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OVERVIEW OF GEOTHERMAL RESOURCE EXPLORATION AND DEVELOPMENT IN THE EAST AFRICAN RIFT SYSTEM

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ABSTRACT

The East African Rift System (EARS) is one of the major tectonic structures of the earth where the heat energy of the interior of the earth escapes to the surface. This energy flow takes place in the form of volcanic eruptions, earthquakes and the upward transport of heat by hot springs and natural vapor emissions. The EARS extends for about 6500 km from the Middle East (Dead Sea-Jordan Valley) in the North to Mozambique in the South. The EARS passes through Eritrea, Djibouti, Ethiopia, Kenya, Tanzania, Uganda, Rwanda, the Democratic Republic of Congo (DRC), Zambia, Malawi, Mozambique and Madagascar. Estimated Geothermal energy resource potential in the EARS is more than 15,000 MWe.

Despite the high geothermal potential of the EARS, only Kenya and Ethiopia have installed a capacity of about 217 MWe. Countries such as Djibouti, Eritrea, Tanzania, Uganda, Rwanda and Comoros are at various exploration stages. So far, other countries such as Burundi, DRC, Malawi, Zambia, and Mozambique have not gone beyond the inventory work of the resource potential.

Geothermal energy presents a clean and more environmentally friendly alternative to traditional fuels. Geothermal energy has the potential to provide long-term, secure base-load energy and greenhouse gas (GHG) emissions reductions. Accessible geothermal energy from the Earth's interior can supply heat to generate electric energy and for direct use. Climate change is not expected to have any major impact on the effectiveness of geothermal energy utilization, but the widespread deployment of geothermal energy could play a meaningful role in mitigating climate change.

Geothermal development, in the East Africa region, has been constrained by the risks that are associated with resource exploration and development and financial risks associated with investment in power development projects. Lack of appropriate investment and institutional settings in many countries have also contributed to the slow pace of development. Therefore, overall strategy to reduce the above risks and to accelerate geothermal development in the countries of EARS is to adopt a regional geothermal resource development approach. One of the main regional geothermal programmes in the region is the African Rift Geothermal Development Facility Programme (ARGeo).

The ARGeo Project originated in 2003 with a view of the fact that the region has a large and untapped geothermal resource potential that is indigenous, environmentally clean, economically viable and renewable energy resource. The project's objective is to promote geothermal resource utilization by reducing the risks associated with resource's exploration and development. ARGeo aims to accelerate geothermal energy investments in both public and private sector. The utilization of the resource in agriculture and industry will also be promoted.

1. INTRODUCTION

Energy use in Africa is the lowest in the world and also has the least developed structure. The continent has about 15 % of the world's population but its share of electricity use is less than 5 % of the world. Only about 25 % of the African population has access to electricity. More than half of the current energy use is traditional biomass that causes health problems and deforestation. Although Africa endows with abundant energy resources such as hydropower, geothermal, wind and solar it is only less than 10% and 1% of the continent's hydroelectric and geothermal power generation potentials have been developed to date, respectively.

African countries that are located along the East African Rift System (EARS) have the largest hydroelectric and geothermal potentials of the continent. EARS is one of the major tectonic structures of the earth where the heat energy of the interior of the earth escapes to the surface. This heat energy flow takes place in the form of volcanic eruptions, earthquakes and the upward transport of heat by hot springs and natural vapor emissions. The EARS extends for about 6500 km from the Middle East (Dead Sea-Jordan Valley) in the North to Mozambique in the South (Figure 1). The EARS passes through Eritrea, Djibouti, Ethiopia, Kenya, Tanzania, Uganda, Rwanda, the Democratic Republic of Congo (DRC), Zambia, Malawi, Mozambique and Madagascar. Estimated Geothermal energy resource potential in the EARS is more than 15,000 MWe.

