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REASONS FOR AND IMPACT OF HAVING MAJORLY GEOTHERMAL POWERED ECONOMY: A CRITIQUE OF KENYAN POWER SYSTEM

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ABSTRACT

Kenya utilizes various sources to generate electricity ranging from hydro, geothermal, thermal and wind. Hydro power stations are the leading source, with the highest installed capacity. This is from 14 hydro power stations located around the country. The current electricity demand is 1,191 MW while the effective installed capacity under normal hydrology is 1,429 MW. Generation capacities from range from Hydro, Geothermal, bagasse (cogeneration), wind and fossil based thermal. The peak load is projected to grow to about 2,500MW by 2015 and 15,000 MW by 2030. This is due the fact Kenya has a long-term development strategy, 'The Vision 2030', whose aim is to drive the country into a globally competitive and prosperous economy with high quality of life. Covering the period 2008 to 2030, the country's new development blueprint aims to transform Kenya into a newly industrializing, "middle-income country providing a high quality life to all its citizens by the year 2030." It calls for rehabilitating among other infrastructural pillars; very key being expanding access to stable and reliable electricity supply.

Geothermal energy resources are abundant in Kenya. They are located within the Rift Valley with an estimated potential of between 7,000 MWe to 10,000 MWe spread over 14 prospective sites. Geothermal has numerous advantages over other sources of power: it is not affected by drought and climatic variability; has the highest availability at over 95 %; is green energy with no adverse effects on the environment; indigenous and readily available in Kenya unlike thermal energy that relies on imported fuel. This makes geothermal the most suitable source for base load electricity generation in the country. The current installed capacity in the country is 198 MW. An additional 280 MW, scheduled for commissioning in 2013, is also under development in the same Block. Drilling is ongoing in the Menengai Field for Phase I of 400 MW whilst initial project development activities have commenced for the development of 800 MW in the Bogoria – Silali Block along the Kenyan rift valley. These are geared towards meeting the Vision 2030 Medium Term target of 1,600 MW by 2016 and eventually 5,000 MW by 2030. Realizing the need to reduce the long gestation periods in the development of geothermal the Government is set, through Geothermal Development Company (GDC) to undertake integrated development of geothermal through initial exploration, drilling, resource assessment and promotion of direct utilization of geothermal. By undertaking the initial project activities, it will absorb the attendant risks associated with geothermal development and therefore open up opportunities for both public and private participation. The Government of Kenya is cognizant that joint efforts will be required from both the public and private sectors for accelerated development of the country's geothermal resources.

With almost two third of total generated reserves coming from geothermal sources; this source will eventually become the key and the electric energy generating driver for the Kenyan economy.

This paper defines the significance and merits in the Kenyan electrical energy requirements', value of investment, having a green energy as major source (significant reduction in carbon emissions) and diversity of applications in direct uses of this resource as attributions of making the geothermal resources the leading source of installed generated electricity in Kenya.

1.0 INTRODUCTION

Energy is considered an essential ingredient for economic growth and social development in the Kenya and anywhere in the world. The growth of energy demand is often driven by several factors namely, population growth, economic growth, urbanization, rural energization programmes, increasing penetration of energy intensive appliances and industrialization. Energy is consumed by all sectors of the economy and therefore growth in the economies of countries in the region leads to a consistent rise in the quantity of energy consumed. While the Kenya is experiencing significant growth in energy demand, energy supply appears to have stagnated or dwindled. The security of energy supply especially electricity generation in Kenya, East and Horn of Africa seems to be threatened by climate change induced phenomenon, chief among them, drought (Karekezi and Kithyoma, Government of Kenya (GoK) 2005; 2004; 2005; 2006; 2007; 2008). Inadequate electricity generation capacity and high power bills have been perennial problems in Kenya prompting the Government to explore various ways of tackling the glitches .Currently, a lot of effort is geared at geothermal power, which experts opine is environmental friendly and more affordable to run compared to other sources of energy like fossil fuel. A major shift to geothermal power will also insulate the country against the effects of drought, which often interferes with hydroelectric power. A major percentage of our installed capacity of power plants has historically been powered by hydroelectric sources with diesel-fired plants also accounting for a significant portion of the total energy demand.

The reliance on diesel to supplement increasing demand is unhealthy, as it has helped push the average cost of production of electricity and made it expensive for consumers. Overall the prices of the commodities we rely on or hope to use for future generation are spiraling and are projected to continue that trend. Here are the numbers: According to the current International Energy Agency's World Energy Outlook, coal prices are projected to increase to about $200 per ton by 2035 and oil prices to $250 per barrel. This means continued reliance on traditional sources of energy could be catastrophic to Kenya's development as a nation. This is why the idea of geothermal power looks and sounds attractive. (IEA Report, 2008)

But to make the dream of having geothermal as the main source of electricity generation, estimates indicate the country requires $20 billion (Sh1.7 trillion), which is about double Kenya's annual budget. This amount is staggering high but must be invested initially as thereafter maintenance cost is significantly low. The money needed is indeed high and together with development partners, the Government of Kenya is making great in roads in harnessing this treasure along the Rift Valley. The proposed shift to geothermal energy is of significant importance for the national economy. It guarantees better commodity prices and less corrosive interference with the environment. Making geothermal Kenya's main source of energy would allow for a complete stop to the usage or reallocation of price-volatile fossil fuels, such as diesel, which otherwise would have been needed for electricity generation.

By reducing the component of our energy mix that is dependent on the price of fossil fuels – and increasing geothermal power use, which in the long term will guarantee stability – takes away fossil fuel price risks. Notably, internal funding should be sourced and encouraged as having borrowed from various international financial institutions for the Olkaria geothermal plants whose total cost is projected to be hundreds of billions; the government says it might be catastrophic to add more domestic debt to its books. (IEA Report, 2008)

This paper proposes geothermal powered economic energy; renewable energy option looking at reasons for and impact of having it major source of power in the economy in the Kenyan power system scenario.

Fig.4: Well MW-01 in the Menengai geothermal field, Kenya.

