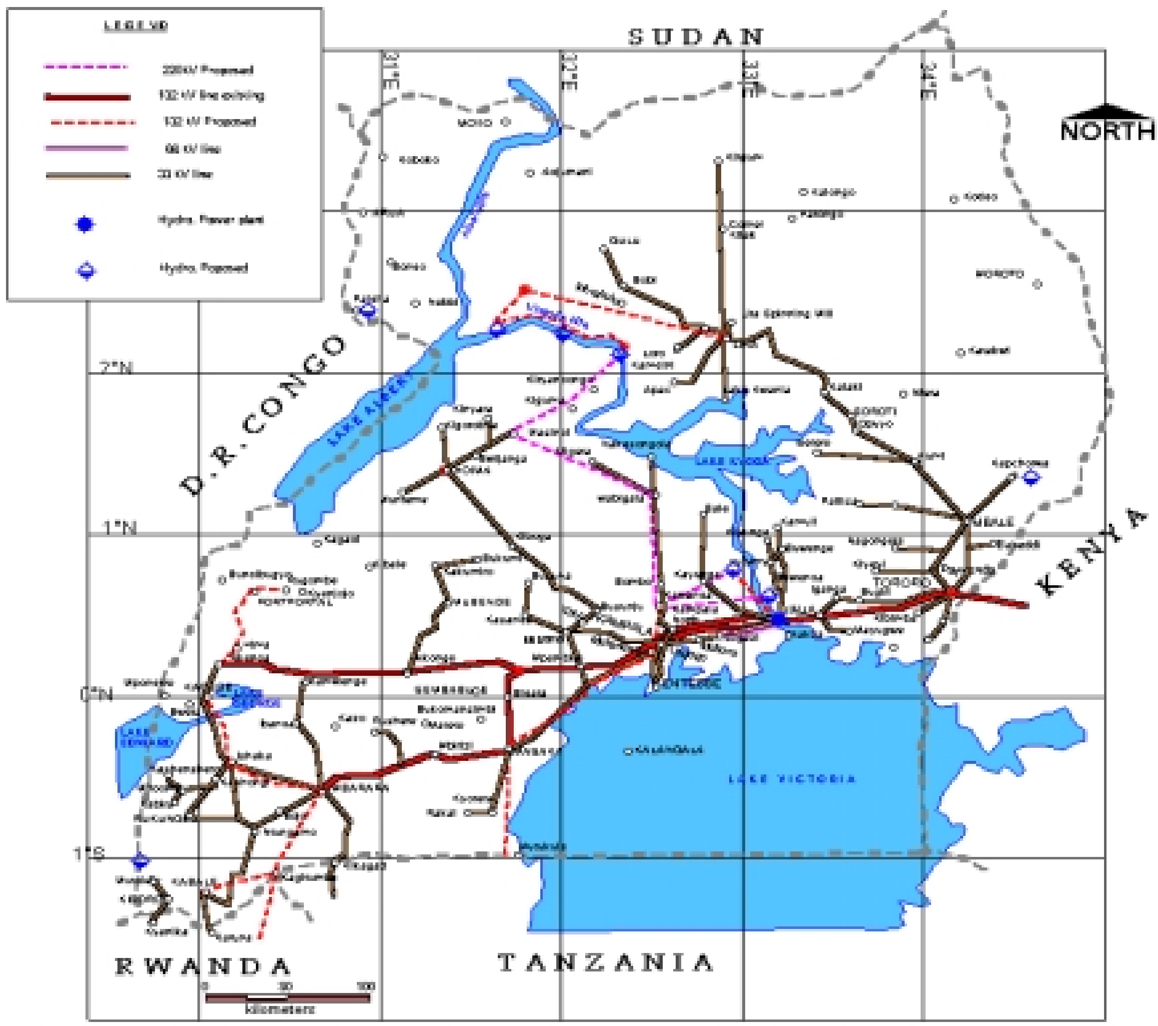


Figure 1: Map of Uganda showing grid infrastructure, present and future network

Figure 3: Grid Infrastructure, Present and Future Network

VII. REFERENCES

Armannsson, H. and Gislason, G., (1995). "The chemistry of the thermal springs in the Katwe-Kikorongo area, Uganda," in Kharaka, Y. and Chudaev, O.V., (Eds.). *Water – Rock interaction 8*, Balkema, Rotterdam, pp 371–374.

Bahati, G., Armannsson. H., (1995). "The chemistry of the waters in the Buranga and Kibiro geothermal fields, West Uganda," in Kharaka, Y. and Chudaev, O.V. (Eds.), *Water – Rock interaction 8*, Balkema, Rotterdam, pp 505 – 509.

Bahati, G., (1996). *Preliminary geothermal investigation of Kisiizi, Minera, Rubabo, Birara, Ihimbo and Kiruruma hot springs in Rukungiri district, South-west Uganda. Unpublished*. GSMD Report GBB/12.

Bahati, G., Joshua Tuhumwire, (2002). *Geothermal Energy in Uganda.*

Brown, J. M, (1954). *Drilling for geothermal power at Buranga hot springs, Toro.* Geological Survey of Uganda, (Unpublished). Report No. JMB/17, 2 pp.

EDICON, (1984). *Aeromagnetic interpretation of Lake Albert/Edward portion of the Western Rift Valley*. EDICON Inc. (Unpublished). Denver Colorado, Sept. 1984.

Matthiasson, M., (1994). *Geothermal Utilization Study*. (Unpublished), UNDDSMS UGA/92/002.

McNitt. J.R., (1982). "The geothermal potential of East Africa." Proceedings of the Regional Seminar on Geothermal Energy in Eastern and Southern Africa held in Nairobi, Kenya. p 3 – 8.

Stefansson, V., (1987). *Geothermal resource of Uganda. Review of chemical data*. United Nations, New York, 19 pp.

Unknown, (1997). *Uganda Power Sector Restructuring and Privatization. The New Strategic Plan and Implementation Plan*. Uganda.

Wayland, E.J., (1935). *Notes on thermal and mineral springs in Uganda*. UGMS Bull. No. 2., 44-54.

TANZANIA COUNTRY GEOTHERMAL REPORT

Figure 1: Map of Tanzania

I. COUNTRY OVERVIEW

1.1. Geography, Population and Government Structure

The United Republic of Tanzania is the largest country in Eastern Africa. It has a total area of 945,090 km^2, of which 886,040 km^2 is land, and includes the islands of Mafia, Pemba and Zanzibar. The Great Rift Valley runs through the center of Tanzania and the country is bordered by Burundi (451 km), Kenya (769 km), Malawi (475 km), Mozambique (756 km), Rwanda (217 km), Uganda (396 km) and Zambia (338 km).

The population of Tanzania is estimated to be 30 million[16], 97 percent of whom live on the mainland. There are more than 100 tribal groups in Tanzania, the majority whom are of Bantu origin. There is also a strong Arab, Shirazi and Comorian influence in Zanzibar and Pemba. Throughout the country, the main languages spoken are Kiswahili (Swahili), English and Arabic.

Tanzania gained its independence from British rule in December 1962, and Julius Nyerere of the Tanganyika African National Union was made the country's first President. Following independence, Kenya, Tanzania and Uganda were linked together in an economic union that shared telecommunications, postal facilities, transportation and customs and freedom of movement. In 1977, this union fell apart because of political differences. Since then Tanzania has adopted a multi-party political system with the mainland currently under the rule of Benjamin Mkapa, a democratically elected President now serving his second five-year term.

1.2. Economy

Tanzania's natural resources include hydropower, tin, phosphates, iron ore, coal, diamonds, gemstones, gold, natural gas, nickel and phosphate. However, the mainstay of the economy is agriculture, which accounts for 57

[16] July 1997

percent of GDP, 85 percent of exports and employs 90 percent of the workforce. Agricultural products include cloves, coffee, cotton, rice, sorghum, sugar, coconuts and tobacco.

Tanzania's manufactured goods include textiles, food processing, cement and cigarettes. Overall, the country's industrial sector only accounts for about 17 percent of its GDP. It grew 12 percent annually during the late 1980s but more recently has grown at a more modest rate. Key industrial activities include refining raw materials, import substitution and processing agricultural products.

In 1986, the government launched an economic recovery program to revitalize and liberalize key sectors of the economy and encourage foreign and domestic private investments. The recovery program seeks to liberalize the trade regime, remove price controls, float interest rates, restructure the financial sector and privatize parastatal enterprises. To date, tax codes have been redrawn, foreign banks licensed and an investment promotion center established to help cut red tape.

Although the Tanzanian government's economic recovery program has helped increase private sector growth and investment, the government is still very dependent on aid from overseas, specifically funds from the World Bank, the International Monetary Fund and bilateral donors that re helping to rehabilitate its deteriorated economic infrastructures. Continued donor support and sound macroeconomic policies should allow Tanzania to achieve an average GDP growth rate of six percent annually.

1.3. Political and Social Issues

Despite a trend toward urbanization in Tanzania, approximately 80 percent of the population remains rural. Inadequacies exist in the basic infrastructure throughout the nation and living standards are deteriorating. This is particularly the case in urban areas due to basic shortfalls of services and a rapidly growing population. The structural reforms put in place to vitalize the private sector and spark industrialization have not aided the situation. By adding to the level of debt owed by Tanzania, the reforms are inadvertently increasing levels of poverty and unemployment throughout the country. Immediate assistance is needed with basic education, healthcare, transportation, water and sanitation systems and electric power. Energy demand from urban areas has grown rapidly with the population creating tension between investments for urban electricity supply and rural electrification. Upgrading the energy infrastructure is an important task in improving living standards and upgrading the industrial base.

II. COUNTRY ENERGY CONTEXT

2.1. Electricity Sector

TANESCO is Tanzania's national power company that is 100 percent government-owned and is responsible for 98 percent of the country's electricity supply. It has an installed capacity of 763 MW in its grid network, of which 561 MW is hydro and 202 MW is thermal. Tanzania's major hydropower plants are Kidatu (204 MW), Mtera (80 MW), Pangani Falls Redevelopment (68 MW), Hale (21 MW) and Kihansi (180 MW). It is estimated that there is approximately 3,800 MW of economic hydro potential capacity in the country. TANESCO also has a PPA with Independent Power Tanzania Limited (IPTL), which owns and operates a 100 MW diesel generating plant at Tegeta in Dar es Salaam that adds another 100 MW to the grid. The commercial operation of this plant began in January 2002.[17]

The Ministry of Energy and Minerals (MEM) is responsible for implementing the government's energy policy and has two technical divisions and four support departments. The technical divisions are Energy and Petroleum Affairs and Minerals. The support departments are Policy and Planning, Administration and Personnel, Accounts and Internal Audit. Energy and Petroleum Affairs is subdivided into four sections: Electricity,

[17]The electricity market was recently opened to the private sector with incentives provided. TANESCO has identified some of its non-core activities and has started divesting them. The power distribution activities of TANESCO have been earmarked for privatization.

