Geothermal Development in Kenya: A Country Update - 2012

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ABSTRACT

Kenya is endowed with vast geothermal resource potential along the world Kenya Rift that transects the country from north to south. Exploration reveals that geothermal potential exceeds 10,000 MWe. Out of this potential, only 212.5 MWe and 18 MWt are being utilized for indirect and direct uses, respectively. Kenya Electricity Generating Company Ltd (KenGen) and Geothermal Development Company Ltd (GDC) have undertaken detailed surface studies of most of the prospects in the Kenya rift and active drilling is in progress in the Greater Olkaria field and at Menengai. The Least Cost Power Development Plan (2010-2030) prepared by the Government of Kenya indicates that geothermal plants have the lowest unit cost and therefore suitable for base load and thus, recommended for additional expansion. Electric power growth in Kenya currently stands at over 8% annually. In order to meet the anticipated growth in demand, The Kenya Government through the newly formed utility (GDC) has embarked on an ambitious geothermal generation expansion to install additional 5,000 MWe of electric power by the year 2030. The planned geothermal developments require huge capital investments and therefore GDC and KenGen are pursuing private sector involvement to finance the projects through PPP or BOT arrangements.

1.0 INTRODUCTION

Energy is one of the infrastructural enablers of the three “pillars” of the Kenya Vision 2030 strategy which aims to transform the country to medium income status by year 2030. The level and intensity of commercial energy use in a country is one of the key indicators of socio-economic development. As incomes increase and urbanization intensifies, household demand for energy will also rise. Kenya is therefore expected to use more energy on the road towards realization of Vision 2030. Players in the Energy Sector are therefore making preparations to meet the growth in demand for energy in order to achieve the objectives of the Vision and its first Medium Term Plan 2012-2016.

Commercial energy in Kenya is dominated by petroleum and electricity as the prime movers of the modern sector of the economy, while wood fuel provides energy needs for the traditional sector including rural communities and the urban poor. At the national level, wood fuel and other biomass account for about 68% of the total primary energy consumption, followed by petroleum at 22%, electricity at 9% and others including coal at about less than 1%. Solar energy is also extensively used for drying and, to some extent, for heating and lighting.

1.1 Electricity Subsector

Electricity remains the most sought after energy source by the Kenyan society and access to it is normally associated with rising, or high quality of life. However, its consumption in Kenya is extremely low at 121 kilowatt hours (KWh) per capita (compared to 503 KWh in Vietnam or 4,595 KWh for South Africa). About 29% of Kenyans are connected to electricity while the connection rate in the rural areas is estimated at 15%. This situation is rapidly changing as the country invests more resources in power generation, transmission and distribution. In addition, policy and institutional reforms in the sector are being implemented to create room for new providers.

1.2 Institutional Structure in Kenya

Following the enactment of the Energy Act No. 12 of 2006 after the adoption of the Sessional Paper No 4 on Energy in 2004, the energy sector was restructured to bring on board more players in line with the new functions. Accordingly the functions unbundled into generation, transmission, distribution, oversight and policy functions.

The Ministry of Energy (MOE) is responsible for policy and overall guidance of the sector while the Energy Regulatory Commission (ERC) oversees all regulatory functions including coordination of the development of indicative energy planning, tariff setting and oversight, monitoring and enforcement of sector regulations. Energy Tribunal is the sector dispute resolution entity largely involved in settling disputes arising from decisions made by the Energy Regulatory Commission.

The Geothermal Development Company (GDC) was incorporated in 2008 as a Government Special Purpose Vehicle (SPV) intended to undertake surface exploration of geothermal fields, undertake exploratory, appraisal and production drilling, develop and manage proven steam fields and enter into steam sales or joint development agreements with investors in the geothermal sector.

Rural Electrification Authority (REA) is charged with the mandate of implementing the Rural Electrification Programme and came into operation in July 2007 while Kenya Power and Lighting Company (KPLC) is the single off-taker in the power market, buying power from all power generators on the basis of negotiated Power Purchase Agreements for onward transmission, distribution and supply to consumers (single seller).

Kenya Electricity Generating Company (KenGen) is the main generator of electricity in Kenya with a current installed capacity of about 1,180W (about 72%). The company’s expansion plan aims to have an installed capacity of 1,600MW by 2014. KenGen has identified geothermal for as the most promising for development in the medium term. Independent Power Producers (IPPs) in the power sector are involved in competitively procured large scale generation and the development of power plants. The current players comprise IberAfrica, Tsavo, Or-power4 Inc., Rabai, Imenti, and Mumias. Collectively, they account for about 28% of the country's installed capacity.