2.0 ELECTRICITY SUPPLY STATUS

Hydro-power constitutes around 60 per cent of the total electricity generated in Kenya. The bulk of this electricity is tapped from five generating plants along the River Tana. The five stations combined - Kindaruma, Kamburu, Gitaru, Masinga and Kiambere - have an installed capacity of more than 400 MW. Kenya is highly dependent on hydroelectricity. Hydroelectricity plants provide about 75% of all electrical output. Five major stations in the Tana River basis supply power to Kenya. They are: Kindaruma (44 MW), Gitaru (225 MW), Kamburu (94.2 MW), Masinga (40 MW) and Kiambere (144 MW). The Turkwel Gorge Hydroelectric station in the Turkana district has a capacity of 106 MW. An additional 30 MW is drawn from the Owen Falls dam in Uganda. Gitaru is the biggest power station in Kenya in terms of installed capacity. There are also several small hydro stations - Mesco, Ndula, Wanjii, Tana, Gogo Falls and Selby Falls - all built before independence in 1963, with a combined generation output of 40 MW.

Kenya Electricity Generating Company Limited, KenGen is the electric power generation company in Kenya, producing about 80 percent of electricity consumed in the country. The company utilizes various sources to generate electricity ranging from hydro, geothermal, thermal and wind. Hydro is the leading source, with an installed capacity of 677.3MW, which is 72.3 per cent of the company's installed capacity.

Four Independent Power Producers among themselves produce about 18 percent of the country's electric power. KenGen sells the power to Kenya Power and Lighting Company (KPLC) is a limited liability company responsible for the transmission, distribution and retail of electricity throughout Kenya. KPLC owns and operates the national transmission and distribution grid, and is responsible for the scheduling and dispatch of electricity to more than 600,000 customers throughout Kenya.

The government is responsible for ensuring that there is adequate line capacity to maintain supply and quality of electricity across the country. The interconnected network of transmission and distribution lines covers about 23,000 kilometers.

The national grid is operated as an integral network, linked by a 220 kV and 132 kV transmission network. Limited lengths of 66 kV transmission lines are also in use. The national grid impacts on the future growth of the energy sector because any new generation capacity must take into consideration the existing network and its capacity to handle new loads.

Efficiency of the transmission and distribution network continues to be enhanced in both technical and non-technical aspects. Planning of transmission and distribution lines and technical improvements include re-conductoring of lines, installation of capacitors, and construction of additional feeders and substations in anticipation of the expanded generation capacity should be done by proper financing and technical preparations. The transmission and distribution networks for power are very crucial for the planning and development of geothermal power plants.

In the long term, the installed capacity is projected to increase between 2004 and 2018/2019 and will comprise geothermal (503 MW), hydro (220.6 MW) sources. National consumption of electricity is projected to rise from 4.9 billion kilowatt hours in 2003/2004 to 5.1 billion in 2004/2005, and 6.9 billion kilowatt hours in 2009/2010 and to 11.8 billion in 2019/20. This require massive transmission capacity.(http://www.mbendi.com/indy/powr/af/ke/p0005.htm)

2.1 Electricity generation in East Africa

Source: GoK, 2008; IEA, 2008

Kenya - 2007
Hydro
57%
Geothermal
10%
Thermal
33%
Tanzania - 2008
Hydro
52%
Thermal
48%
Ethiopia - 2007
Hydro –
85%
Thermal
14%
Geothermal
1%
Uganda - 2007
SHP
4%
Cogeneration
8%
Thermal
38%
Hydro
50%

3.0 GEOTHERMAL RECOURSES

More than 14 high temperature potential sites occur along the Kenyan Rift Valley with an estimated potential of more than 15,000 MWe. Therefore, securing stable energy supply, developing and establishing power plants that meet this demand is a priority for the Kenyan power sector if the economic growth is to be sustained in the future. The current installed capacity in the country is 198 MW with 150 MW operated by KenGen and 48 MW by OrPower 4, both in the Olkaria Block. An additional 280 MW under development is scheduled for commissioning in 2013. In the Menengai Field with a potential of 1,600MW drilling is ongoing at Phase I for development for 400 MW. The first exploratory well in Menengai has been successfully completed with a capacity to generate more than 8MW. Initial project development activities have also commenced for the development of 800 MW in the Bogoria – Silali Block. This is geared towards meeting the 2030 Medium Term target of 1,600 MW by 2016 and eventually 5,000 MW by 2030. (SREP Report 2011.)

Kenya presents various attractive advantages for investment in power generation such as; dynamic electricity markets, abundant indigenous resources (e.g. hydro, wind, coal, solar and geothermal), and relatively low political risks.

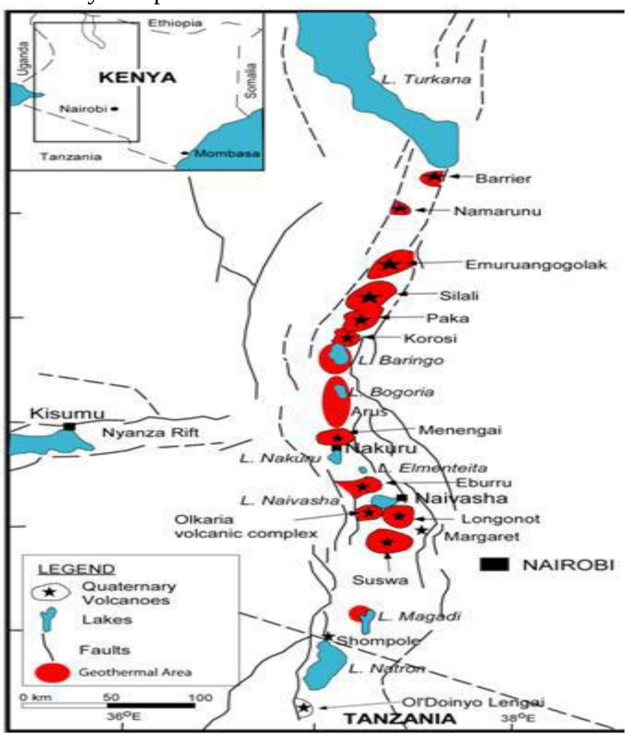

Fig 2: Shows geothermal potential sites (Source: http://www.gdc.co.ke

The estimated potential of over 15,000 MW of geothermal potential in the Rift Valley within Kenya had attracted a lot of attention from government over last 10 years. The intent is meet the very rapidly increasing electrical energy demand due to recovering economy, the fast rural lighting programme; rural electrification and connectivity currently in high gear via Rural Electrification Authority (REA). In rural Kenya, wood is still burned for cooking fires and literacy rates are very low. Access to electricity could help break the cycle of poverty because it would allow students to be able to read at night and do their homework. Drought in Kenya has reduced river flows and hydropower output. It isn't clear exactly what role climate change has had in the droughts, but geothermal energy could fill gaps left by waning hydropower should the drought conditions continue.