Petroleum and Gas, Energy Development and Renewable Energy. Geothermal energy is the responsibility of the renewable energy division.

2.2. Electricity Capacity and Demand

Overview

Tanzania on average produces 2,491.1 GWh of electricity annually, which only accounts for approximately 1.2 percent of total energy consumption by the population. The rest comes from biomass (92 percent) and from commercial energy such as petroleum and coal (seven percent). Of the total commercial energy consumed, 82 percent consists of petroleum products, 15 percent electricity and three percent coal. The transport sector is the main user of commercial energy (40 percent), followed by industry (24 percent), households (21 percent), agriculture (11 percent) and others (four percent). Overall, per capita electricity consumption in Tanzania is 60 kWh per annum, a figure that is growing at an annual rate of 11 to 13 percent[18]. Ten percent of the population has access to electricity.

The maximum grid-based demand in Tanzania is 464.83 MW with an additional 20 to 30 MW of demand coming from isolated systems. Annual demand growth for electricity in the country varies from seven to 11 percent, but it is forecasted that peak demand will double by 2005 to above 800 MW. Demand can be broken down into the following categories:

- households - 40 percent
- industry and businesses - 50 percent
- public lighting and exports to Zanzibar - ten percent

Tanzania has a 220 kV transmission network run by TANESCO that covers 2,605.36 km^2 – less than one percent of its total surface area of 954,000 km^2. It has 1,413 km of 132 kV transmission lines, and the overall distribution network is comprised of 33 kV, 11 kV, and 0.4 kV lines. The main grid serves Dar es Salaam, Arusha, Dodoma, Iringa, Mbeya, Morogoro, Moshi, Musoma, Shinyanga, Singida, Tabora and Tanga. The six largest towns consume 90 percent of the electricity generated in Tanzania. Dar es Salaam consumes approximately 50 percent of the total generation. About 95 percent of these lines are erected on wooden poles (see Figure 3 in appendix).

Fifty five isolated and mini hydroelectric generators with a capacity of 23 MW supply 135 km of land that is not connected to the grid. Currently, isolated small grids are powered primarily by diesel power plants. However, the cost of operating these installations is high because of the difficulty of transporting fuel and spare parts over bad roads.

Power Sector Development Master Plan

TANESCO's 2001 power sector development master plan covers the period up to 2026 and estimates that electrical energy use will increase from 2,118 GWh (1998) to 13,360 GWh by 2025 and peak demand to grow from 367 MW to 2,312 MW. To satisfy this increase, 1,440 MW of new generating capacity will be required between now and 2021. For several years beyond 2004, new generation capacity based on gas will continue to be added to the grid.[19] In the immediate future, the Songo Songo gas to electricity project (run by a Malaysian IPP) is planned for commissioning during the first quarter of 2004, and a fifth gas turbine at Ubungo is expected to come on line in 2004.

Included in this master plan are feasibility studies for the coal-based Mchuchuma power project and the hydro-based Rumakali and Ruhudji projects. The projected increase of electricity to the gold mines in the area south of Lake Victoria (where demand is expected to grow to over 100 MW in the next few years) is also included. The

[18] This is approximately ten percent of the average for all developing countries and one percent of the average of industrialized countries.
[19] ref. 16

mines will initially install their own generators, but they will consider using power delivered from the grid system or other external sources if tariffs and power supply reliability are at acceptable levels.

Regional Interconnection

Regionally, within the framework of the Southern Africa Development Community (SADC), Tanzania is pursuing a 330-kV interconnection with Zambia through a 700 km-long power line that will connect the two countries. This interconnection could enable Tanzania to connect with other SADC member states and become an operating member of the Southern Africa Power Pool (SAPP) that includes Zambia, Zimbabwe, Botswana, Lesotho, Namibia, the Democratic Republic of the Congo and South Africa. The project is estimated to cost approximately US$170 million. Tanzania is also pursuing interconnections with Kenya and Uganda and, under the auspices of the Kagera Basin Organization (KBO), is looking into interconnections with Burundi and Rwanda.

With increased growth in electricity demand and current grid connectivity, Tanzania will need new capacity. Government policy aims to reduce dependence on hydro sources and increase utilization of indigenous thermal resources such as natural gas, coal and renewable energy in the medium-to long-term.

2.3. Competing Resource Options

Tanzania has substantial proven energy resources including hydropower, natural gas, coal, biomass, solar and wind. There are also indications of potential geothermal and oil resources in the country.

Hydropower

The government of Tanzania considers hydropower its most important indigenous source of commercial energy. The country is reported to have a potential of 4.7 GW. To date, only 560 MW has been developed. However, in the 1990s, the risks of Tanzania's dependency on hydropower became apparent as low rainfall in the hydroelectric dam catchment areas created persistent power shortages.

Petroleum-based Fuels

Transportation and agro-based industries depend largely on petroleum-based fuels. Petroleum imports comprise about 25 percent of total imports and consume about 65 percent of export earnings. Reducing this dependency and finding alternatives for petroleum for both transportation and decentralized electricity generation are important national objectives.

Natural Gas

Natural gas has been discovered in the vicinity of Songo Songo Island and in the Mnazi Bay area near Mtwara. The Songo Songo gas field has proven recoverable reserves of nearly one trillion ft^3. The Mnazi Bay gas field is estimated have a similar quantity of reserves.

Coal

Tanzania's reserves are estimated at about 1.2 billion tons, of which 304 million tons are proven. The government, through the National Development Corporation, is promoting the use of coal at Mchuchuma for power generation. A six-MW power station has already been built at Kiwira, and plans are underway to expand the power generation capacity to 30 MW under a joint venture with CHITEC, a Chinese investment company.

Renewable Energy

Currently, renewable energies have to compete with other conventional forms of electricity in Tanzania, such as hydropower and natural gas. However, the new energy policy does allow IPPs to generate electricity from different sources including new and renewable sources of energy, particularly for the rural population, where the majority of energy needs are currently met by wood and other sources of traditional biomass.

In 1999, Tanzania announced very attractive financial terms for potential investors in developing its renewable energy resources. It simplified procedures for those interested in investing in solar, wind and micro-hydro projects including a 100 percent depreciation allowance in the first year of operation, exemption from excise duty and sales tax and concessionary customs duty on the first import of materials used in renewable energy projects. Despite this, and the fact that Urambo, a local power cooperative, showed that rural people are prepared to pay very high charges for reliable electricity (up to US$.53 per kWh), development has been slow.[20] There is also a lack of awareness and confidence in renewable energy technologies in Tanzania, a weak institutional infrastructure for effective support and no mechanisms to provide credit to potential users in the country.

2.4. Rural Electrification

Although the national grid extends to 14 of the 20 regions of mainland Tanzania and to Zanzibar, less than 15 percent of Tanzania's population lives in areas served by the grid, and in these areas even fewer are connected. In villages that have access, only a few households (one to five percent) are connected.[21] Countrywide, only one percent of the rural population has access to electricity. The Tanzanian government supports renewable energy. The 2001 Draft National Energy Policy seeks to:

- Promote entrepreneurship and private initiative in the production and marketing of products and services for rural and renewable energy.
- Ensure continued electrification of rural economic centers and make electricity accessible and affordable to low income customers.
- Facilitate increased availability of energy services, including grid and non-grid electrification to rural areas.

III. GEOTHERMAL RESOURCES AND DEVELOPMENT

3.1. Overview

Geothermal exploration in Tanzania took place from 1976 to 1979 under the directive of SWECO, a Swedish consulting group, and in collaboration with Virkir-Orkint of Iceland. Financial support was given by the Swedish International Development Authority (SIDA). Reconnaissance missions and surface exploration were carried out in the northern part of the country (near Arusha, Lake Natron, Lake Manyara and Maji Moto) and in the south (Mbeya region). The objective of these missions was to make a preliminary appraisal of the existence and feasibility of exploiting geothermal resources in Tanzania. Approximately 50 hot springs were mapped that are associated with block faulting and recent volcanicity.[22] The results were considered promising, and SWECO, Virkir and SIDA prepared a draft geothermal development plan.

As a result of the missions two potential target areas for geothermal exploration were identified as:

- The Arusha region near the Kenyan border in the north
- The Mbeya region between Lake Rukwa and Lake Nyasa (Malawi) in the southwest (see Fig. 2)

3.2. Geothermal Resources of the Arusha Region

The Swedish mission concluded that most of the thermal manifestations in northern Tanzania indicated the existence of geothermal resources that could be used for power generation. Specifically, the report recommends the following areas for further investigation:

- Lake Manyara area (possible high temperature resources present)

- Lake Eyasi area (initial tests indicate low temperatures at depth)
- Lake Natron area (possible high temperature resources present)
- Ngorongoro Caldera (possible high temperature resources present)
- Musoma area (initial tests indicate low temperatures at depth)

The report also recommended the following program:

- Inventorying existing reports, maps, photos, analyses and other available information including other geophysical surveys performed for water master plans and prospection for minerals and other natural resources
- Reconnaissance of other sites not investigated during the Virkir/SWECO/SIDA survey
- Geophysical surveys in three areas including (1) Lake Manyara, Lake Eyasi, Lake Natron and the surrounding areas, (2) a site 60 km east of Musoma in the Mara Region and (3) areas around Mt. Kilimanjaro and Mount Meru

3.3. Geothermal Resources of the Mbeya Region

Mbeya is located at the crossing of two arms of the East African Rift at latitude 9.00° south and longitude 33.30° east. The 1976 Icelandic/Swedish/Tanzanian team found a number of hot springs in the Mbeya region with surface temperatures up to 86°C. Chemical geothermometers indicated subsurface temperatures possibly as high as 220°C to 271°C. In 1983, a UNDP-funded geothermal mission came to Tanzania. The results of their visit suggested that additional geothermal studies be carried out in the Mbeya region for the following reasons:

- The Mbeya area is accessible
- Mbeya was considered to have good potential for industrial development
- The predicted subsurface temperatures suggested the existence of high enthalpy fluids

3.4. Tanzania Geothermal Exploration II Project Objectives

To move ahead with geothermal exploration and development in Tanzania, it is important to build on the work already done. Since the geothermal resources in both the Mbeya and Arusha regions are not confirmed, further exploration and analysis is required. These activities are included as part of the proposed Tanzania Geothermal Exploration II project, that will be hosted by the MEM and require the participation of private geothermal exploration companies and international donor support.