Kenya Electricity Transmission Company (KETRACO) is a new government owned company established to plan, design, construct, own, operate and maintain new high voltage (132kV and above) electricity transmission infrastructure that will form the backbone of the National Transmission Grid and regional inter-connections.
Nuclear Electricity Project Committee (NEPC) was established in November 2010 by the Government of Kenya to drive the preparation for nuclear energy generation programme for Kenya comprising preparation, endorsement and implementation of a detailed road map for the realization of the requirements and guidelines by the International Atomic Energy Agency (IAEA).

1.3 Status of Electricity Demand in Kenya

The interconnected system in Kenya had a total installed capacity of 1,593 MW as at June 2011; made up of 763 MW of hydro, 586 MW of thermal, 198 MW of geothermal, 5 MW of wind, 26MW from cogeneration and 14MW in isolated mini-grids. The total effective capacity was 1,479 MW during normal hydrology. Hydro accounts for around 49% of the total energy supply. Registered interconnected national sustained peak demand was 1,194MW (1,294 MW unconstrained) registered in May 2011 and 1,211.9 MW in January 2012 (Table 1).

In 2010/2011, the un-served energy averaged 25GWh, with a maximum suppressed demand of 150MW. On average un-served energy stands at between 3GWh to 5GWh per month with a maximum of 20MW of suppressed demand for less than 3 hours per day (Medium term plan 2012-2016).

Table 1: Generation Capacity by Sources

Sources	Installed Capacity (MW)	% Share	Effective Capacity (MW)	% Share
Hydro	763	50%	735	52%
Thermal	532	35%	455	32%
Cogeneration	26	2%	26	2%
Wind	5	0%	5	0%
Imports	0	0%	-	0%
Geothermal	198	13%	191	13%
Isolated Grid	9	1%	8	1%
Total	**1,533**	**100%**	**1,420**	**100%**
EPP	60		60	
Total	1,593		1,480	

EPP-Emergency power producers

There is strong electricity demand growth in Kenya that is being driven by a combination of factors: economic growth, increased connection rate and enhanced rural electrification. The growth is further expected to increase resulting from the implementation of Vision 2030 projects that include in the medium term implementation of light rail for Nairobi, Lamu port, and second container terminal in Mombasa, among other projects. The first new power project that is assumed to be achieved in the medium term is 200 MW of imported power in 2014 and a 280 MW geothermal plant in 2015. The first two gas-fired power plants are assumed to come online in 2017; these will mainly be used as peaking plants. The next new type of technology for Kenya will be a 300 MW coal plant in 2015 and the first 1,000MW nuclear plant to be commissioned in 2022. The total new additional capacity to the system over the long term period will be 18,920 MW including 5,040MW from geothermal.

2.0 STATUS OF GEOTHERMAL DEVELOPMENT IN KENYA

The Kenya rift valley (Figure 1) is part of the African rift system that runs from Afar triple junction in the north to Beira, Mozambique in the south. It forms a classic graben averaging 40-80 km wide. Geologically, the rift is an intra-continental divergence zone where rift tectonism accompanied by intense volcanism, has taken place from late Tertiary to Recent. Most of the volcanic centers had one or more explosive phase including caldera collapse. The centers are dotted with hydrothermal activity and are envisaged to host extensive geothermal systems. The prospects from south to north are Lake Magadi, Suswa, Longonot, Olkaria, Eburru, Badlands, Menengai, Arus Bogoria, Lake Baringo, Korosi, Paka, Silali, Emuruangogolak, Namarunu and Barrier.