Climate change could wreak havoc on Kenya's economy, which is dependent in part on electricity generation, agriculture and tourism, because drought conditions would wipe out crops and wildlife and hamper energy supply for economic development encapsulating the envisaged Kenya's 2030 economic blue print. This necessitates shift focus on the alternative sources of energy like geothermal.

4.0 TECHNICAL INFERENCES

4.1 HYDRO GENERATION SET UP

A. Power from Dams (Potential Energy)

A hydroelectric dam installation uses the potential energy of the water
retained in the dam to
drive a water turbine which in turn drives an electric generator. The available energy therefore depends on the head of the water above the turbine and the volume of water flowing through it. Turbines are usually reaction types whose blades are fully submerged in the water flow. The diagram opposite shows a typical turbine and generator configuration as used in a dam.

The civil works involved in providing hydro-power from a dam will usually be many times the cost of the turbines and the associated electricity generating equipment. Dams however provide a large water reservoir from which the flow of water, and hence the power output of the generator, can be controlled. The reservoir also serves as a supply buffer storing excess water during rainy periods and releasing it during dry spells. The buildup of silt behind the dam can cause maintenance problems hence limitation of this source.

For water flowing at one cubic meter per second from a head of one meter, the power generated is equivalent to 10 kW assuming an energy conversion efficiency of 100% or just over 9 kW with a turbine efficiency of between 90% and 95%.

B."Run of River" Power (Kinetic Energy)

"Run of river" installations are typically used for smaller schemes generating less than 10 Megawatts output. Water from a fast flowing river or stream is diverted through a turbine, often a Pelton wheel which drives the electrical generator. The head of water is essentially zero and the turbine converts the kinetic energy of the flowing water into the rotational energy of the turbine and the generator. The available energy therefore depends on the quantity of water flowing through the turbine and the square of its velocity. Impulse turbines which are only partially submerged are more commonly employed in fast flowing run of river installations while in deeper, slower flowing rivers, submerged Kaplan turbines may be used to extract the energy from the water flow. Run of river projects are much less costly than dams because of the simpler civil works requirements. They are however susceptible to variations in the rainfall or water flow which reduce or even cut off potential power output during periods of drought. During flood conditions the installation may not be able to accommodate the higher flow rates and water must be diverted around the turbine losing the potential generating capacity of the increased water flow. Because of these limitations, if the construction of a dam is not possible, run of river installations may need to incorporate some form of supply back-up such as battery storage, emergency generators or even a grid connection.

Available Power is the maximum power output from a turbine used in a run of river application is equal to the kinetic energy of the water impinging on the blades.

As seen from the above types of hydroelectric scenarios, the power output is site restricted as it is function of economic effective head coupled with gravitational pull. These sites in Kenya are limited compared to vast geothermal fields in The Rift valley.

4.2 ELECTRICAL ENERGY TRENDS WITH FIXED HYDRO-ELECTRIC OUTPUT

The Electricity production (kWh) in Kenya was 6875000000 in 2009. Electricity production is measured at the terminals of all alternator sets in a station. In addition to hydropower, coal, oil, power generation, it covers generation by geothermal, solar, wind, and tide and wave energy, as well as that from combustible renewables and waste. Production includes the output of electricity plants that are designed to produce electricity only as well as that of combined heat and power plants. The production data is shown in the bar graph below:

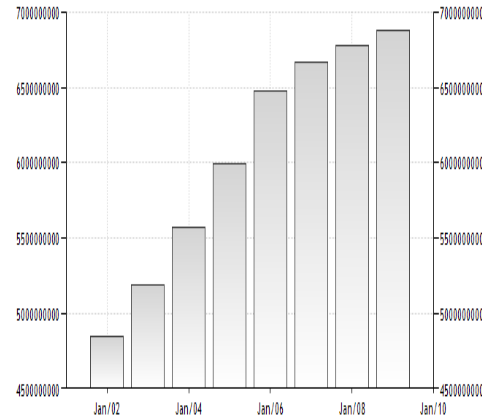

Fig.4 Electricity production (KWh) in Kenya: Source: World Bank report, published in 2010

The Electric power consumption (kWh per capita) in Kenya was 147.43 in 2009. Electric power consumption measures the production of power plants and combined heat and power plants less transmission, distribution, and transformation losses and own use by heat and power plants. The chart below gives an insight:

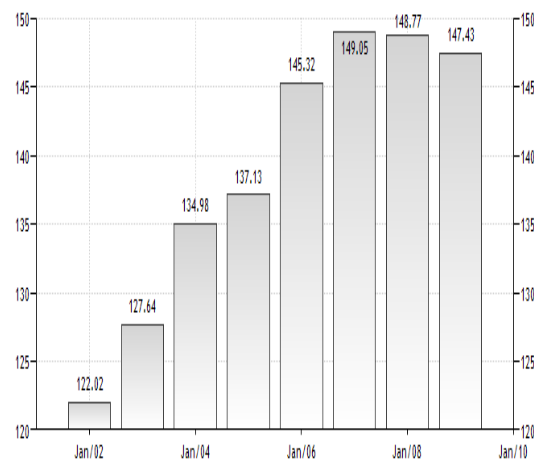

Fig.5 Electricity Consumption (KWh) in Kenya: Source: World Bank report, 2010

The Electricity production from petroleum oil sources (kWh) in Kenya was 3029000000 in 2009, according to a World Bank report, published in 2010. Sources of electricity refer to the inputs used to generate electricity. Oil refers to crude oil and petroleum products as shown below:

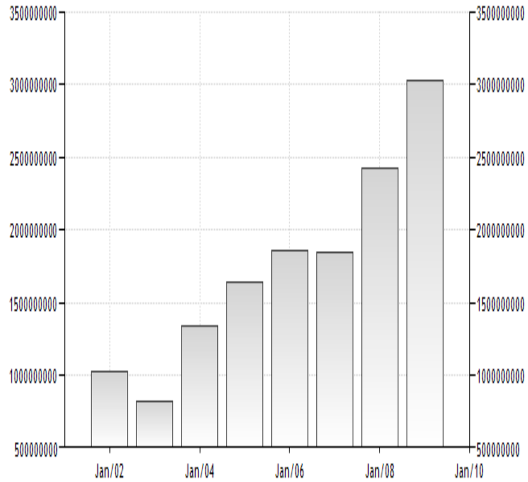

Fig.6 Electricity Production from Petroleum (KWh) in Kenya: Source: World Bank report, 2010

From fig. 6 it clear that the demand for power continues to rise over the time against a back drop of constant supply an since the generation is limited, fossil fuel sources become inevitably valuable. This comes with very dear cost of power.