The objectives of Geothermal Exploration II program include:

- Upgrading of geologic, geochemical and geophysical information for the assessment of the spatial extent of geothermal prospects in the Mbeya and Arusha regions, using this information to establish a geothermal model and identifying high-probability borehole targets for drilling
- Identifying and testing, through drilling at selected sites, geothermal resources in one or more of the identified target areas
- Preparing technical and financial/investment plans for the installation of an appropriately sized geothermal power plant that will meet a portion of the increasing power demand in the country. Also, studying the feasibility of direct-use of the same geothermal resource(s) in industry and agriculture
- Increasing the number of Tanzanians within the public and private sectors with experience in geothermal resource testing, evaluation, project design and financing. Public sector trainees will come from within the MEM and Tanzania Petroleum Development Corporation (TPDC)

Project Description

The Tanzania Geothermal Exploration II will consist of two phases – A and B. The purpose of the studies in Phase A is to provide additional information about the likely spatial extent and structure of the reservoirs as well as to aid in selecting the sites of the first boreholes. Phase A will also provide the due diligence with regard to demand, legal and tax aspects of private power development. The evaluation of the geologic, geochemical and geophysical data and the feasibility study will proceed concurrently. If Phase A is successful, then Phase B will be initiated for drilling and feasibility assessment at one or more prospects.

Phase A includes two components as follows:

(1) Evaluation of geologic, geochemical, and geophysical data

- Evaluation of existing data
- Field checking existing data, interpretation and planning for drilling (Phase B)
- Geophysical surveys over key target areas to improve delineation of the resources and assist in reliable exploration well-targeting

(2) Feasibility study

- Electrical demand in western Tanzania (geothermal regions)
- Process heat (agricultural) demand in western Tanzania
- Legal, tax and other aspects related to private-power development

Phase B will consist of exploratory drilling, well testing and the preparation of a plan for the installation of a commercially-sized geothermal power plant that will meet a portion of the increasing power demand in the country. The decision to proceed to Phase B will depend on the results of Phase A.

Expected Outputs

Expected outputs of the Geothermal Exploration II program include:

- A feasibility study including legal and tax constraints and other requirements for a private power agreement.
- A demand study, including electricity generation and process heat.
- An evaluation of geothermal resources in three areas of Tanzania based on geology, geochemistry and geophysics.
- A reliable evaluation of the geothermal energy potential in one or more areas of Tanzania based on drilling.
- Establish a viable geothermal energy resource exploration and development capacity within the Geological Survey of the MEM.

Budget

In Phase A.1, the two known geothermal areas (Mbeya and Arusha) will be considered. Phase A will cost approximately US$500,000 and take 18 months to complete. These figures, however, assume that the detailed work planned for Phase A will only occur in only one of the prospects. If the results of preliminary work indicate that more than one geothermal field warrants detailed analysis, the budget for Phase A should be increased by approximately US$300,000 per additional field. Phase B will include the drilling of three boreholes in one of the geothermal prospects at a cost of US$5,000,000 and will take 18 months to complete.

Follow-on to the SWECO Study

In addition to the above, a proposal has been sent by the Department of Geology of the University of Dar Es Salaam for discussion purposes with the US Geological Survey to carry out geophysical studies of the areas that were recommended by SWECO in 1978 in order to achieve a better understanding of geothermal resources in the area and recommend sites for drilling. As proposed, the study would be carried out in three phases. Phase one would cover the Rungwe Volcanic Province prospects. Phase two would cover the geothermal prospects in the Rufiji basin and phase three would cover the Northern Tanzania (Arusha, Singida and Musoma) prospects. The projected cost is approximately US$400,000. (See Fig. 2 for prospect locations)

The Rufiji Prospect

In addition**,** First Energy Company Limited (FEC) of Dar es Salaam, a private company registered to operate in Tanzania since 1997, holds a geothermal energy exploration license in Rufiji district. Based on preliminary investigations using surface exploration, literature, geological, geophysical information and well data, FEC has established the likelihood of an economic geothermal resource in the Rufiji trough.

FEC has formulated a project consisting of production and injection well-drilling, steam gathering and processing facilities, a five-MW power plant and transmission line from Luhoi to Utete and from Kibiti and Ikwiriri. Total cost is estimated to be US$14.8 million. FEC plans to be a co-owner of the project and seeks to partner with one or more local or international geothermal companies or financiers.

3.8. Government Support

Geothermal exploration falls under the responsibilities of the renewable energy section of MEM. During a 1999 consultant mission, MEM indicated it would participate in a private sector-led initiative to carry out the research required to develop geothermal power to supply the national grid. Mr. K. R. Abdulla, TANESCO's Director of Corporate Planning, also indicated he would wholeheartedly support such a program. MEM further indicated it would welcome a cost-sharing agreement between a bilateral (or multilateral) donor agency and the government of Tanzania to carry out the preliminary geothermal exploration. If support to carry out such geothermal-related research in Tanzania were to be made available, MEM would be the counterpart agency. Ministry officials indicated they would enlist the assistance of the Tanzania Geological Survey as the operational entity.[23]

IV. POLICIES THAT RELATE TO PRIVATE SECTOR INVESTMENT

4.1. Private Power Development

The 2002 Revised National Energy Policy (not yet approved by the President's cabinet) seeks to attract private investment capital and increase efficiency. It also plans to divide TANESCO into separate segments, each individually responsible for power generation, transmission and distribution. Generation and distribution activities will be further divided into a number of companies to allow private participation and competition. Transmission will be maintained as a single entity for the short-to medium-term.

Although energy policy formulation and strategic planning remain in the hands of government, the Tanzanian government's involvement in the day-to-day operations of the power sector will decrease.

4.2. Government Policy

As stated in 1992, the Tanzanian government policy on geothermal energy states:

> Geothermal sources do exist in Tanzania. Active volcano centers, the rift system, numerous geological faults and hot water springs are an indication of the possible occurrence of the sub-surface steam or hot water reservoirs that may be used for the generation of power. The Olkaria geothermal development in the Kenyan part of the rift system has increased the possibility of this occurrence in areas of Tanzania adjacent to it.

[23]The Tanzania Geological Survey-an Executive Agency under MEM, is located in Dodoma, about 250 miles west of Dar es Salaam.

> Geothermal sources are expensive to develop. The capital expenditure on the initial investment is high and the mineral content of the hot water and steam is such that pollution can be a serious problem.
>
> With the large potential of hydropower, coal and natural gas, lesser priority will be accorded to the development of the geothermal resources in the immediate future except where exploitation of geothermal is the least-cost alternative to providing electricity to a location. Studies to assess the magnitude of this resource will however be undertaken.

The new 2002 (revised) Energy Policy recognizes the need to have a hydro-thermal energy mix that can respond adequately to drought possibilities. Currently, the mix is about 70 percent hydro and 20 percent thermal, which seems to provide a satisfactory level of confidence in the system. However, the present hydro-thermal ratio assumes a thermal capacity of 112 MW from Ubungo beginning in 2004.

The 2001 Power Sector Master Plan does not cover geothermal because there is insufficient data on the resource. Therefore, it is difficult to include it in master planning simulations. However, the Draft National Energy Policy does includes a number of references to geothermal energy and preparation of a Rural Energy Master Plan (to be supported by the African Development Bank) will incorporate studies on geothermal potential.

4.3. Duties, Fees, Licenses, Permits and Tax

Foreign companies must be registered in Tanzania by the Business Registration and Licensing Authority (BRELA). There is no legal restriction on foreign companies making loan or equity investments in Tanzania provided the funds to be invested are free from criminal sources. However, for protection and other investment incentives, registration with the Tanzania Investment Centre is recommended.

Before July 1998, the electricity tariff levels were subject to a five-percent sales tax per unit and the same tariff blocks applied across the country regardless of the cost of supply. The rates depend on the total consumed during the one month. Tariff restructuring was implemented between April and May 2002. Cross-subsidies have been eliminated, and a new tariff structure has been put in place.

The withholding tax on interest is 15 percent for non-residents and 20 percent on dividends. Holders of a Certificate of Incentives pay zero percent interest and a withholding tax of ten percent on dividends.

With the liberalization of the financial sector, a number of private local and foreign banks are now operating in Tanzania. The private banks include: CRDB Ltd, Stanbic Ltd, CITIBANK Ltd, Kenya Commercial Bank, Standard Chartered Ltd, EuroAfrica Bank Ltd, East African Development Bank, Tanzania Investment Bank, Tanzania Development Finance Ltd, First Adili Bank Ltd, Akiba Commercial Bank, Ltd, Ex-Im Bank Ltd, Trust Bank Ltd and Bank of Malaysia. The Tanzanian Shilling is freely convertible and has been relatively stable against the dollar since 1994. Occasionally there are shortages of foreign exchange. Repatriation of all capital, profits, dividends, royalties and loan servicing is permitted.

Tanzania is a member of multilateral arbitration agencies in case of disputes concerning investors, notably the World Bank's Multilateral Investment Guarantee Agency (MIGA) and the international Center for Settlement of Investment Disputes (ICSID).

For up to date information on business conditions and registration procedures, see http://www.cats-net.com/tic/bizguide.htm.

IV. CONTACT INFORMATION

1. Local Power Company

Mr. K. R. Abdulla,
Director of Corporate Planning and Research,
Tanzania Electric Supply Co. (TANESCO),
Samora Avenue, 3rd floor,
P.O. Box 9024,
Dar es Salaam, Tanzania
Tel. 255-51-114981, 122213
Residence 255-51-120560
Fax 114 981, 113 836

2. Ministry of Energy

Mr. Bashir J. Mrindoko
Commissioner for Energy and Petroleum
Ministry of Energy and Minerals
Corner of Mkwepu/Sokoine Drive,
P.O. Box 2000,
Dar es Salaam, Tanzania
Tel. 255-51-117153 ext. 224, or 0255-22-2139455
Fax 255-22-2120799
Residence: 255-22-2843140
Mobile 0748-784958
Email: bashir-mem@raha.com, or mrindoko-mem@raha.com

Mr. C. X. Mwihava,
Assistant Commissioner for Renewable Energy
Ministry of Energy and Minerals
Renewable Energy Section
Corner of Mkwepu/Sokoine Drive
P.O. Box 2000
Dar es Salaam, Tanzania
Tel. 255-22-2119158
Mobile: 0741 261367
Fax 255-22-2120799
Email: mwihava-mem@raha.com

Mr. Aloyce L. Tesha, Geologist,
Ministry of Energy and Minerals
Corner of Mkwepu/Sokoine Drive
P.O. Box 2000
Dar es Salaam, Tanzania
Tel. 255-22-2150547
Mobile: 0811-332874
Fax: 255-22-2116719
Email: madini-unido@raha.com

3. Geological Survey

Mineral Resources Department (MRD),
Ministry of Energy and Minerals,
P.O. Box 903,
Dodoma, Tanzania

Tel. 255-61-24943
Fax 255-61-24943
Email: mrd@twiga.com

4. Ministry of Finance or Investment Authority

Tanzania Investment Centre,
No. 9 a & b Shaaban Robert Street,
P. O. Box 938,
Dar es Salaam, Tanzania
Tel. 255-22-2113365 or 255-22-2116328/32
Fax 255-22-2118253
Email: information@tic.co.tz
Website: www.tic.co.tz