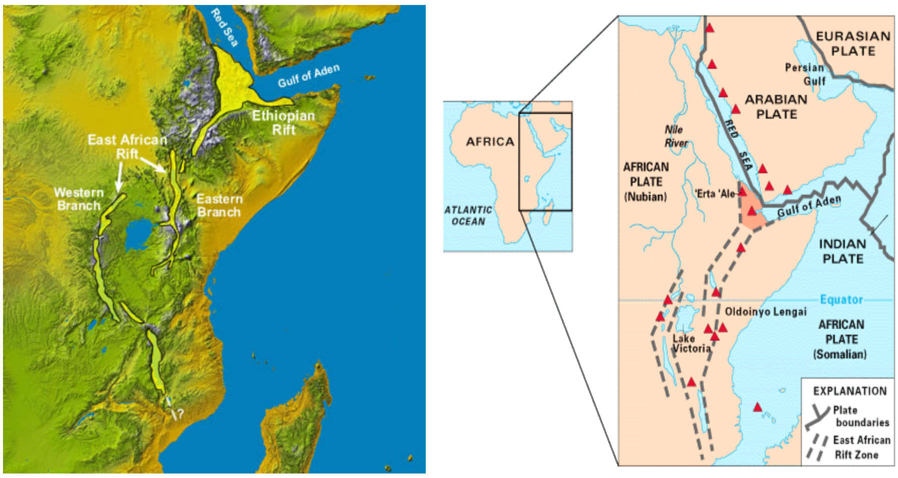

FIGURE 1: The Great East African Rift System

Despite the high geothermal potential of the EARS, only Kenya and Ethiopia have installed a capacity of about 217 MWe. Countries such as Djibouti, Eritrea, Tanzania, Uganda, Rwanda and Comoros are at various exploration stages. So far, other countries such as Burundi, DRC, Malawi, Zambia, and Mozambique have not gone beyond the inventory work of resource potential.

The governments of East African Countries are keen to investigate and further develop geothermal energy in order to supplement and diversify energy sources. This commitment arises due to:

- Strong growth in electricity demand & urgent need to increase access to electricity
- Hydro proven unreliable as a base load source due to climatic fluctuations
- Volatile price of petroleum fuels etc.

All East African countries import petroleum products mainly for transport and electricity production. Renewable energy sources (hydro, geothermal, solar, etc.) represent a small portion of total energy production, averaging less than 10% for hydropower, solar, wind and geothermal production combined.

Hydropower is currently the predominant mode of electricity production in the region (~70%), yet climatic fluctuation and silting of reservoirs pose questions concerning the reliability of these resources. Thermal production (mainly diesel generation) is used in most countries and is the only source of power production in Eritrea and Djibouti. Volatile prices and high import costs make diesel based power production costly.

Therefore, to decrease imports and save foreign currency and in the face of the increasingly recurring severe drought it is important for the region avoid relying solely on hydroelectricity and to make geothermal energy generation a complementary part of future development, as generation mix. Most of the East African countries with geothermal potential are turning to their own indigenous resources to help them meet their growing energy needs.

Geothermal energy presents a clean and more environmentally friendly alternative to more traditional fuels. Geothermal energy has the potential to provide long-term, secure base-load energy and greenhouse gas (GHG) emissions reductions. Accessible geothermal energy from the Earth's interior supplies heat to generate electric energy and for direct use. Climate change is not expected to have any major impacts on the effectiveness of geothermal energy utilization, but the widespread deployment of geothermal energy could play a meaningful role in mitigating climate change.

This paper is an update and a summary of literature review from various papers presented and/or published in various geothermal workshops and conferences and their proceedings. The paper also covers the main observations, strategies for development and regional geothermal development approach.

2. PRESENT STATUS IN DEVELOPMENT AND UTILIZATION OF GEOTHERMAL ENERGY

2.1 The world

The history of geothermal usage began with bathing, washing, and cooking by native peoples throughout the world. One of the earliest historical uses of power from geothermal energy was produced in Larderello, Italy, in 1904.

At present, a total of about 24 countries in the world have over 10,000 MW generating facilities that use geothermal energy. Many more use the energy resource in agriculture, industry, especially in agro-industry, and in the health, recreation and tourism industries.

A developing country, the Philippines, is now the second world leader (next to USA) in geothermal resource development, having nearly 2,000MW installed electricity generation capacity using geothermal resources. This capacity is about ten times the total electricity generation capacity from geothermal sources in the East Africa Region.