4.3 LIMITATIONS HYDRO OF ELECTRIC POWER:

Although hydroelectric power plants do have some benefits, there are drawbacks to their use as well. There are many environmental concerns in building a hydroelectric power plant, including disrupting local ecology and displacement of nearby people and animals. The demerits are:

1) Disrupts aquatic ecosystems: The dams developed across the rivers can disturb aquatic life and lead to their large scale destruction. There is a chance that fish and other water animals may enter the penstock and ultimately the power generation turbines where they will be killed. Dams can also disturb the mating seasons and mating areas of the water animals. In some cases water animals have to swim against the water stream during breeding seasons. If a dam is built in the path of migrating fish they could be stuck there and killed, never reaching their destination. This could devastate a population of fish.

2) Disruption in the surrounding areas: Plant and animal life around rivers thrive due to continuous fresh flowing water in the river. Due to construction of the dams lots of areas have to be cleared that disrupt the plant and animal life. In many cases even a number of trees have to be cut that destroys not only the plant life but also the animals dependent on them. Even changing the course of flow of water in the river due to the construction of the dam disrupts the plants and animals life.

3) Requires large areas: In order to build a dam, power generation unit and transformers, and connect them to the national grid, a huge amount of land is needed. This requires forests to be cleared disrupting many local, natural ecosystems.

4) Large scale human displacement: Because these dams take up such a large area, it is often necessary for humans to relocate. It is not easy to convince people to uproot their lives and businesses. Often they are not compensated fairly for their land and the inconvenience. This creates large scale opposition and revolts against construction of the dams. For instance, In India there has been a large opposition to the one of the biggest hydroelectric power projects named “Sardar Sarovar.” Though millions of people are to benefit from the project, government didn’t manage the important issue of the resettlement of people who were displaced from the adjoining areas of project. This led to one of biggest protests in Indian history, which saw a number of hunger strikes, protest marches and even police attacks on the protesters.

5) Hydroelectric scenarios the power output is site restricted as it is function of economic effective head coupled with gravitational pull. These sites in Kenya are limited compared to vast geothermal fields in The Rift valley. (http://www.brighthub.com/environment/renewable-energy/articles/7729.aspx)

4.4 IMPACT OF DROUGHT ON HYDROPOWER GENERATION AND ECONOMIES

Recurrent droughts - thought to be linked to climate change - feature among the key challenges that face the economies of the East Africa and Horn of Africa region especially in Kenya. They have serious negative impacts on the region’s power sector. Drought-induced reduction in electricity generation from hydropower has become a persistent feature in the region’s power sector. The adverse impacts of what is thought to be “climate change-related” power crises have had far-reaching and devastating impacts on both the power sectors and the economies of the countries within the Kenya. These impacts are expected to become even stronger in the next years; hence their consequences are likely to become ever more serious as well.

As a result, during power crises, the most common response option from governments in the Kenya has been to procure very high cost emergency thermal electricity to meet the shortfall in power supply.

In Kenya, Tanzania and Ethiopia, drought-related power shortages and their impacts were similar to Uganda.

Government and electricity utility companies within Kenya, there are need to adopt more robust, resilient and well thought out response options for addressing drought induced power crises. A key response option is the adoption of mature renewable energy technologies, majorly geothermal that provide multiple benefits. Renewables are ideal candidates for development as complements to hydropower generation.

Renewable energy option such as Geothermal is attractive since the resources are widely available in the Kenyan rift. These options are not only environmentally friendly but also provide additional developmental benefits such as job creation and reduction of oil import bills.

In light of the drought related problems facing the power sector in Kenya, and the environmental, commercial and social benefits of the aforementioned renewable energy options, this study calls for an urgent implementation of renewable energy options in the Kenya. The development of renewables can protect the region's power from what is thought to be climate change induced drought that affects its hydroelectric power generation. It is worth noting that, although large-scale hydro is a renewable energy, it is likely to be more vulnerable to the impacts of drought than decentralized approaches.

4.4.1 Climate Change and Drought

Africa, with the exception of the Congo/Zaire river basin is normally considered one of the driest continents (apart from Australia) and experiences the most unstable rainfall regime. Droughts are frequent in most African countries and each year more people are at risk from the effects of inevitable droughts of greater or lesser severity. Recent World Bank studies on incidences of drought indicate that, since 1991, East and Horn of Africa has been experiencing significant rainfall shortages (Table 1) which are increasing in frequency.

There is a direct relation between climate change and energy security, in that varying rainfall patterns have led to severe drought affecting hydro power generation, and in some cases, flooding. Excessive flooding on the other hand contributes to a rapid buildup of silt in hydropower dams affecting the amount of water available for electricity generation. Silt can also damage turbines of hydropower stations. Flooding also leads to spillage of excess water, which cannot be stored for use during water shortages.

Table 1: Years of Significant Rain Shortages in Agriculturally Productive Areas.