Mr. P.A Mwafongo
Assistant Commissioner – External Finance,
Ministry of Finance,
P.O. Box 9111,
Dar es Salaam, Tanzania
Tel. 255-22-2111174/6
Fax 255-22-2110326

5. Interested Multilateral Agencies

None currently listed

6. Interested Bilateral Agencies

Ralph Karhammar, (Tanzania responsibility) Embassy of Sweden,
Mirambo Street/ Garden Ave. PO Box 9274,
Dar es Salaam, 22 Tanzania
Tel. 255-22-2111235
Fax 255-22-2113420
Email: ralph.karhammar@sida.se

Anders Hagwall, (Regional Advisor),
Embassy of Sweden,
Mirambo Street/Garden Ave.,
PO Box 9274,
Dar es Salaam, 22 Tanzania
Tel. 255-22-2111235
Fax 255-22-2113420
Email: anders.hagwall@sida.se
Website: www.swedemb-dar.com

7. US Embassy

Ambassador Robert V. Royall
36 Laibon Road
P. O. Box 9123
Dar es Salaam, Tanzania
Tel. 255-51 66010 through 66015
Fax: 255 51 66701

VI. MAP OF COUNTRY GEOTHERMAL PROSPECTS AND GRID

Figure 2: Map of Tanzania Illustrating Areas of Geothermal Interest (Mbeya, Rufiji, Ngorongoro, Singida, Arusha and Musoma)

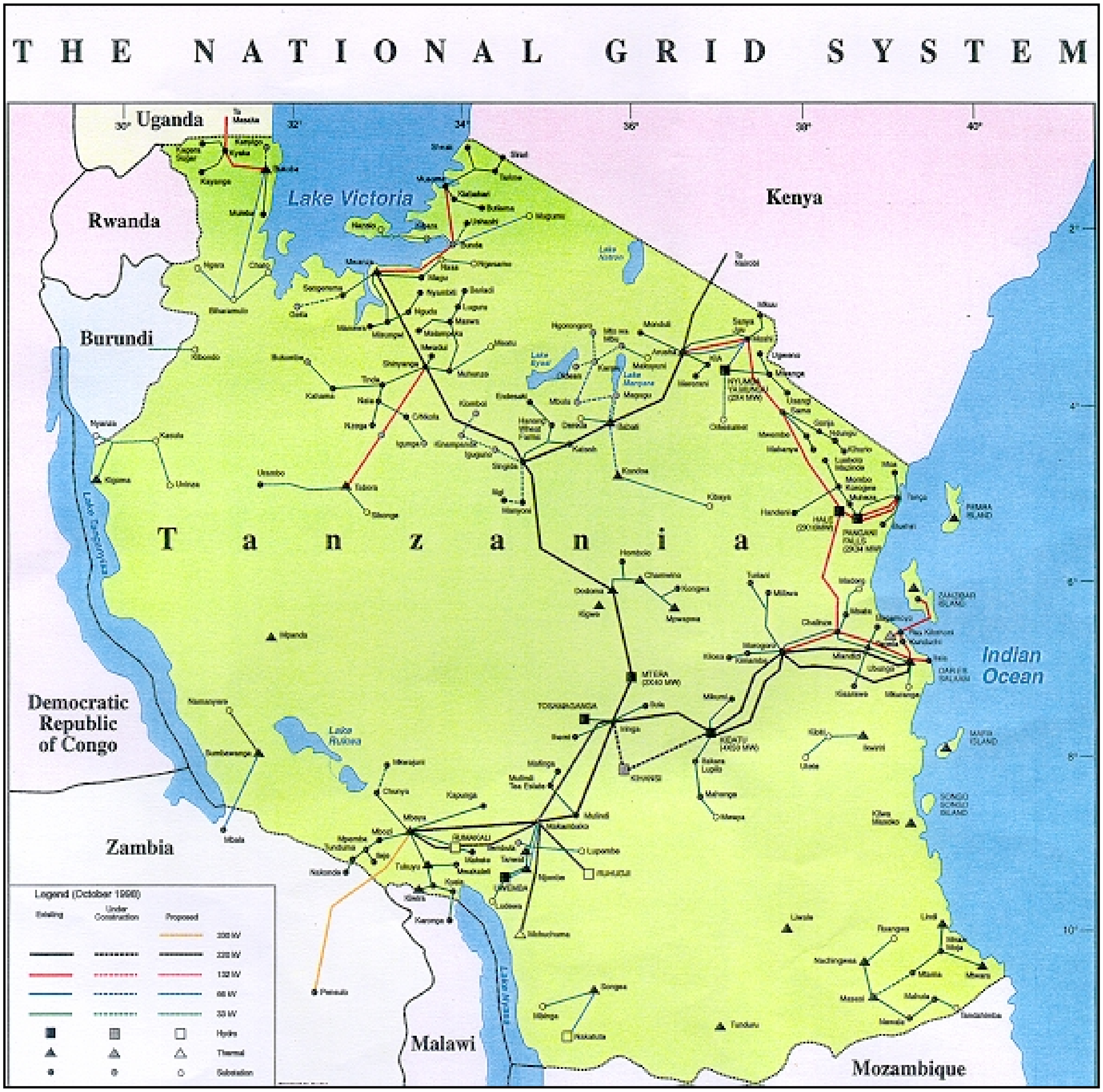


Figure 3 Tanzania Electricity Grid

VII. DETAILED REPORTS AND MAPS OF GEOTHERMAL AREA(S)

The 1976-9 SWECO/Virkir/SIDA report could not be located in Dar es Salaam by a US consultant in July 1999 nor in January 2003. This document should be obtained from either Virkir-Orkint or SIDA for further review and analysis. The SWECO/Virkir/SIDA document is reported to recommend (a) reconnaissance missions to sites that were not visited by the team, (b) measurement of the geothermal gradient in available wells throughout the country, (c) resistivity analyses at the most promising sites, (d) aeromagnetic reconnaissance surveys and (e) micro earthquake surveys at volcanoes that might be associated with geothermal reservoirs.

VIII. REFERENCES

Abdallah O. Kigoda (M.P.), (May 1999). "Power Sector Policy and Development in Tanzania." Paper presented to The African Energy Forum Power May 2000 Meeting, Amsterdam.

Acres International, (June 1998). *Update of Least Cost Power Development Plan.*

Fairhead J.D., (1979). *The Structure of the Cross-Cutting Volcanic Chain Of Northern Tanzania and is Relation to the East African Rift System*. Department of Earth Sciences, University of Leeds, UK.

Government Printer of the United Republic of Tanzania, (1992). *The Energy Policy of Tanzania,* Ministry of Water, Energy and Minerals, Dar es Salaam.

Hirsch, S., (1994). "Tanzania Trip Summary", report for US/ECRE-sponsored Renewable Energy Program in Tanzania.

Hirsch, S. (1999). "Tanzania Trip Summary", report for INEEL/DOE, July 1999.

Hitab International Tatedo, (1998). *Tanzania Rural Energy Study*. Tatedo, September 1998.

Kjellstrom, B., Katyega M., H. Kadete, Noppen D., and A. Mvungi (1992). *Rural Electrification in Tanzania. Past experiences - New approaches.* Stockholm Environment Institute in collaboration with Swedish International Development Authority, Stockholm, Sweden.

Luhanga B.E.A.T., (1999). "Tanzania Electricity: Current Status and Future Prospects." Paper presented to The Africa Energy Forum Power May 2000 Meeting, Amsterdam.

Makundi, J.S., and Kifua G.M., (1985). *Geothermal Features of the Mbeya Prospect in Tanzania*. Ministry of Energy, Waters and Minerals, Dar es Salaam.

Mwihava N.C.X., and Towo, A., (1994). *A Study and Assessment of Energy Projects and Their Effective Utilization in Tanzania,* Tanzania Commission for Science and Technology (COSTECH), Dar es Salaam.

Nielson, D.L., (1989). *Report On Geothermal Mission To The United Republic Of Tanzania - Concept For Geothermal Assessment And Development*. University of Utah Research Institute, USA.

Saint P.K., (1975). "East African Rift Valleys - Tectonic Setting for New Geothermal Development, Geothermal Energy Magazine, May." *The East African*, July 7, 1999.

South African Development Coordination Conference (1990). New *and Renewable Sources of Energy in Tanzania,* SADCC, Energy sector technical and administrative unit (TAU), Luanda, Angola.

Tanzania Commission for Science and Technology (1994). *Proposed Work Programmes and Budget for the Fiscal Year 1994/95,* Tanzania Commission for Science and Technology, Dar es Salaam.

The Centre for Energy, Environment, Science and Technology (CEEST), (1992). *The Centre's Objectives and Core Research Programmes.* CEEST, Dar es Salaam.

Thouin, T., Kalala and Mondeguer, (1989). "Discovery of Sublacustrine Hydrothermal Activity and Associated Massive Sulfides and Hydrocarbons in the North Tanganyika Trough, East African Rift." *Geology*, vol. 17, pp. 1053-1056.

Unknown (1998). *A Framework for a National Programme to Promote Renewable Energy Technologies and Energy Conservation*.

ZAMBIA COUNTRY GEOTHERMAL REPORT

Figure 1: Map of Zambia

1. COUNTRY OVERVIEW

1.1. Geography, History, Government Structure and Population

Zambia is a land-locked country. It shares borders with Zaire to the north, the United Republic of Tanzania to the northeast, Malawi to the east, Mozambique to the southeast, Zimbabwe to the south, Botswana and Namibia to the southwest and Angola to the west. The country is located on a high plateau in central Africa and covers a land surface area of 752,620 km^2. It is made up of three main topographic parts: mountainous range, high plateau and low valley areas.

Zambia (previously known as Northern Rhodesia) was part of the Federation of Southern Rhodesia from September 1953 to December 1963. The Zambian people gained self-rule from the British on October 24, 1964. Since then, the country has undergone three major phases of governance. During the post-independence era, the country was ruled by multi-party politics until 1971, when a one-party system was introduced. This second system of governance was brought to an end in October 1991 when the multi-party system was re-established. Zambia's current President and Chief of State is Levy Mwanawasa. Mwanawasa was democratically elected by popular vote in January 2002 for a five-year term and is head of the Movement for Multiparty Democracy's party. He is Zambia's third president.

Administratively the country is divided into nine provinces: Central, Copperbelt, Eastern, Luapula, Lusaka, Northern, North-Western, Southern and Western provinces. These provinces are further divided into 72 districts that are each run by a district council that administers the local government. The district councils are classified into three categories: city councils, municipal councils and township councils. There are four major cities in Zambia: Lusaka, Ndola, Kitwe and Livingstone. Lusaka is the capital city of Zambia and seat of the country's central government.