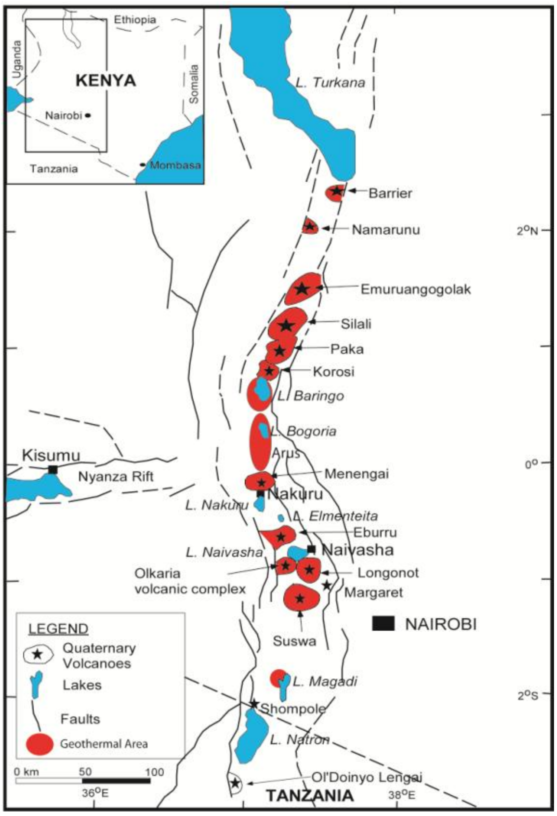

Figure 1: Simplified geological map of Kenya showing locations of the geothermal fields and prospects.

Exploration for geothermal energy in Kenya started in the 1960's with surface exploration that culminated in two geothermal wells being drilled at Olkaria. In early 1970's more geological and geophysical work was carried out between Lake Bogoria and Olkaria. This survey identified several areas suitable for geothermal prospecting and by 1973, drilling of deep exploratory wells at Olkaria commenced and was funded by UNDP. The Government through the Ministry of Energy, GDC, KenGen and other partners has undertaken detailed surface studies of some of the most promising geothermal prospects in the country.

The areas that have been studied in detail include Suswa, Longonot, Olkaria, Eburru, Menengai, Arus-Bogoria, Lake Baringo, Korosi, Paka and Silali. Other areas with not very detailed studies include Lake Magadi, Badlands, Emuruangogolak, Namarunu and Barrier geothermal prospects. Evaluation of these data sets suggest that over 10,000 MWe can be generated from the high temperature resource areas in Kenya.

2.1 Olkaria Geothermal Field

Currently, in Kenya, geothermal energy is being utilized in Olkaria and Eburru fields only. A total of 214MWe interconnected and off grid are installed at Olkaria while about 18 MWt is being used directly in green houses at Oserian farm. The installations are as shown in the following Table 2.

Table 2: Geothermal Plants at Olkaria

Plant	Owner	Installed Capacity	Year Commissioned	Plant type
Olkaria I	KenGen	45	1981-1985	Condensing
Olkaria II units 1 & 2	KenGen	70	2004	Condensing
Olkaria II Unit 3	KenGen	35	2010	Condensing
Olkaria III	Orpower4	55	2000-2009	Binary
Olkaria Wellhead	KenGen	5	2012	Condensing
Oserian	ODCL	4	2004	Binary and condensing
Total		**214**		

Following successful appraisal of Olkaria Domes field and re-evaluation of Olkaria I and II sectors, KenGen has drilled over sixty productions wells in the two areas and resulted in committing the fields to additional 280MW power plants (Figure 2). Construction of the power plants was commissioned in July 2012 and it is planned that the power plant will be commissioned in 2014. Drilling in the eastern Olkaria sector has revealed that additional 560MW can be produced from the field over and above the 280MW currently under development. Orpower4 has also commenced production drilling in the Olkaria III field with an intention of expanding the installed capacity by at least 36MW. The new plant by Orpower4 will be commissioned in 2015.

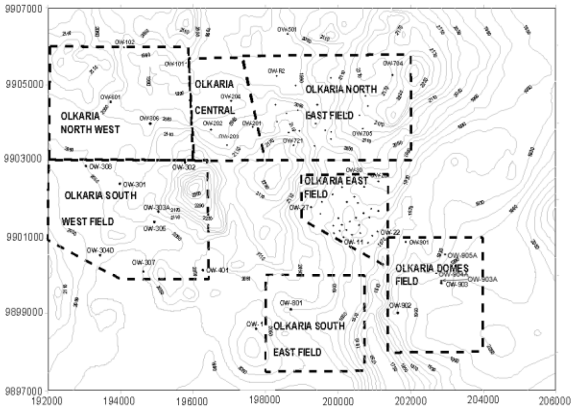

Figure 2: Map of the Greater Olkaria geothermal area showing the locations of the fields.

2.2 Direct use at Oserian

ODLC who grow cut flower for export is also utilizing steam from a 1.28 MWe well to heat fresh water through heat exchangers, enrich CO_2 levels and to fumigate the soils. The heated fresh water is then circulated through greenhouses. The advantage of using geothermal energy for heating is that it results in drastic reduction in operating costs.