D = Year in which there was a significant rain shortage in agriculturally productive Areas

Source: World Bank, 2005

Country	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Burundi								D	D	D				
Djibouti									D	D				
Eritrea						D	D		D	D	D	D	D	D
Ethiopia	D	D		D			D		D	D	D	D	D	D
Kenya		D	D				D	D	D	D	D	D	D	D
Rwanda					D	D		D	D	D				
Sudan					D		D			D	D	D	D	D
Tanzania		D					D	D	D	D		D	D	D
Uganda							D		D	D	D	D	D	

Table 2: Impact of Drought Related Power Crisis on the Kenyan Economy

Source: Eberhard et al, 2000

Source: Eberhard et al, 2000

Country	Drought period	Consequences
Ethiopia	2006-2008	Experienced more than six months of power cuts due to low water levels in hydro dams – scheduled blackouts initially once a week, but as the drought wore on, customers lost power for 15 hours two days a week
Uganda	2004/2005	Reduction in water levels at Lake Victoria resulting in reduction in hydro- power generation by 50 MW
Kenya	1998–2001	Massive drought decreased hydro generation (25% in 2000), which had to be replaced by more expensive fuel-based generation. Power rationing in 1999–2001.
Malawi	1997–1998	Engineering operations affected by drought. Amount of hydro energy generated was 6% less than in years of normal rainfall.
Mauritius	1999	Massive drought led to 70% drop in normal annual production of electricity.
Tanzania	1997	The Mtera dam reached its lowest ever level resulting in a 17% drop in hydro generation. Use of thermal generation to meet the shortfall, and power rationing

Source: Karekezi and Kithyoma, 2005

Table 3: Impact of Emergency power generation on GDP

Country	Date	Contract Duration	Emergency Capacity (MW)	Percentage total installed capacity (%)	Estimated annual cost as % GDP	Drought Related?
Rwanda	2005	2 years	15	48.4	1.84	Yes
Uganda	2006	2 years	100	41.7	3.29	Yes
Tanzania	2006	2 years	180	20.4	0.96	Yes
Kenya	2006	1 year	100	8.3	1.45	Yes

Source: Eberhard et al, 2000

Power in the region is that it is expensive and leads to higher costs for consumers .The impact of drought on the region's power sector has adversely affected national economies. In Uganda, for example, the hydroelectric generating capacity dropped by half following Lake Victoria's nearly 2 meter drop in water levels (Wines, 2007). As a result, economic growth projections dropped from 6.2% - 5.3% (Baanabe, 2008; Bloomberg, 2006; Oxford Country Briefings, 2007). The country had to turn to costly thermal generators to ease the supply deficit. Electricity supply was more intermittent than usual, and the price of electricity increased.

4.4.2 Impact of Drought Related Power Crisis on the Kenyan Economy

The first spell of drought that affected hydropower generation in Kenya occurred in 1992, when failure of rains led to power rationing between April–May. In 1999/2000, a severe drought, decreased hydro generation (by up to 25% in 2000) and led to unprecedented power supply shortfall resulting in a serious power rationing program. In 2006-2008, low water levels at hydro dams (due to both drought and siltation) resulted in a decrease in power generation - Emergency Diesel Power Plants are currently supplying high cost 100 MW to the national grid (KPLC, 2007; GoK, 2007; KenGen, 2007).

Emergency power generation resulted in higher costs of power, since the cost of diesel used for generating power was passed on directly to the consumer. The estimated loss of GDP due to power sector crises was estimated at about 1.45% of Kenya's GDP (the country's GDP is about US$ 29.5 billion). This loss in GDP translates to US$ 442 Million. Assuming this loss in GDP was used to develop renewable energy options to compliment hydro power resources, about 295 MW worth of renewable energy power could be generated, assuming 1 MW costs US$ 1.5 Million to install. This equates to about 3 times the installed emergency power capacity, and twice the capacity of hydro power lost during drought periods. It is safe to suggest that if the equivalent sum of money was spent on diversifying sources of electricity generation through greater use of renewables drought related hydro power crises could be avoided in the future.

For Kenya, it is therefore a fact that renewable energy systems offer diversification in energy supply, thus strengthening energy security by broadening national energy generation portfolios. Countries with diversified energy generation sources are better- off compared to those which heavily depend on centralized large-scale hydro or conventional thermal plants that rely on imported petroleum fuels which have a degree of uncertainty in supply and cost. The following discusses geothermal development in Kenya and how its impact gives weight the argument that Kenya could be better economically if it is majorly powered by geothermal energy.

5.0 GEOTHERMAL - MAJOR SOURCE

Geothermal energy is energy from depths of the earth, which is exploited after exploration, drilling, power plant construction and operation for electricity generation and other direct uses. The medium of this energy transfer are geothermal fluids. On the surface, these are manifested as hot grounds, fumaroles, geysers, mud-pools and hot springs (source: Simiyu, 2006).

Currently, the installed geothermal capacity in Kenya is 202 MW. Kenya geothermal power plants account just over 10% of the country's total installed capacity. In the Least Cost Power Development Plan (LCPDP), geothermal is a low-cost source of power that provides some protection against high and fluctuating oil prices and drought-related hydropower problems. There is renewed interest in the development of geothermal in Kenya, and the Ministry of Energy has set out explicit and specific targets for geothermal development and by the year 2020, geothermal power is expected to account for a quarter of total power installed capacity up from current 10% (GoK, 2004b).

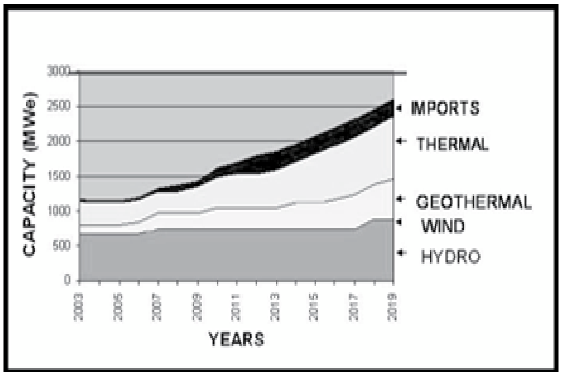

Fig. 7 Base load power survey; Source: Simiyu, 2006

During the drought period of 1999-2002 in Kenya, when hydroelectric power generation in Kenya was severely affected, national demand for electricity was partially met by the generation from geothermal sources, which was not affected by the prevailing drought at that time and was operating at a nearly 100% capacity, 24 hours a day during the drought period.

The main advantages of geothermal are that it generates continuous reliable "base load" power whenever needed. Owing to its modular nature, geothermal offers investors with incremental development opportunities as one can start with small installations of about 10 MW and increase them slowly over time. In addition, geothermal energy has the potential to provide power to remote sites that are far away from the national grid owing to the location of the stations i.e. deep in the rural areas.