2.2 The East African rift region

Using today's technologies, Eastern Africa has an estimated potential of more than 15,000 MWe. Despite this potential, only Kenya and Ethiopia have geothermal operations as part of the country's electricity generation infrastructure. The progress of geothermal development in the region is affected by (among others):

(i) High upfront cost of exploration including drilling;
(ii) Inadequate access to funding and guarantee;
(iii) Inadequate policy and legislation as well as institutional and regulatory framework to attract private developers and
(iv) Inadequate infrastructure and database in resources.

East African countries that have identified the presence of geothermal energy resource and/or carried out research on, geothermal resources include: Burundi, Comoros Islands, Djibouti, Democratic Republic of Congo (DRC), Eritrea, Ethiopia, Kenya, Rwanda, Malawi, Tanzania, Uganda and Zambia. Brief description of exploration and utilization of geothermal resources in some Eastern Africa countries is given below.

2.2.1 Kenya

In the East African Rift region, Kenya is the leader in advancing geothermal resource exploration and development. This has partly been due to the problems that it has in developing its limited hydro resources and the successes that it had in small scale development since 1981. Kenya's first electricity generating plant has been operating now for more than 25 years and has proven reliable and economic, running at 98% availability. This compares very favorably with the 50-60% that is typical for hydro-power plants, effectively reducing the investment cost per unit of energy produced. This has confirmed experience elsewhere that geothermal power plants operate at much higher load factors compared to hydro and are particularly suited for base-load power supply. This has encouraged Kenya to speed up its geothermal power development program and is now generating about 210 MWe.

Kenya has fast tracked the development of geothermal resources in the country as a source of affordable and clean power. The Government established the Geothermal Development Company (GDC) with the sole purpose of making available enough steam for electricity generation by Independent Power producers (IPPs) and KenGen. At present, GDC is carrying out deep exploratory drilling in Menengai. Menengai is the second geothermal field outside of the Olkaria geothermal field. Other geothermal areas such as, Eburu, Silali, Longonot, Suswa, etc. are at a various stages of exploration (Figure 2).

In the process of these activities, Kenya has acquired considerable expertise in geothermal related earth sciences and engineering. It has also lead to a development of the institutional infrastructure that is necessary for geothermal resource exploration, development and utilization.

At present, the Government of Kenya submitted a project proposal to the United Nations Environment Programme for acquiring technical and financial assistance to carry out surface investigations in Silali geothermal prospect area with a view to confirm the resource potential and minimize the drilling failure risk.

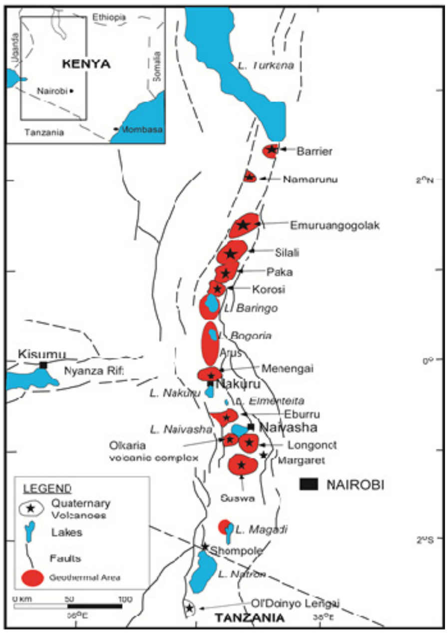

FIGURE 2: Location of geothermal prospects areas in the Kenyan rift (Omenda, P. 2010)

2.2.2 Djibouti

Djibouti lies at the junction of three active, major coastal spreading centers: (a) the Eastern Africa Rift zone; (b) The Gulf of Aden Rift; and (c) and the Red Sea Rift (Figure 3). This structural junction is unique being the focal point of very high heat flux.

According to various studies (GEA, 1999; Mohammed, 2010) the geothermal potential in Djibouti is between 230-860 MWe from a number of prospects including: (i) Lake Assal; (ii) Lake Abbe; (ii) Hanle; (iii) Gaggade: (iv) Arta; (v) Tadjourah; (vi) Obock; (vii) and Dorra (Figure 3) .