The population of Zambia has grown from an estimated 7,759,167 in 1990 to 10,285,631 in 2000.[24] Copperbelt province has the highest population followed by Lusaka, Northern, Southern and Eastern provinces. North-Western province has the lowest population.

The official language in Zambia is English, although other major dialects include Bemba, Kaonda, Lozi, Lunda, Luvale, Nyanja and Tonga.

1.2. Economy

Zambia is one of the most urbanized countries in Sub-Sahara Africa with approximately 40 percent of the population living in urban areas. The remaining 60 percent of the population are scattered throughout the rural parts of Zambia, working the country's relatively infertile soil as subsistence farmers. Commercial agriculture is confined to a small number of large farms. Approximately 23 percent of Zambia's economy comes from agriculture, 40 percent from industry and the remaining 37 percent from the service sector.

Between 1964 and 1991, Zambia's socialist government controlled the majority of the country's social and economic activities. Following the successful establishment of a multi-party system in 1991, Zambia changed tracks and embarked on a vigorous Structural Adjustment Program. With the backing of the World Bank, the Structural Adjustment Program was created to help address the country's economic imbalance through privatization and budgetary reform. Despite progress in these areas, Zambia's economy still has a long way to go. Inflation, while slowing, continues to be a major concern at around 40 percent, and Zambia's copper mining sector, which accounts for over 80 percent of the nation's foreign currency intake, is struggling. The long-term goal of the Structural Adjustment Program is to reduce inflation and stabilize the economy to stimulate economic growth, reduce poverty and improve living standards. Current activities under the Structural Adjustment Program include:

- Privatization of state-owned companies
- Liberalization of domestic and international trade
- Liberalization of the foreign exchange market
- Strong fiscal policy to reduce inflation
- Health and education sector reforms, which include the introduction of user fees
- Transformation of the civil service
- Transformation of the agriculture and transport sectors

The economy in Zambia has been turned from a state-controlled economy to a market-led economy and now boasts a fully operational stock exchange. The economy also registered a growth of 5.2 percent in 2001 compared to 3.6 in 2000. This was due in part to the strong growth of the wholesale and retail trade, manufacturing and mining sectors in 2001. The electricity, gas and water sector's real output also grew in 2001 from K72.9 billion (approximately US$14 million) to K82.1 billion (approximately US$16 million), representing an increase of 12.5 percent. Below is a table showing key macroeconomic targets and results for Zambia economy in 2001:

Table 1: Key Macroeconomic Targets and Results, 2001

Indicator	target	outputs	difference
GDP growth rate (percent)	5.0	5.2	0.2
Money supply growth rate (percent)	20.5	11.0	(9.5)
Inflation rate (percent)	17.5	18.5	1.0
International reserves US $ million	150	74	(76)
Fiscal deficit (percent GDP)	0.75	2.4	1.65

Source, Economic Report 2001, Ministry of Finance and National Planning

[24] Current census data shows the population growth rate at 2.2 percent (2000).

1.3. Political and Social Issues

Sustaining economic reform through the Structural Adjustment Program, achieving consistent growth and bringing tangible benefits to Zambia's people are the central concerns of the government. However, a steep decline in copper revenues, the heavy debt burden and the diminished flow of external aid have limited the Zambian government's ability to reduce poverty. The lack of access to electricity is also a significant factor in preventing growth in rural productivity and income generating activities. In the majority of rural and peri-urban areas, people use kerosene for lighting and commercial farmers use diesel-powered irrigation.

II. COUNTRY ENERGY CONTEXT

2.1. Electricity Sector

Overview

The development of the electricity system in Zambia began in the 1930s with isolated systems owned by individual municipalities supplying power. The most elaborate systems were owned by the copper mining companies on the Copperbelt, which operated coal-powered thermal stations for mining operations. These power stations were later interconnected to the Congolese system to improve reliability and to access hydropower from the Congo that would act as a standby power system.

A major milestone for Zambian electricity transmission was the development of the Kariba scheme in the late 1950s. This involved the construction of the Kariba dam, a 600-MW power station on the south bank and a 330-kV transmission system on the north bank. The transmission line targeted the cooper mines in Zambia. This scheme was operated by a federal agency known as Central African Power Corporation (CAPCO) while the Copperbelt system continued to operate as a subsidiary of the mining companies.

Today, the electricity industry in Zambia is comprised of four electric utilities: (a) the Zambia Electricity Supply Corporation (ZESCO), a parastatal vertically integrated utility that went up for privatization in 1999; (b) Copperbelt Energy Corporation (CEC), (formerly ZCCM-Power Division) a relatively new privately owned utility whose shareholders are the National Grid Company of the UK, Cinergy from the US, the Government of Zambia and a Zambian management team; (c) Kariba North Bank Company (KNBC), a state-owned generation company that until recently was run under leasehold to ZESCO; and (d) Lunsemfwa Hydro Power Company (LHPC).

ZESCO generates, transmits, distributes and supplies power to consumers and owns and operates the Kafue Gorge power station, the Victoria Falls power station and the majority of Zambia's transmission and distribution networks. ZESCO also supplies bulk power to CEC and CEC distributes this power to the mines in the Copperbelt province. The CEC also owns and operates 80 MW of standby gas turbine generation. CEC aggregates these sources of power and transports it through its control center and transmission system to provide a higher reliability of supply to the copper mines. In addition, CEC's network is used to distribute power to ZESCO's retail customers in the Copperbelt province. KNBC operates the 600 MW Kariba North Bank power station.

The LHPC is a private investor and management team. It recently acquired two relatively small hydro facilities at Mulungushi and Lunsemfwa at Kabwe in the Central province from Zambia Consolidated Copper Mines (ZCCM), a state-owned company. The infrastructure consists of the Lunsemfwa and Mulungushi power stations located to the east of Kabwe, transmission lines into Kabwe and a small distribution system that supplies two industrial loads and some townships within Kabwe. The network infrastructure under the Mulungushi and Lunsemfwa facilities is under negotiation for sale to ZESCO.

South African Power Pool (SAPP)

Zambia is also member of the South African Development Community (SADC). Central to the SADC's energy program is the South African Power Pool (SAPP), under which the member states are linked into a single electricity grid. The SAPP consists of 12 national utilities: ENE of Angola, BPC of Botswana, SNEL of the Democratic Republic of Congo, LEC of Lesotho, Escom of Malawi, EdM of Mozambique, NamPower of Namibia, Eskom of South Africa, SEB of Swaziland, Tanesco of Tanzania, ZESCO of Zambia and ZESA of Zimbabwe. SAPP was formed in 1995 and allows member countries to source electricity in bulk and redistribute it nationally at cheaper prices. Zambia's location and landlocked status makes it an important link to the SAPP.[25]

The SAPP is not the only way that Zambia is encouraging growth and development of its electricity market. Through the country's Structural Adjustment Program, the government is also promoting the entry of private companies in the Zambian power sector through the amendment of the legislation that affects generation, transmission, distribution and supply of electricity. At present, the government has focused on pushing the following projects as opportunities for private sector finance:

- Kafue Gorge Lower Hydro-electric project
- Itezhi-Itezhi Hydro-electric project
- Zambia-Tanzania Interconnector
- Zambia-Namibia Interconnector

2.2. Electricity Capacity and Demand

Zambia has an installed capacity of 1,774 MW with a peak load of 1,028 MW. Of that over 1,600 MW comes from hydropower developed by the Zambian government during the ten-year period between 1966 to 1976. The remaining fraction of electrical power is from fossil fuels. The three major hydroelectric power stations in Zambia are: Kariba North Bank (600 MW), Victoria Falls (108 MW) and Kafue Gorge (900 MW). There are also six small hydropower stations: Lisiwasi, Chishimba falls, Musonda falls, Lunzua, Mulungushi and Lunsemfwa, that contribute to the national grid and supply outlying areas. The distribution of hydroelectricity is mainly concentrated in Livingstone, Lusaka and the Copperbelt towns.

In spite of Zambia's surplus availability of electricity, only about 20 percent of the total population has access to electricity and only two percent of the rural sector has access to the national grid. General consumption of electricity by sector is as follows:

- Agriculture and Forestry - one percent
- Commerce and Industry - four percent
- Mining - 60 percent
- Household - 30 percent
- Government and Services - five percent

The majority of all electricity is need by the copper mines on the Copperbelt.

Over the last ten years, there has been a reduction in demand for electricity from the Zambian manufacturing industry from 622 GWh in 1991 to only 260 GWh in 2001. Failures to adapt to the market liberalization policies of country's new Structural Adjustment Program reduced productivity drastically. Despite this reduction, future electricity demand forecasts still suggest that Zambia could run out of its installed capacity within the next ten years. These estimates are based on increasing levels of electricity consumption as a result of the government's plans to set up tax-free zones to help promote exports and rejuvenate industry. If the status quo were maintained, Zambia would continue to have excess capacity until the year 2020.

The best way to look at the energy demand for Zambia is to consider the SAPP and to consider Zambia's highly competitive position in this regional market. All the members of SAPP are interconnected and the projected electricity demand for southern African countries is tabulated in Table 3 below:

[25] It is surrounded by Tanzania, Angola, Mozambique, Botswana, Zimbabwe, Malawi and the Democratic Republic of Congo.

Table 2: Estimated Electricity Demand Forecast for Southern Africa in MW

Country		**2000**	**2005**	**2010**	**2015**	**2020**
Botswana	Demand Surplus/(deficit)	301 (238)	443 (380)	674 (611)	832 (769)	1,027 (964)
DR Congo	Demand Surplus/(deficit)	1,003 1,400	1,189 1,218	1,405 998	1,573 830	1,762 641
Mozambique	Demand Surplus/(deficit)	221 1,686	286 1,621	369 1,538	417 1,490	472 1,435
Namibia	Demand Surplus/(deficit)	341 (11)	531 (201)	868 (538)	1,102 (772)	1,400 (1,070)
South Africa	Demand Surplus/(deficit)	30,301 5,802	31,883 4,220	33,548 2,555	35,301 802	37,147 (1,044)
Tanzania	Demand Surplus/(deficit)	517 (22)	669 (174)	945 (450)	1,264 (769)	1,692 (1,197)
Zambia	Demand Surplus/(deficit)	1,143 465	1,190 418	1,241 367	1,309 299	1,393 215
Zimbabwe	Demand Surplus/(deficit)	2,090 (682)	2,393 (985)	2,741 (1,333)	3,101 (1,693)	3,509 (2,101)
Total surplus/(deficit)		**8,400**	**5,737**	**2,526**	**(582)**	**(4,085)**

Source: SAD ELEC

Using these figures, southern Africa will be running an electricity deficit by 2012, with South Africa, Zimbabwe and Tanzania most adversely affected. These deficits will have to be offset by new generation projects, and the Zambian Government is currently in talks with the governments of Tanzania and Kenya to discuss the establishment of new interconnectors. These will connect the Zambian grid to the Tanzanian grid and the Tanzanian grid to the Kenyan grid. If all goes to plan, this will allow an IPP in Zambia to export power to both Southern and Eastern Africa.[26]

2.3. Competing Resource Options

Zambia has vast water and coal reserves (estimated at 80 million tons), and renewable sources of energy such as biomass (estimated 14 million m^3 of wood fuel annually) solar and small hydropower. Together these resources offer abundant investment opportunities for small and large power generation, supply and distribution. In the North-West province, there are a number of small hydro sites that have been identified as suitable for developing a mini-grid system and providing electricity to towns currently supplied by small diesel generators.