The main key success factors that led to the speedy development of geothermal in Kenya include:

Long-term commitment to supportive policies and local skills development*:* Geothermal development in Kenya began in the 1970s, and has been growing in a modular fashion over the years. Geothermal is now fully integrated in the country's long- term national power master plan.

Specialization*:* A dedicated team focused on geothermal power development is stationed at the source of geothermal power in Kenya's Rift valley. Kenyan geothermal experts are beginning to provide technical assistance in the region and even outside Africa

All the countries in the Kenya could reap significant benefits from, and hedge their respective power sectors from the effects of what is believed to be climate change induced drought by investing in the development of geothermal energy sources. The potential of geothermal energy in East and Horn of African countries is shown in the table below. It is estimated that a portion of the geothermal potential, would be sufficient to hedge against drought related power crises in East and Horn of Africa.

5.1 Why a major source?

The expansion to existing geothermal operations offers the least cost, environmentally clean source of energy (green) and highest potential to the country.

Kenya is one of the leading countries globally with significant geothermal resources. The Government of Kenya through the Ministry of Energy has already undertaken significant investment in developing this sector. This includes supporting scientific research, drilling and generation of electricity. However, geothermal development has stalled in recent years because of limited funding and lack of private sector participation in this sub sector due to high risks associated with exploration and development of geothermal sites.

In order to fast track the installed capacity to meet the increasing demand for electricity, the Government of Kenya has embarked on developing the available geothermal resources. Geothermal has been chosen as the best alternative for capacity expansion because of the following reasons:

Geothermal energy is an indigenous, environmentally attractive and proven energy resource. It is quite abundant and widespread throughout the Rift Valley of Kenya, and perhaps locally elsewhere in the country. Geothermal energy, unlike hydroelectric power, is immune to the adverse effects of climate change. This enhances its value as base load electricity.

Geothermal energy does not have the adverse environmental effects unlike coal, diesel or gas-fired generation. Through geothermal electricity generation valuable CO2 credits can be earned through CDM thus reducing overall cost while protecting Kenya's environment.

The cost of hydrocarbon-based fuels is likely to remain high throughout the foreseeable future. The effect of this will be less on geothermal energy than on diesel or gas fired generation.

The ability to maintain and grow hydro generation capacity is increasingly limited, at a time when the country's demand for electricity is close to the boundary of the existing plants' output capabilities.

Surface exploration has indicated potential geothermal reserves at Longonot, Suswa and Menengai, Korosi, Paka, Silali and Chepchuk. All of these are easily accessible to transmission lines and to load centers.

There is a fully trained, capable and experienced team of geothermal experts within Kenya today. In addition, facilities such as laboratories and equipment are available.

Modern technology has made it possible to undertake deep drilling to depths of more than 3 km vertically and directionally thus improving the chances of striking more steam.

Kenya's Least Cost Power Development Plan has ranked geothermal power as a cost effective source for continued electricity development. As depicted in the Screening Curves, geothermal is one of the most economical electricity generation options over a wide range of capacity factors. The annualized cost of electricity for geothermal is lower than most thermal alternatives.

As evidence of the effectiveness of geothermal energy, the installed generating capacity at Olkaria I power station has produced electricity as base load since 1981 at an average operating factor above 90%. (Least cost plan paper for Kenya, 2011)

6.0 IMPACT OF A MAJORLY GEOTHERMAL ECONOMY

The period after which geothermal projects in Kenya are expected to start generating electricity can be reduced further to two or three years by installing plants and generators on the already drilled productive wells. This strategy will not only generate power for project implementation by providing power for powering the economy, but also provide opportunities for other direct uses using the low enthalpy geothermal resources.

6.1 Significant reduction of effects of drought and climate change on hydroelectric units

Government and electricity utility companies within the Kenya need to adopt more robust, resilient and well thought out response options for addressing drought induced power crises. This study concludes that mature renewable energy options with multiple benefits are ideal candidates and can be developed to complement hydropower generation. Options such as geothermal, small hydro, biomass cogeneration and wind are attractive since the resources are widely available in the region. These renewable energy options are not only environmentally friendly but provide additional developmental benefits such as job creation and reduction of oil import bills.

In light of the numerous problems facing the energy sector in the Kenya, and the environmental, commercial and social benefits of the geothermal, there is urgent need for East and Horn of African Governments to implement this renewable energy options order to protect their power sectors from what is thought to be climate change induced drought that affects hydroelectric power generation within the region.

6.2 Power System Reliability and Stability

Geothermal energy is a relatively low-cost and indigenous generation option that can contribute to New Zealand's growing demand for electricity. It is uniquely reliable, with geothermal power stations typically achieving load factors of 95%, compared to typical load factors of 30 - 50% for hydro and wind power stations. The Wairakei power station has operated at a load factor of more than 90% for over 40 years with low operating costs. This inherent reliability makes geothermal generation a valuable component in a diverse electricity supply system such as Kenya's.

On stability, the geothermal power plants to be installed have larger inertia than the power hydro plants they substitute. Therefore, the system is more likely to maintain stability under transient condition when the load is supplied from geothermal plants. When a large power demand is met with only geothermal power plants, the system will be more stable than if it is met with hydro plants.

Geothermal electricity power thus plants enhances transient, small signal and voltage stability of the power system compared to hydro power plants.

(http://eeweb.poly.edu/faculty/fdeleon/students/pdfs/Olof%20Helgadottir.pdf)

6.3 Significant cut in emergency Power (Expensive thermal plants)

Emergency power generation resulted in higher costs of power, since the cost of diesel used for generating power was passed on directly to the consumer. The estimated loss of GDP due to power sector crises was estimated at about 1.45% of Kenya's GDP (the country's GDP is about US$ 29.5 billion). This loss in GDP translates to US$ 442 Million. Assuming this loss in GDP was used to develop renewable energy options to compliment hydro power resources, about 295 MW worth of renewable energy power could be generated, assuming 1 MW costs US$ 1.5 Million to install. This equates to about 3 times the installed emergency power capacity, and twice the capacity of hydro power lost during drought periods. It is safe to suggest that if the equivalent sum of money was spent on diversifying sources of electricity generation through greater use of renewables drought related hydro power crises could be avoided in the future

The first spell of drought that affected hydropower generation in Kenya occurred in 1992, when failure of rains led to power rationing between April–May. In 1999/2000, a severe drought, decreased hydro generation (by up to 25% in 2000) and led to unprecedented power supply shortfall resulting in a serious power rationing program. In 2006-2008, low water levels at hydro dams (due to both drought and siltation) resulted in a decrease in power generation –

Emergency Diesel Power Plants are currently supplying high cost 100 MW to the national grid (KPLC, 2007; GoK, 2007; KenGen, 2007).
The tariff increases due to installation of emergency diesel generated electricity are likely to indirectly affect low income urban residents who have electricity. Energy costs form a significant share of total household expenditure and low income households in East and Horn of Africa spend a significant share of their income on energy. For example, the poor in South Africa spend up to 20% of their income on energy. (AFREPREN/FWD, 2008).
High cost of energy costs impedes industrialization and overall economic development of any Country.