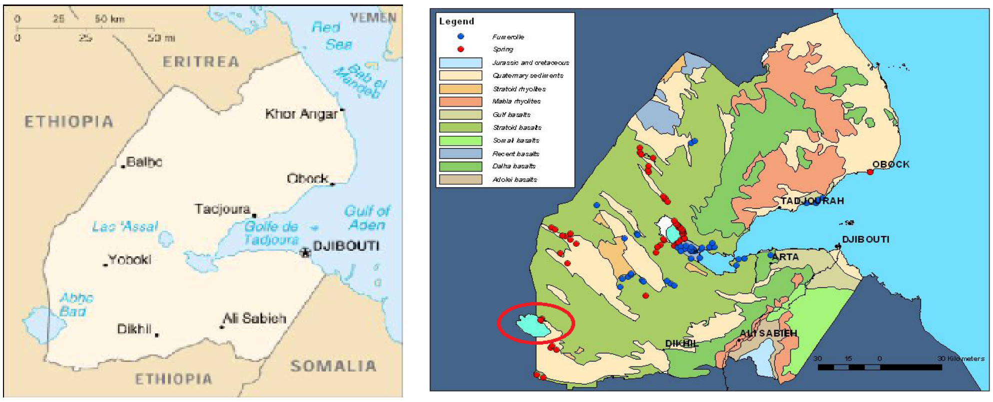

FIGURE 3: Location of geothermal prospects areas in Djibouti (Mohammed, 2010)

Much effort has been expended in Djibouti since the 1970s, in view of the country being deficient of indigenous energy resources. Djibouti's' current energy production is by fossil fuels. The first concerted effort to assess and explore Djibouti's geothermal resources took place in the Assal area from 1970-83. About six exploratory wells were drilled in the Assal geothermal fields. While a very high temperature system has been successfully located, problems related to high salinity of the discovered fluids, which is due to the close proximity of the field to the Gulf of Aden, has delayed resource development and exploitation.

Recent geothermal investigations have also been carried out in Djibouti in new target area of the Lake Assal Rift Zone, in Nord Gubhet and Lake Abhe geothermal prospect areas (Mohammed, 2010).

2.2.3 Eritrea

In 1973, the United Nations Development Programme (UNDP) identified potentially significant exploitable geothermal resources in Eritrea. In 1995 with help of United States Geological Survey (USGS), Eritrea identified the Alid geothermal prospect area for follow up detailed investigations. This area is located about 120km south of Massawa (Figure 4).

The eastern lowlands of the country are of potential geothermal interest. First priority was given to the Alid Volcanic center for exploration as it has numerous manifestations in the form of hot springs and fumaroles. Detailed geoscientific investigations revealed a reservoir temperature of about 250°C (Yohannes, 2011). There are also other sites (e.g. Nabbro Dubbi) suitable for discovery of a high temperature resource. A recent volcanic eruption took place in Nabbro Dubbi area (Yohannes, 2011).

At present, the Government of Eritrea submitted a project proposal to the United Nations Environment Programme for acquiring technical and financial assistance to carry out surface inviestigations in Alid geothermal prospect area with a view to confirm the resource potential and minimize the drilling failure risk.

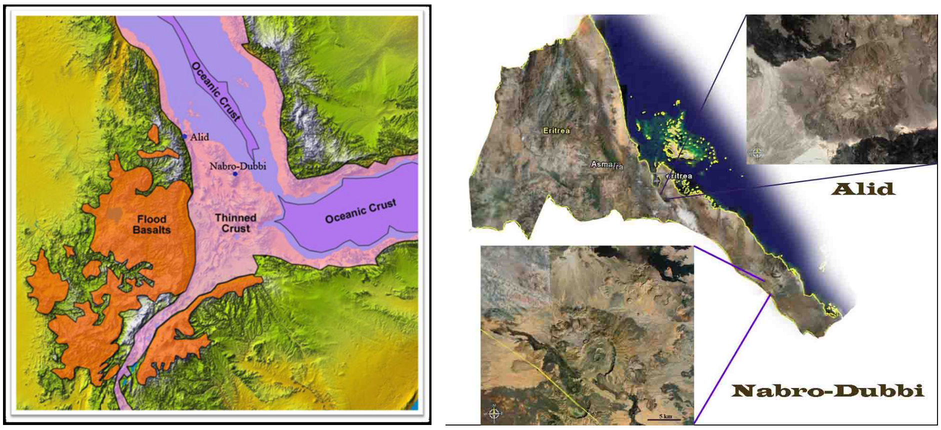

FIGURE 4: Location of geothermal prospect area in Eritrea (Yohannes, 2011)