Zambia has been a major exporter of electricity to neighboring countries, averaging 1.47 billion KWh per year. The country's only major energy import is petroleum, which is approximately 12,000 barrels per day (1998 Figures). Zambia also operates its own pipeline-fed oil refinery at Ndola, with a capacity 1.1 million tons per year (7.7 million barrels per day). While there have been no discoveries of oil or gas reserves, the Indeni Refinery in Ndola provides most of the petroleum products required by the local market and for export.

2.4. Rural Electrification

To increase the rate of rural electrification and create conditions favorable in the development of rural areas, in 1994 the Zambian government created a Rural Electrification Fund (REF) by committing 3.45 percent of the sales tax on electricity to expanding the electricity network to rural areas.

[26] Current discussions surround the construction of a 200 km, 123 kV transmission line between the Western province of Zambia and parts of Namibia that will be financed by the African Development Bank (US$6.5 million) and the Development Bank of Southern Africa (US$4.5 million). Norway has also awarded Zambia a US$13 million grant for the rehabilitation of ZESCO's transmission system and the World Bank approved a US$75 million grant for rehabilitation of Zambia's electricity infrastructure.

In order to establish a system of administering the REF and prioritizing projects, the government created the Rural Electrification Fund Committee. The Permanent Secretary, from the Ministry of Energy and Water Development with the Department of Energy, serves as the Secretariat Chair for the REF Committee. Other members of the committee are drawn from Ministry of Finance and National Planning, Ministry of Local Government and Housing, Engineering Institution of Zambia and ZESCO, the implementing agency. The committee's terms of reference are as follows:

- To ensure that the funds are used solely for the intended purpose
- To apportion and authorize the disbursement of amounts agreed upon for each project
- To achieve and review progress reports for each project
- To receive and consider new projects keeping in mind the financial resources and progress made on on-going projects
- To provide guidance to ZESCO in the implementation and management of the rural electrification program

The implementation of the REF, however, has so far been restricted to national electricity grid extension in most cases and this has excluded a lot of people who are either far from the grid or do not benefit from transmission lines that run nearby.[27] The funding and administration of REF is also characterized by a number of problems, primarily caused by the current low demand for electricity and the subsequent reduced level of funds raised from the tax. The delays in transferring these funds between the respective government organizations has also caused problems for rural electrification projects,[28] and the use of ZESCO as the sole agent has further hindered the process by reducing the scope for competitive bidding on projects.

The government of Zambia is highly conscious of the need to increase access to electricity throughout the country to help alleviate poverty, among other things. As such, it has set a goal to increase energy access from 20 percent to 50 percent by the year 2010 through a proposed rural electrification project. The government has offered this to the World Bank and is currently seeking US$120 million to implement the project.

The project will include the extension of the grid to peri-urban areas, mini-grid systems and solar home systems. A master plan for electrification is going to be prepared, taking into consideration the most effective way of electrifying each and every part of the country. A unit called the Rural Electrification Agency (REA) will be set up to operate independently and award contracts to the most competitive bidder. This is expected to end the monopoly of ZESCO as the sole rural electrification contractor. The REA will also be responsible for mobilizing resources from the government, the private sector and donors. Legislation is currently prepared to support the existence of the REA.

Table 3: Members of the SAPP and Related Access to Electricity

Country	Percent of population with access to electricity	Population (millions)
Angola	-	-
Botswana	33	1.0
Lesotho	-	1.0
Malawi	2.5	9.0
Mozambique	6	14.0
Namibia	-	-
South Africa	68	38.0
Swaziland	22	0.7

27 The main transmission lines run from the southern part of the country to the Copperbelt to supply electricity to the mines. Voltage is only stepped down in towns, not in villages.

28 The tax charged on the electricity industry is collected through the Zambia Revenue Authority and deposited into the national treasury. The Ministry of Finance and National Planning transfers these funds to the Ministry of Energy and Water Development. In most cases, the full amount of money collected for rural electrification is not transferred to the sector Ministry.

Country	Percent of population with access to electricity	Population (millions)
Tanzania	8.0	31.0
DR Congo	2.0	51
Zambia	20	10
Zimbabwe	24	12

III. GEOTHERMAL RESOURCES AND DEVELOPMENT

3.1. Overview

Hot springs have been known to exist in Zambia for a long time and over 80 have been recorded throughout the country. The earliest description is in 1889 when the springs on the southern edges of Lakes Mweru Wantipa and Chishi were observed (Legg, 1974). Ferguson (1902) made chemical analyses of springs in the Zambezi Valley and attempted to relate them to mineral occurrences. Guernsey (1941) compiled data on hot springs from different sources and listed 31 geothermal occurrences in the Luangwa concession area. Since 1950, the Geological Survey of Zambia, the Department of Water Affairs and mining companies have examined various springs during routine regional mapping exercises.

In 1986, the Zambian Geological Survey Department of the Ministry of Mines in collaboration with DAL SpA of Italy, surveyed 90,000 km^2 of the Zambian territory, visiting over 80 spring sites and studying 40 of the most promising springs in detail.[29] The geothermal explorations focused on 11 prospects in Kapisya, Kaputa, Lupiamanzi, Lubungu, Chongo, Nabwalya, Musaope, Chikowa, Chinyunyu, Mafwasa and Kasho and included geology, photogeology, and geochemistry explorations, Redon surveys, geophysics (electric) and drilling operations.

After taking into consideration a series of factors, including geothermal potential, desirability of developing particular sites and accessibility, a list of seven priority sites were selected for development as possible pilot demonstration projects. They were: Kasho, Lubungu, Lupiamanzi, Chinyunyu, Chikowa, Kapisya and Chongo. To date, development has been considered at only two of the seven prospects: (a) the Kapsiya geothermal project; and (b) the Chinyunyu hot springs project.

3.2 The Kapsiya Geothermal Project

The Kapsiya geothermal project is located in Sumbu on the shores of Lake Tanganyika. Following further evaluation of the site by the Zambian Department of Geological Survey and DAL SpA of Italy, two turbo-generators were installed. Although the turbines were examined and cleared by inspectors from the Italian government in 1988, a transmission line to sumbu was never constructed training of local technical personnel in the maintenance and operation of the plant never occurred. The construction of the transmission lines to carry the electricity to the surrounding communities and to boost the fishing and tourist industries was delayed due to insufficient funds.[30]

The Kapsiya plant which is owned by the government of Zambia has been dormant for 15 years. After construction by the Italians, the plant was first turned over to the Ministry of Energy and Water Development for operation and then handed over to ZESCO. The Zambian government is now exploring different options for commissioning and refurbishing the plant which will include the following work:

---

[29] As part of the 1984 Bilateral Agreements between the governments of Zambia and Italy, the Italians agreed to finance a study to examine and demonstrate the feasibility of using Zambia's geothermal resources for the generation of electricity. The Italian firm DAL SpA was assigned the task of undertaking the study and providing a practical demonstration of their proposed system by installing two geothermal-powered electric turbogenerators in the more remote parts of Zambia.

[30] *N.J. Money, Zambian Geological Survey. Taken from* IGA News #17 - April-June 1994. *(Also see the IGA Home Page)*

- Inspection of the plant and commissioning the turbo-generators by replacing all the missing and faulty parts in order to conduct trial runs to determine whether the plant can run
- Training of local technical personnel in the maintenance and operation of the geothermal plant
- Constructing a transmission line from the geothermal plant to Nsumbu to supply power to consumers
- Forming a consortium of the civil society and the private sector in Nsumbu to run the power plant on behalf of the government of Zambia

If the plant is found to be obsolete the project will not proceed. The availability of suitable spare parts will also be an important factor that will have to be considered. Some parts will require replacing, some have outlived their usefulness and others have been vandalized. Once the plant has been commissioned, the construction and commissioning of the transmission line from the plant to Nsumbu will have to be completed. As the proposed budget below indicates, the construction of the transmission line is the most expensive part of the overall project.

Table 4: Kapsiya Geothermal Project Budget

Activity	**Total Cost (US$)**
Plant commissioning	110,000
Training of personnel	30,000
Formation of consortium	5,000
Construction of transmission line	2,000,000
Commissioning of line	2,000
Total Cost	**2,147,000**

3.3. Chinyunyu Hot Springs Project

A second geothermal project involves the development of a health resort and the potential construction of a geothermal power plant providing cheap electric power to the local community at the Chinyunyu Hot Springs, 50 km east of Lusaka on the Great East Road. This project was being undertaken by the Japanese International Cooperation Agency (JICA) in conjunction with the Zambian Geological Survey, but has not progressed beyond the planning stages due to a lack of funds.[31]

3.4. Other Applications

Geothermal hot springs in Zambia could also be used for domestic applications. However, the technology is not yet available in Zambia to make the heat from the hot springs accessible for domestic applications, like space heating and cooking. The following is a list of springs that have been identified with their associated surface temperatures:

- Kapisya (85^{o} C)
- Kaputa (51^{o} C)
- Lupiamanzi (73^{o} C)
- Lubunga (77^{o} C)
- Chongo (87^{o} C)
- Nabwalya South (67^{o} C)
- Musaope (60^{o} C)
- Chikowa (64^{o} C)
- Chinyunyu (60^{o} C)
- Mafwasa (60^{o} C)
- Kasho (72^{o} C)

3.5. Government Support

[31] http://geoheat.oit.edu/bulletin/bull17-1/art7.htm.

Beyond the 1986 Department of Geological Survey and DAL SpA study, little has been done to identify Zambia's geothermal resources, and there are few maps available that indicate the actual location of the geothermal sites. During the survey conducted by DAL SpA, a map was produced indicating the location of the hot springs, which were investigated. This map is available from the Geological Survey Department, although it does not appear on the official list of publications.

3.6. Laws and Regulations

Geothermal resources are considered minerals and the responsibility of the Geological Survey Department within the Ministry of Mines. This Department conducts all exploration work and maintains records of potential geothermal energy resources in the country. However, when a geothermal power plant is developed the Ministry of Energy and Water Development also must be involved. In the case of Kapisya, the exploration work and the installation of the plant were overseen by the Geological Survey Department.