6.4 Carbon credit earnings

Carbon trading is the sale of gases that contribute to global warming, e.g. carbon dioxide, which are not emitted to the atmosphere following installation of environment friendly production systems. Carbon trading involves, though is not limited to, industrialized nations funding clean energy projects in the developing world to meet their greenhouse gases emission targets set by Kyoto Protocol under the treaty's Clean Development Mechanism (CDM).
Kenya is looking to generate revenue from its planned geothermal project in Menengai by selling carbon credits. The is currently working on modalities of registering the Menengai Geothermal Project under the Clean Development Mechanism of the Kyoto Protocol, which is under the aegis of the United Nations Framework Convention on Climate Change. The overall objective is to contribute to national sustainable development and increased electricity generation towards attainment of Vision 2030.
Kenya has so far earned Sh534 million in carbon credit trading out of five national projects. The system issues carbon credits to the government of the country in which reforestation or growing of other plants takes place.
In developing countries, one gets credited to the extent to which one is emitting less carbon as per the standards fixed by the United Nations Framework Convention on Climate Change. The five projects that have benefitted from the project are Bagasse Based Cogeneration project by Mumias Sugar, Olkaria Phase 2 Geothermal Expansion project, Olkaria II Geothermal Expansion project by KenGen, Lake Turkana 310 MW Wind Power project and the Abaredares small scale reforestation initiative. (The Star, MAY 9, 2012).
Kenya will channel earnings from the carbon credit market towards realizing the full potential of the country's geothermal energy resources in addressing the growing demand for power.
Kenya earnings are estimated KShs.442 million every year from the sale of 662,000 tons of carbon credits at Sh670 per ton to the World Bank. 2011 KenGen and the World Bank signed an Emission Reduction Purchase Agreement (ERPA) for the purchase of 900,000 tons of carbon generated from one of the six Clean Development Mechanism (CDM) projects that it has offered to purchase emission reductions. The projects include Olkaria II 3rd Unit, Eburru, Kipevu Combined Cycle, Kiambere, Sondu Miriu and Redevelopment of Tana Power Station.
The bulk of the money will be used to finance geothermal development while an additional dollar per ton of carbon credits will be used in community development projects. The World Bank Community Development Carbon Fund (CDCF) contributes an additional dollar for every purchase of a ton of carbon credits to benefit communities. With hiked clean energy generation capacity more carbon credits will ploughed back into the country's energy development and exploitation agenda. (Kenya Engineer, 2011)

6.5 Benefits associated with modular well head generating units

6.5.1 Early generation for geothermal development with modular plants

Geothermal sites Kenya are found in remote locations; off-grid (Outside national power network) and hence diesel generators are used to provide power the drilling rigs. For instance, Menengai well 03 and 04 have used diesel to power the drilling rig, base camp and associate equipment of over Kenya shillings 100 million(USD1.2 million) which is about a quarter 25% of the total cost of drilling the well. Menengai well one and four can produce over 10MWe.peak loads for our 2000 horse power rigs is 1.5MWe. By connecting these wells to well head generators producing over 10MWe, we can save over a quarter of drilling and base camp facility costs. Moreover, procurement and logistics period required before obtaining the diesel fuel will be eliminated hence reducing the drilling period significantly. This is notwithstanding the fact that diesel generators require maintenance periodically. Oil filters; oil and fuel filters alongside labor required for maintenance are eliminated by use well head generators.
Since the use diesel will completely be eliminated by the portable well head generators, the use of geothermal energy amount to use of green energy which environmental friendly, cheaper and clean.

Drilling, design and construction of a traditional geothermal power plant can take up to 7 years to complete (Green Energy Group; www.geg.no/product-sheet). This involves the need for big capital injections while at the same time not being able to cater for the short term needs of energy. Well head manufacturers like Toshiba and Green Energy Group have developed a standardized module system which is in mass production today. The production capacity of each module is up to 15 MW and can be put together to produce a larger scale power station. It takes one year from module construction to it being installed and operational. The considerable time before power production can take place lies in the amount of wells that need to be drilled.

The portable geothermal units can be installed in the Menengai geothermal field especially to displace the diesel being currently used to run the rigs, compressors and auxiliary equipment in the field. The two already producing wells (well MW-01 and MW-04) can be harnessed to generate over 10 MWe as well tests are ongoing. As more wells are drilled in the field, the number of wellhead plants can be increased to supply electricity to the grid. This is practical as the Menengai field is close to Nakuru town which will provide a ready market.

The same concept can either be applied to existing geothermal fields like Olkaria, where more wells are being drilled for expansion or new fields like Korosi-Paka-Silali block, as part of the geothermal field development program.

By implementing this concept, the subsequent early generation programs will benefit from the experiences of the first implementation and the reuse of the portable wellhead units.

6.5.2 Integration of small power plants with agribusiness and tourism

The integration of small geothermal power projects with agribusiness and tourism is rapidly growing in popularity. This trend is a result of advancements in the generation of electricity from low to moderate temperature geothermal resources (100°C-150°C) and the economic advantage that full use of the resource provides.

Opportunities for integration of small geothermal plants with other direct uses exist in the Kenyan rift where most of the viable geothermal sites are found i.e. Nakuru, Baringo and Turkana counties.

The use of wellhead type generation coupled with agribusiness systems e.g. agriculture crop dehydration, greenhouses, milk processing and aquaculture in these remote regions of the Kenya will not only support the above processes but also supply power off grid. In addition, the infrastructure built in the process of developing the geothermal resources will promote tourism activities in these regions. Consequently, there will be need to provide power off-grid and using the geothermal fluid for tourism activities like outdoor bathing, warm swimming pools and water heating for sauna baths. Table 2 summarizes some of the integrated direct uses of geothermal fluid from the small power plants.