2.2.4 Ethiopia

Ethiopia started a long-term geothermal exploration undertaking in 1969. Over the years, a good inventory of the possible resource areas has been built up and a number of the more important sites have been explored in the Ethiopian Rift Valley. Of these areas, about sixteen are judged to have potential for high temperature steam suitable for electricity generation (Figure 5). A much larger number are capable of being developed for direct utilization of geothermal heat in agriculture, agro-industry etc.

In Ethiopia, estimated geothermal resource potential for power generation is about 5,000 MWe. So far, exploratory drilling has taken place in Aluto-Langano (1982 to 1985) and Tendaho (1993 to 1998) geothermal fields. Detailed surface exploration has been completed in four other geothermal prospect areas (Corbetti, Abaya, Dofan Fantale and Tulu Moye).

A 7.3 MWe geothermal pilot power plant has been installed at Aluto. This pilot plant is currently generating about 4 MWe. Feasibility study for the expansion of the Aluto Langano Geothermal power has been recently completed with the Japanese Overseas Development Assistance. The study indicated expansion of the Aluto Geothermal power to additional 35 MWe is feasible (Kebede, 2010). On the basis of this study, drilling of four deep appraisal wells is planned for 2011 with the technical assistance of government of Japan and loan from the World Bank. Other geothermal prospect areas in the Ethiopian Rift Valley that are at reconnaissance stage of exploration are: Teo, Danab, Kone and others (Figure 5).

During the four decades that the geothermal resources exploration work was carried out in Ethiopia, a good information base and degree of exploration capacity has been developed. This is especially true in the human capacity and basic infrastructure development that will be critical in ensuring that future selected resources sites are advanced to the development phase much more rapidly than before.

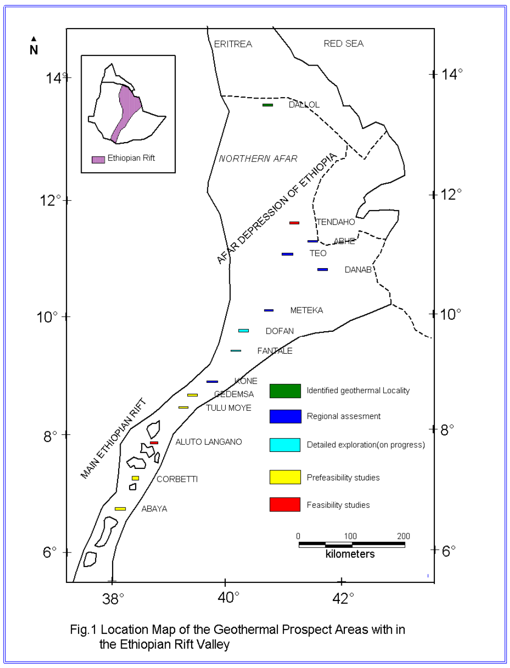

FIGURE 5: Location of geothermal prospect areas in Ethiopia (Teklemariam and Kebede, 2010)

At present, the Government of Ethiopia submitted a project proposal to the United Nations Environment Programme for acquiring technical and financial assistance to carry out further surface investigations in Tendaho geothermal prospect (new target area) with a view to confirm the resource potential and minimize the drilling failure risk.

2.2.5 Tanzania

Geothermal exploration in Tanzania was carried out between 1976-79. Reconnaissance studies for surface exploration were carried out in the north (near Arusha, Lake Natron, Lake Manyara and Maji Moto) and in the south (Mbeya region) (Mayalla, 2010). Geothermal work in all locations in Tanzania is at the surface exploration stage.

Two potential target areas for geothermal exploration singled out so far are: (a) Arusha region near the Kenyan border in the North; and (b) Mbeya region between Lake Rukwa and Lake Nyasa in the southwest (Figure 6). Another potential area (Luhoi) was prospected during 1998-2002 by First Energy Company (a local firm). It conducted important project definition and reconnaissance evaluation work. This area is located 160 km south of Dar es Salaam. The work conducted so far indicates the existence of a geothermal reservoir with a temperature greater than 200 °C .