3.7. Infrastructure

The road infrastructure in the rural parts of the country is poor, especially during the rainy season from November to April when most of the bridges are impassable. The road leading to Kapisya Geothermal plant is bad throughout the year, and the best means of transport is to use a boat on Lake Tanganyika.

Below is a list of some sites that were investigated by A. C. Legg in 1974 with the distances to the nearest power line:

Site	Distance to the grid (km)
Kapisya	120
Kaputa	130
Lupiamanzi	60
Lubunga	90
Chongo	100
Nabwalya South	100
Musaope	30
Chikowa	40
Chinyunyu	40
Mafwasa	80
Kasho	50

IV. POLICIES THAT RELATE TO PRIVATE SECTOR INVESTMENT

4.1. Overview

Private power company involvement in Zambia's power sector is governed largely by the following legal instruments: (a) the National Energy Policy (1994) and the Energy Regulation Act (1995) which establish an Energy Regulation Board (ERB); and (b) a the Electricity Act (1995) that permits private investment in the power sector.

The National Energy Policy defines the framework for sector restructuring, transparent legislation and regulation and liberalization of entry. It also sets strategic objectives for improving accessibility to electricity by the majority of people and promoting electrification of productive areas and social institutions. The government took a major step in 1994 by creating a Rural Electrification Fund financed by a three-percent sales tax on all electricity consumption.

In May 1999, the government published "Framework and Package of Incentives for Private Sector Participation in Hydropower Generation and Transmission Development." An Office for Promotion of Private Power Investment was set up under the Ministry of Energy and Water Development to implement the framework.

In June 2001, a cabinet decision was made on the steps needed to divest the government's interest in ZESCO. The steps include: (a) the Zambia Privatization Agency (ZPA) undertaking the necessary studies to enable the private operation and management of ZESCO; (b) identification and establishment of suitable modalities for peri-urban and rural electrification; and (c) regulatory capacity building.

4.2. Guarantees

In October 1998, the government released the framework and package of incentives for private sector participation in hydropower generation and transmission development, which included a set of security features. Although these incentives were meant for hydropower stations, most of them can also apply to other types of power stations, such as geothermal. The security package includes the following features:

- Model Implementation (Concessions) Agreement (IA), PPA and Transmission Service Agreements (these will be prepared by the Office for Promoting Private Power Investment and eliminate the need for protracted negotiations between the government and project sponsors)
- For transmission projects, the long-term Transmission Service Agreements shall be guaranteed by the government for performance obligations of the utilities where appropriate
- For private power projects, the Implementation Agreement shall, among other things, provide for: Force majeure; Changes in certain taxes; and Convertibility of the Kwacha and remittability of dividends and equity

4.3. Customs, Sales and Tax Incentives

Special incentives such as exemption from customs duties, sales duties and sales taxes on machinery and equipment (other than motor vehicles) required for the establishment, rehabilitation or expansion of eligible enterprises are open in Zambia to:

- exporters of non-traditional products which result in net foreign exchange earnings
- producers of products used locally in agriculture
- enterprises engaged in tourism resulting in foreign exchange earnings of 25 percent of their gross annual earnings
- import substitution industries and enterprises located in rural areas

See http://www.comesa.int/states/zambia/qzaminlg.htm and http://www.zic.org.zm/IPA_Information.asp?hdnGroupID=2&hdnLevelID=1 for complete investment information.

4.4. Foreign Investment Laws

All foreign investors are required by law to obtain an Investment Certificate from the Zambia Investment Center. Investors seeking to obtain an investment certificate to set up new business or expand, rehabilitate and modernize an existing enterprise in Zambia are required to complete a standard application form (obtainable free of cost) and submit it to the investment center once the following requirements are met:

- Processing fee of K1,280,000 (equivalent US$260, inclusive of VAT at 17.5 percent)
- Certificate of Incorporation
- Certificate of Share Capital
- Official List of Directors/Shareholders
- Business Plan/Feasibility Study
- Evidence of Finance (to cover the project cost)

The Projects Approval Committee of the Investment Board meets every month to consider applications for Investment Certificates. The application should be submitted at least a week before the consideration date. It is imperative that promoters submit sufficient detailed information to enable the center to evaluate the investment proposal and make an informed opinion on the project before presenting it to the Board for consideration. Once an application has been approved, a fee of K7,670,000 (US$1,600 inclusive of VAT) is charged before receiving the Investment Certificate.

Investors in the power sector are also expected to obtain a license from the ERB. Investors are expected to submit the following information together with a standard application form, which can be obtained from the ERB:

- An outline of the business proposal for the next five years
- Details of any expected subsequent substantial capital outflows including major decommissioning costs
- Estimates of net annual cash flows for subsequent periods sufficient to demonstrate the financial security and feasibility of the project(s) to which the application relates

The application fee for any business project or undertaking is 0.1 percent of the total cost of the project.

4.5. Foreign Currency Controls

In 1992, the government of Zambia suspended the Exchange Control Act, which was enacted during the socialist era of the country from 1964 until 1991. The exchange rate of the Kwacha now freely floats on the market. However, in 2001 as a result of continual investor abuse and the resultant loss of large sums of foreign exchange, the Zambian government announced new foreign exchange transaction restrictions. These are as follows:

- All exports have to be receipted locally and 75 percent of the proceeds to be banked locally
- Money arising from exports has to be collected within 180 days after the date of exporting
- Remittances other than dividends by entities must be made against invoices consistent with bill of entries collected by the Zambia Revenue Authority
- Business entities wishing to make remittances will be required to furnish the banks with invoices or supporting documents
- All external payments above $5,000 must be channeled through commercial banks

4.6. IPP Structure

If an IPP wants to sell power to customers other than ZESCO, but still needs to use wheeling arrangements through the grid,[32] an application will be made to the Energy Regulation Board (ERB), which will issue the necessary license and determine the wheeling charges. New IPPs can also "Build Own and Maintain" (BOM) transmission lines although the operation will have to be done by the system operator (ZESCO). In this case, the developers may sell power directly to customers of their choice.

4.7. Environmental and Emission Institutions and Regulations

Major environmental challenges in Zambia include air pollution and acid rain, especially in the mineral extraction and refining region of the country. The regulation and protection of the environment falls under the jurisdiction of the Ministry of Environment and Natural Resources, the Ministry of Agriculture, Food and Fisheries, the National Heritage Conservation Commission and the National Parks and Wildlife Service.

Environmental controls in Zambia are affected through resource management legislation. In 1990, Zambia enacted the Environmental Protection and Pollution Control Act. The Act established an Environmental Council, which plays an important role in the formulation of environmental policy and lays down various environmental standards. The Council also has the power to establish water quality and pollution control

---

[32] Wheeling is the use of a transmission or distribution facility which is not owned, controlled or leased by the utility that wishes to use it to transmit electricity produced by another.

standards, air ambient quality and emission standards and standards for the classification and analysis of waste. The quality standards laid down by the Council have legal force and their breach can incur criminal penalties.

The major international agreements which Zambia is party to include Biodiversity, Climate Change, Endangered Species, Hazardous Wastes, Law of the Sea, Nuclear Test Ban, Ozone Layer Protection and Wetlands. Agreements signed but not ratified include Desertification and the Kyoto Protocol.

4.8. Host Country Personnel with Geothermal Experience

Neither the Geological Survey Department nor the Department of Energy has any geothermal field experts among their employees. The Geological Survey Department has 12 qualified geologists; two with Masters degrees and the rest with Bachelor of Science degrees, but none are geothermal specialists.[33]

4.9. Employment of Foreigners and Locals

Employment for both locals and foreigners in Zambia can be on a permanent, contract or temporary basis. One must be a minimum of 16 years of age and have obtained a national registration card in order to be employed. Foreigners are required to obtain a work permit before they can be employed. An application has to be made to the Ministry of Labor indicating why a foreign person should be employed over a local person.

In some cases investors have included the number of foreign employees that they would wish to bring to Zambia in the initial application for an investment license. With unemployment rates at 20 percent and higher, the Zambia government is keen on creating employment and prefers investors hire Zambians. The country also has a relatively highly educated population and the parastatal companies like ZCCM and ZESCO often train their own professionals which is often works cheaper for companies than bringing in expatriates.

There is no minimum or standardized wage rate in Zambia. The wage and conditions of service are normally agreed upon by way of consultations between management and the respective trade unions. Workers are divided into two main categories, namely management and unionized workers. The workers in management do not belong to the unions and their wages are normally determined either by the board of directors or through bilateral talks between the board and individual workers. Wages tend to differ from one organization to another, and it is common to find that a technician with a certificate earns more money than a technician in another company in the same sector.

V. CONTACT INFORMATION

1. Local Power Company

Mr. Rodney Sisala
Managing Director
Zambia Electricity Supply Corporation Limited (ZESCO)
P. O. Box 33304
Lusaka, Zambia
Tel: 260-1-228084
Fax: 260-1-222753

2. Ministry of Energy and Water Development

Hon. George Mpombo
Minister of Energy

[33] Unfortunately, geologists Henry Chikwekwe and Fred Sakungo, who were trained in geothermics and worked on the Kapisya geothermal project, passed away.

Ministry of Energy and Water Development
Mulungushi House
P.O. Box 36079
Lusaka, Zambia
Tel. 260-1-252011
Fax: 260-1-252589; -254268

Dr. Austin Sichinga
Permanent Secretary
Ministry of Energy
P. O. Box 50288
Lusaka, Zambia
Tel: 260-1-252559
Fax: 260-1-252589

Mr. John Wright
Director
Office for Promoting Private Power Investments (OPPI)
Ministry of Energy and Water Development
P. O. Box 36079
Lusaka
Tel: 260-1-254948
Fax: 260-1-254948
Email: oppi@zamnet.zm

3. Geological Survey

The Director
Geological Survey Department
P.O. Box 50135
Lusaka, Zambia
Tel. 260-1-251655
Fax: 260-1-250174
Email gsd@zamnet.zm

4. Ministry of Finance or Investment Authority

Zambia Investment Centre
6457 Los Angeles Boulevard
P.O. Box 34580
Lusaka, Zambia
Tel. 260-1-254214
Fax 260-1-252150
Email invest@zamnet.zm
Website www.zic.org.zm

5. Environmental Council of Zambia

Mr. Edward Zulu,
Acting Director
Environmental Council of Zambia
P. O. Box 35131
Lusaka
Tel: 260-1-254094
Fax: 260-1-250230/254164
Email: ezulu@necz.org.zm

6. Interested Multilateral Agencies

World Bank Mission in Zambia
P.O. Box 35410
Lusaka, Zambia
Tel. 260-1-252811

7. Interested Bilateral Agencies

Japan International Cooperation Agency (JICA)
Plot No 59B, Mulundwa Road, Roma
Lusaka, Zambia
Tel. 260-1-291075
Fax 260-1-292619

8. Non Governmental Organizations

Mr. Geoffrey Musonda
The Secretary
Energy and Environmental Concerns for Zambia
P.O. Box 51288
Lusaka, Zambia
Tel. 260-96-751871
Fax 260-1-254491
Email: gmusonda@zamnet.zm

9. US Embassy

The Ambassador
American Embassy
Independence Avenue
P.O. Box 31617
Lusaka, Zambia

VI. DETAILED REPORTS AND MAPS OF GEOTHERMAL AREA(S)

According to the list of publications obtained from the Geological Survey Department in Lusaka, the following relevant maps and publications are in stock:

Geological Map of Zambia	1:1,000,000
Quarter Degree Sheets Geological Map	1:1,000,000

Geothermal Resources of Zambia by Fred K. Sakungo
Geothermal Resources in Zambia and their Possible Utilization by H. Chikwekwe

In his report, Fred K. Sakungo makes reference to other publications, that are not listed by the Geological Survey Department, including:

Ferguson, D., (1902). *The Geysers and Hot Springs of the Zambezi and Kafue Valleys*.