Table 4: Opportunities for integrated geothermal power generation and direct uses in Kenya

Item	Area (county)	Type of integrated direct use
1	Nakuru	Crop dehydration; maize, onions, wheat Greenhouse use Milk and pyrethrum processing
2	Baringo	Crop dehydration; tomatoes, onions Greenhouse uses Tourism applications; swimming pools, outdoor bathing and heating of sauna baths
3	Turkana	Fish drying Greenhouse uses Tourism applications; swimming pools, outdoor bathing saunas

The integration of small power production with agribusiness projects and off grid power supply in remote Kenya by use of portable wellhead turbine power generators can significantly improve the economic viability of using lower temperature geothermal fluids and can result in a much higher overall “fuel use efficiency” than can be achieved with stand-alone power or direct use projects.

6.5.3 Investment opportunities

By embracing the early generation concept, the geothermal industry in Kenya will provide a great investment opportunity to the private sector. The portable well head technology will enable power developers, utilities and independent power producers to significantly reduce capital costs since no need for steam lines to connect many well to the power plant as is the case in traditional power plants. The reduced time between exploration and revenue generation in geothermal projects will accelerate the growth in the geothermal development in Kenya. The investor can generate power from a single or more wells and generate revenue to invest in other fields being drilled. More significantly the government would have shielded the investor from the high risk initial stages of the field development and proved the existence of the resource, and hence enables the investor to concentrate on power generation.

8.0 THE CHALLENGES TOWARDS A WHOLLY GEOTHERMAL ECONOMY

•Large Upfront cost of geothermal exploration and development
•High Risks Associated with Resource Exploration and Power development
•Inadequate skilled manpower and equipment for geothermal Resource Exploration and development
•Limited national budgetary allocation and donor funding
•Inadequate Private Sector Participation in the region
•Lack of Supportive government policy and Regulatory framework
(Peter Omenda, Feb 2012)

9.0 WAY FORWARD

Institution of attractive and pre-determined standard Power Purchase
Agreements (PPAs) for generated power: A standard PPA can limit market uncertainty, which stands in the way of substantial investment in renewables in the region. A PPA linked to a pre-determined standard-offer or tariff, from the national utility to purchase all energy produced by geothermal electricity and renewable energy plants can be instrumental in the successful scaling up of renewables-based power investments in the African power sector (UNEP/GEF, 2006).
Innovative Financing: Innovative financing schemes should be developed by financial institutions in collaboration with project developers. Interaction between financiers and project developers could help bridge the knowledge gap on both sides – financiers would gain a better understanding of this renewable source of energy while project developers would have a better appreciation of pre-requisites for raising financing for renewable energy investments. Bundling of smaller/medium sized projects would help them access funds that have minimum investment caps, and lower the upfront cost of financing.
Kenya and other African countries can tap into the various international and regional initiatives that can provide funding for renewable investments like geothermal resources. These initiatives include: the Global Environment Facility (GEF) and the Kyoto Protocol's Clean Development Mechanism (CDM). One drawback of the CDM, however, is its high transaction costs and specialized skills requirements that have tended to limit the participation of African countries and experts to date.
Innovative Revenue-Sharing Mechanisms: One way of ensuring support for the development of renewables is by instituting appropriate revenue-sharing mechanisms. The benefits of renewables such as geothermal are immense. Revenue sharing mechanisms can be used as incentives for local participation in developing geothermal resources and other renewables, and are useful for building local support for scaled-up renewables development.
To make the dream of having geothermal as the main source of electricity generation, estimates indicate the country requires $20 billion (Sh1.7 trillion), which is about double Kenya's annual budget; this money must be raised.
Planning of transmission and distribution lines and technical improvements alongside complex power system control and protection is critical. The transmission and distribution networks for power are very crucial for the planning and development of geothermal power plants but they need huge financial investment.
(LSHREACC Occasional Paper no.33)

10.0 CONCLUSION

Inadequate electricity generation capacity and high power bills have been perennial problems in Kenya prompting the Government to explore various ways of tackling the glitches. Currently, a lot of effort is geared at developing the country's geothermal power capacity, which experts opine is environmental friendly and more affordable to run compared to other sources of energy like fossil fuel.
A major shift to geothermal power will also insulate the country against the effects of drought, which often interferes with hydroelectric power. Over 70 per cent of our installed capacity of power plants has historically been powered by hydroelectric sources with diesel-fired plants also accounting for a significant portion of the total energy demand. The reliance on diesel is unhealthy, as it has helped push the average cost of production of electricity and made it expensive for consumers. Overall the prices of the commodities we rely on or hope to use for future generation are spiraling and are projected to continue that trend**.**
The proposed shift to geothermal energy is of significant importance for the national economy. It certainly would guarantee better prices and less corrosive interference with the environment. Making geothermal Kenya's main source of energy would allow for a complete stop to the usage or reallocation of price-volatile fossil fuels, such as diesel, which otherwise would have been needed for electricity

generation. By reducing the component of our energy mix that is dependent on the price of fossil fuels – and increasing geothermal power use, which in the long term will guarantee stability – takes away fossil fuel price risks.

Government of Kenya and all Key stakeholders should move fast and explore other alternatives to ensure that plans to generate up to 30 per cent of the country's total energy demands from geothermal materializes. As it is not exposed to price increases, geothermal could provide a very important element in the country's total electricity energy portfolio. If the total benefits of using this form of energy are extrapolated the country could possibly save billions of shillings. International lenders partner with government in this project and given a window to recoup their investment after a period of time, say 10 to 20 years. If done, this will expand geothermal share of the national energy mix, and help reduce greenhouse gas emissions and dependence on hydroelectric power and with the delivery of real fiscal incentives for this form of renewable energy development.

Government, investors and utility companies need to adopt more robust, resilient and well thought out response options towards this dream. This paper has focused on the adoption of geothermal energy renewable energy options with multiple benefits are ideal candidates and can be developed to complement hydropower generation. In light of the numerous problems facing the energy sector in the Kenya and in order to protect their power sectors from climate change this option is invaluable.

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