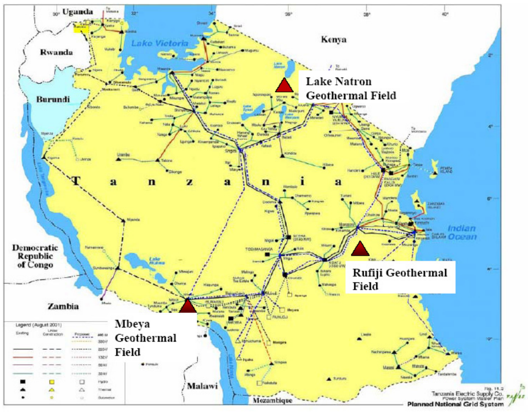

FIGURE 6: Geothermal prospect areas in Tanzania (Mayalla, 2010)

2.2.6 Uganda

Exploration for geothermal energy in Uganda has been in progress since 1993. The studies have focused on three major geothermal areas namely Katwe, Buranga and Kibiro (Figure 7). The three areas are in semi-detailed to detailed stages of surface exploration (Bahati and Natukunda, 2010). The overall objective of the study is to develop geothermal energy to complement hydro and other sources of power to meet the energy demand of rural areas in sound environment.

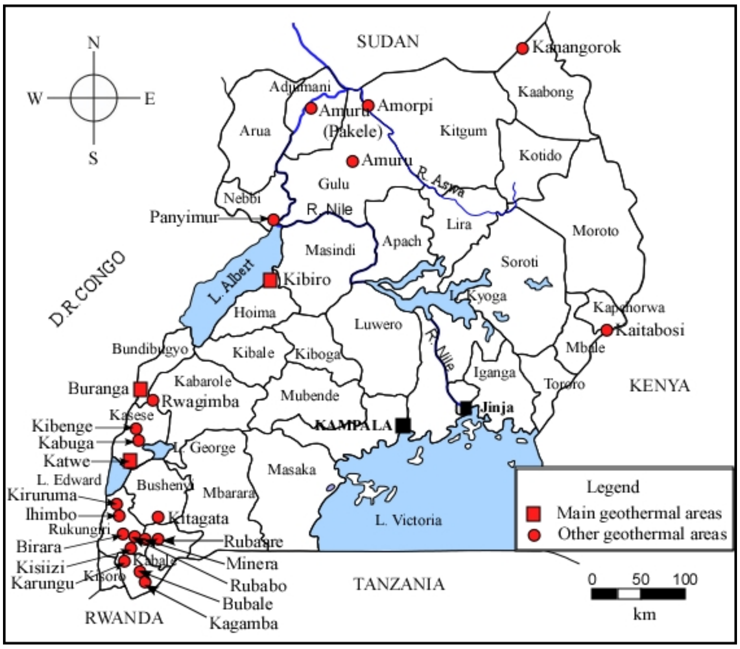

FIGURE 7: Location of geothermal prospect areas in Uganda (Bahati and Natukunda, 2010)

At present, the Governmnt of Uganda submitted a project proposal to the United Nations Environment Programme for acquiring technical and financial assistance to carry out surface investigations in the kibiro geothermal prospect area with a view to confirm the resource potential and minimize the drilling failure risk.

2.2.7 Others

Countries such as Rwanda and Comoros are also at a stage of semi-detailed and detailed stages of geothermal resource exploration. Rwanda is now carrying out a detailed geothermal investigation in Karisimbi geothermal field (Gisenyi) with a view to start exploratory drilling and develops power from geothermal energy resource (Irabaruta, 2010). Other countries such as Burundi, DRC, Malawi, Mozambique and Zambia are not gone beyond the reconnaissance geothermal resource exploration and resource potential inventory.