Legg, A.C., (1974). *A Reconnaissance Survey of the Hot and Mineralized Springs of Zambia. GSZ Rep* 50.

Geological Survey of Zambia (1986). *Zambia-Italian Geothermal Project Phase I-Preliminary Site Selection* (Final Report). Geological Survey of Zambia.

VII. REFERENCES

Department of Energy (1980-2001). *Energy Statistical Bulletin*, Department of Energy, Lusaka.
Electricity Prices in Southern and East Africa: February 2002 (including selected Performance Indicators for 2000/01).

Geological Survey Department List of Publications 2002/2003.

Ministry of Energy and Water Development (1998). *Framework and Package of Incentives for Private Sector Participation in Hydropower Generation and Transmission Development*. Ministry of Energy and Water Development, Lusaka. October 1998

Ministry of Energy and Water Development, (1994). *National Energy Policy*. Ministry of Energy and Water Development, Lusaka.

Ministry of Financial and National Planning (2002). *Economic Report 2001*. Ministry of Financial and National Planning, Lusaka. February 2002.

Musonda, G., (1997). *Technical Inspection of Kapisya Hotsprings Power Plant at Nsumbu*, Report, July 1997.
Republic of Zambia, (2000). "Census of Population and Housing", April 2001.

Sakungo, Fred K., Geothermal Resources of Zambia, Geological Survey of Zambia, P.O. Box 50135, Lusaka, Zambia. Geothermic, Vol. 17, No. 2/3. pp. 503-514, 1988.

EMAIL REFERENCES

Kenya

http://allafrica.com/stories/200211110484.html
http://www.afrepren.org/op12.pdf
http://www.state.gov/www/about_state/business/com_guides/2000/africa/kenya00_01.html
http://www.worldenergy.org/wec-geis/edc/countries/Kenya.asp
http://www.kengen.co.ke/
http://allafrica.com/stories/200302030473.html
http://mbendi.co.za/land/af/ke/p0005.htm
http://www.britain.or.ke/commerce/energy.html
http://www.odci.gov/cia/publications/factbook/geos/ke.html
http://gsa.confex.com/gsa/2002SC/finalprogram/abstract_32883.htm
http://www.fe.doe.gov/international/kenya.html
http://www.state.gov/www/about_state/business/com_guides/2000/africa/kenya00.html
http://www.countrywatch.com/cw_country.asp?vCOUNTRY=89
http://www.dfat.gov.au/geo/kenya/
http://www.sas.upenn.edu/African_Studies/NEH/k-ener.html
http://www.state.gov/www/issues/economic/trade_reports/africa95/KENYA.html
http://www.mbendi.co.za/werksmns/lexaf/buske.htm
http://gsa.confex.com/gsa/2003SC/finalprogram/abstract_47759.htm
http://www.ormat.com/news_019.htm
http://www.kestrelcapital.com/profiles/KPLC%20Profile.html
http://www.esd.co.uk/downloads/icc_Geothermal.pdf
http://iga.igg.cnr.it/kenya.php

Djibouti

http://www.mbendi.co.za/indy/oilg/af/dj/p0005.htm
http://www.odci.gov/cia/publications/factbook/geos/dj.html
http://www.fe.doe.gov/international/djibouti.html
http://www.countrywatch.com/cw_country.asp?vCOUNTRY=049
http://www.eia.doe.gov/cabs/hornafrica.html
http://www.nusacc.org/cntryprofiles/ctrprf2001/dj.pdf
http://www.lonelyplanet.com/destinations/africa/djibouti/
http://www.republique-djibouti.com/
http://iga.igg.cnr.it/djibouti.php

Ethiopia

http://www.ethiopianembassy.org/index.shtml
http://www.fe.doe.gov/international/ethiopia.html
http://www.gcrio.org/CSP/IR/IRethiopia.html
http://www.frameweb.org/CtryRegHome/Ethiopia.htm
http://www.ethioinvestment.org/
http://www.worldbank.org/afr/et/et_ctry_brief.htm
http://www.1upinfo.com/country-guide-study/ethiopia/ethiopia112.html
http://www.mbendi.co.za/indy/oilg/af/et/p0005.htm

http://www.devinet.org/eea/econ-focus/vol3%20No5/mekonnenk.htm
http://www.odci.gov/cia/publications/factbook/geos/et.html
http://unfccc.int/resource/docs/natc/presentations/ethincpresent.pdf
http://www.state.gov/www/about_state/business/com_guides/2000/africa/ethiopia00.html
http://www.countrywatch.com/cw_country.asp?vCOUNTRY=58
http://www.unitedworld-usa.com/reports/ethiopia/energy.asp
http://web.worldbank.org/WBSITE/EXTERNAL/NEWS/0,,contentMDK:20026746~menuPK:34471~pagePK:40651~piPK:40653~theSitePK:4607,00.html
http://www.eia.doe.gov/cabs/hornafrica.html
http://lcweb2.loc.gov/frd/cs/ettoc.html
http://www.tradepartners.gov.uk/energy/ethiopia/profile/overview.shtml
http://www.worldenergy.org/wec-geis/edc/countries/Ethiopia.asp
http://web.worldbank.org/WBSITE/EXTERNAL/NEWS/0,,contentMDK:20015929~menuPK:34466~pagePK:34370~piPK:34424~theSitePK:4607,00.html
http://iga.igg.cnr.it/ethiopia.php

Eritrea

http://www.mbendi.co.za/land/af/er/p0005.htm
http://denbe.asmarino.com/asmarino/Eritrea/Government.htm
http://strategis.ic.gc.ca/SSG/da90621e.html
http://www.eia.doe.gov/emeu/cabs/hornafrica.html#eri
http://iga.igg.cnr.it/eritrea.php
http://www.reisenett.no/map_collection/map_sites/country_sites.html#E
http://www.punchdown.org/rvb/wind/karen/kth-StudyArea.htm
http://www.punchdown.org/rvb/
http://www.punchdown.org/rvb/energy/EngSector.html
http://www.afrepren.org/op9.pdf
http://library.louisville.edu/government/international/eritrea/eritenv.html
http://www.afrepren.org/spsh.htm
http://www.oekozentrum.ch/pdf/eritrea.pdf
http://biz.yahoo.com/ifc/er/
http://denbe.asmarino.com/asmarino/Eritrea/
http://wrgis.wr.usgs.gov/docs/geologic/jlwnstrn/alid/Alidpage.html
http://www.oilsurvey.com/php/countries.php3?chosenCountry=63&chosenCategory=0
http://www.mbendi.co.za/indy/oilg/af/et/p0005.htm

Uganda

http://www.cia.gov/cia/publications/factbook/geos/ug.html#Govt
http://www.ugandainvest.com/18.htm
http://www.eia.doe.gov/emeu/cabs/eafrica.html
http://iga.igg.cnr.it/pdf/0864.PDF
http://iga.igg.cnr.it/uganda.php
http://www.energyandminerals.go.ug/
http://www.uganda.co.ug/bujagali/index.htm
http://www.worldbank.org/afr/ug/

http://www.ueb.co.ug/
http://www.ugandainvest.com/energy.htm
http://www.sas.upenn.edu/African_Studies/NEH/u-energy.html
http://web.worldbank.org/WBSITE/EXTERNAL/NEWS/0,,contentMDK:20026051~menuPK:34470~pagePK:40651~piPK:40653~theSitePK:4607,00.html
http://web.worldbank.org/WBSITE/EXTERNAL/NEWS/0,,contentMDK:20034412~menuPK:34465~pagePK:34370~piPK:34424~theSitePK:4607,00.html
http://www.1upinfo.com/country-guide-study/uganda/uganda91.html

Tanzania

http://www.cats-net.com/tic/bizguide.htm
http://www.ceest.com/index.html
http://www.sei.se/eed/eedhome.html
http://www.esi.co.za/last/ESI_2_2002/ESI2_02_20_1.htm
http://www.eia.doe.gov/emeu/cabs/eafrica.html
http://iga.igg.cnr.it/pdf/0580.PDF
http://iga.igg.cnr.it/tanzania.php
http://www.leat.or.tz/publications/foreign.investment/1.eia.law.php
http://www.sovereign-publications.com/tanzania.htm
http://unfccc.int/resource/ccsites/tanzania/activity/enabling.htm
http://unfccc.int/resource/ccsites/tanzania/activity/enabling.htm
http://216.239.51.100/search?q=cache:Olivrv6Vc5UC:www.areed.org/country/tanzania/energy.pdf+Tanzania+Energy&hl=en&ie=UTF-8
http://www.tanzania.go.tz/energyf.html
http://www.tanzania.go.tz/visaform.htm

Zambia

http://biz.yahoo.com/ifc/zm/
http://www.eia.doe.gov/emeu/international/zambia.html
http://www.usaid.gov/press/releases/2000/pr000525.html
http://www.sei.se/dload/2001/PV%20ESCOs%20phase%20I%20final%20report.pdf
http://www.sadcreview.com/country%20profiles%202001/zambia/zamWater&Electricity.htm
http://www.zana.gov.zm/energy.html
http://www.odci.gov/cia/publications/factbook/geos/za.html
http://www.countrywatch.com/cw_country.asp?vCOUNTRY=189
http://mbendi.co.za/land/af/za/p0005.htm
http://www.energy.gov.zm/
http://www.zic.org.zm/IPA_Information.asp?hdnGroupID=8&hdnLevelID=2
http://unfccc.int/resource/ccsites/zambia/comm/study.htm
http://www.state.gov.zm/energy1.html
http://www.thezambian.com/Zambia/electricity.aspx
http://www.state.gov.zm/
http://www.eia.doe.gov/emeu/cabs/sapp.html
http://iga.igg.cnr.it/zambia.php