3. LESSONS LEARNED

3.1 Main observations

Exploration, Development and utilization of geothermal energy resources in the East African region for the last four decades have indicated that:

- The region has a large untapped geothermal resource potential (> 15,000 MWe);
- The geothermal resource is an indigenous, reliable, environmentally clean and economically viable, renewable energy resource;
- Development of geothermal resources are constrained by (among others): (i) the risks that are associated with resource exploration and development; (ii) High upfront cost of exploration including drilling; (iii) the financial risks that are associated with investment in power development projects ; and (iii) Inadequate policy and legislation as well as institutional and regulatory framework to attract private developers.
- Diversified use of geothermal energy augments energy supply from hydro power plants and improves the generation mix. It avoids vulnerability to climatic and oil price fluctuations.
- Holistic Utilization of Geothermal energy resource (both Power generation and Direct Uses) can create wealth, tackle food insecurity and boost socio economic development.

4. STRATEGIES FOR DEVELOPMENT

In order to promote the geothermal resource exploration and utilization optimal strategies for development are to:

- look for loans and grants from International Organizations to finance the projects for further exploration and development;
- Look for Private Sector participation and financing from developers, investors, equipment suppliers and development banks;
- Establish long-term conducive policies and incentives that attract private investment;
- Promote Public Private Partnership
- Establish Regional Training Center to build skilled manpower
- Establish a Risk Guarantee fund by donor and development agencies for exploratory and appraisal drilling of projects;
- Set up Regional Network of Geothermal agencies to ensure the promotion and use of geothermal expertise in the East Africa Region.

5. AFRICAN RIFT GEOTHERMAL DEVELOPMENT FACILITY PROGRAMME

The African Rift Geothermal Development Facility (ARGeo) was originated in 2003 with a view of the fact that the East Africa Region has a large untapped geothermal resource potential that is an indigenous, environmentally clean, economically viable and renewable energy resource. The ARGeo Project's objective is to promote geothermal resource utilization by reducing the risks associated with such resource's exploration and development. ARGeo aims to accelerate geothermal energy investments in both public and private sector.

The project is funded by the Global Environment Facility (GEF) and was initiated by six countries: Djibouti, Eritrea, Ethiopia, Kenya, Tanzania, and Uganda. The project has two main components: (i) a Regional Network and Technical Assistance component implemented by United Nations Environment Programme (UNEP) and (ii) Risk Mitigation Fund component implemented by the World Bank (WB). The WB and UNEP are the Implementing Agencies for their respective components of the project.

The project partners are: the Icelandic International Development Agency (ICEIDA), the German Federal Institute of Geosciences and Natural Resources (BGR), the United Nations University-Geothermal Training Programme (UNU-GTP), and the International Atomic Energy Agency (IAEA).

The UNEP ARGeo Component has already started its operation whereas the World Bank's ARGeo Component is not yet operational.

5.1 UNEP ARGeo component moving full steam ahead

The ARGeo project was officially launched on November, 22nd, 2010. On that occasion, it was agreed that priority focus (for the UNEP component) be on the upstream geo-scientific surface investigation work of geothermal prospect areas in ARGeo countries. The results of this work would generate viable proposals for exploration drilling to the RMF with minimized drilling failure risks.
Some progress milestones to note:

- Four project proposals from Eritrea, Ethiopia, Kenya and Uganda received for surface exploration studies with a view to minimize the "Drilling Risk"; these proposals were reviewed and prioritized to be technically and scientifically evaluated by the Technical Advisory Team and start surface exploration studies.
- East Africa Countries status report published, report on inventory of equipment and manpower prepared, and East African geothermal data-base developed with the support of ICEIDA.
- UNEP held discussions and reached to an "in principle" agreement with African Union Commission (AUC) – German Development Bank (KfW) with a view to exploit synergy and take advantage of complementarities with its Geothermal Risk Mitigation Facility Programme.
- The Second ARGeo Steering Committee Meeting held in Kenya (September 1, 2011) leading to accelerated plans for implementation. A linked meeting (September 2, 2011) at "ARGeo Ministerial Level" was held leading to greater commitment at political level to move the project forward quickly.

5.2 Expected output of ARGeo

- Potential number of geothermal fields explored in the region;
- Number of geothermal resources sites with confirmed energy potential;
- Number of skilled human resources in geo-scientific investigations and management of geothermal projects;
- Adequate networking and information exchange;
- Partnership developed and synergy and complementarities created.

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