2.3 Eburru

Eburru volcanic complex (Figure 1) is located to the north of Olkaria. KenGen carried out detailed surface studies between 1987-1990 that culminated in the drilling of six exploration wells in Eburru between 1989 and 1991 (Omenda and Karingithi, 1993). Further infill MT surveys done in 2006 revealed that the Eburru field is able to support up to 60 MWe. The results from the exploration wells indicate that the field had experienced temperatures of over 300°C possibly due to localized intrusive. The maximum discharge temperature was 285°C and the total output from the two wells that discharged (EW-1 & EW-6) is 29 MWt (Ofwona, 1996). The estimated power potential of the field based on the data from the wells is about 50-60 MWe (Wameyo, 2006; Mburu, 2006; Omenda et al, 2000). KenGen commissioned in 2011 a 2.5MW condensing pilot power plant. The company will drill in the near future appraisal and production wells for a large power plant.

2.4 Menengai

Menengai caldera is the most recent discovered geothermal fields in Kenya. Detailed surface exploration was carried out in 2004 and culminated in drilling of exploration wells in 2011 by Geothermal Development Company (GDC). MT resistivity distribution at 2000 mbsl shows a conductive body of less than 5 ohm-m centred in the western caldera floor "lobe" and a smaller anomaly at the centre of the caldera. Seismology indicates seismic wave attenuation at 7-8 km depths underneath Menengai caldera and Ol'rongai suggesting the presence of magma bodies, which could be heat sources. The mapped potential area in Menengai is over

80 Km^2 translating to 1,200 MWe of electric power (Geothermal Development Company internal reports).

So far, seven wells have been successfully completed and more than 25MW proved. Production drilling is continuing in the field using four high capacity rigs. GDC has advertised for expression of interest for 400MW phase one development by IPPs expected to be commissioned by 2016. To fast track development of the resources in Menengai, GDC has advertised for joint development of Menengai phase 2 with private sector on 40/60 percent equity arrangement.

2.5 Suswa
Suswa is a Quaternary caldera volcano in the southern part of the Kenya rift. Volcanism at Suswa started about late Pleistocene and the earliest products overlie the faulted Plateau Trachyte of late Pleistocene epoch. The Plateau Trachyte Formation comprises of flood trachytes that erupted on the developing graben. The age of the recent volcanism which is estimated at few hundred years resulted in the formation of the annular trench and the Island block, while the oldest forming the outer caldera is 400±10 ka (Omenda, 1997; Omenda et al, 2000).

Surface manifestations occur around the margins of the outer and inner caldera, on the Island block and in the trench surrounding it. These include fumaroles, steam jets, steaming and hot grounds and solfatara with temperatures of over 93ºC. Detailed surface studies undertaken by KenGen indicate reservoir temperatures of over 250°C, which is comparable to that at Olkaria large potential. Suswa prospect was concessioned for development to WalAm Inc. of Canada.

2.6 Longonot
Longonot volcanic complex is a Quaternary caldera volcano in the southern sector of the Kenya rift. The volcano is dominated by a central volcano with a summit crater and a large outer caldera. Detailed surface exploration work in Longonot was carried out in 1998, with some follow-up MT studies in 2005 and 2010.
Magmatism directly associated with the development of the volcano started about 0.4 ma BP and involved eruption of trachytes and their pyroclastic equivalent. These activities were succeeded by caldera collapse and resurgence within the caldera floor, which resulted to the present day high rising volcano with a crater at the top. The latest trachytic lava flow has been dated about 200 years BP. Surface studies indicate that Longonot volcano has a centralized magma chamber beneath the summit crater.

The geothermal reservoir from the low resistivity anomaly occurs in the southern part of the central crater extending to outside the caldera (KenGen, 1998, 1999; Alexander and Ussher, 2011). The geothermal reservoir is most likely hosted within the faulted Plio-Pleistocene plateau trachytes, which is common within the floor of the southern Kenya rift valley. The heat source is expected to be about 6 km deep (KenGen, 1998; Alexander and Ussher, 2010). Exploration wells have been sited and will be drilled probably in 2013. Estimated power potential is over 700 MWe (KenGen, 1998, Alexander and Ussher, 2011). The field has been concessioned for development to Africa Geothermal International Limited (AGIL).

2.7 Bogoria – Silali Block
The Bogoria – Silali block refers to the geothermal areas from north of Menengai extending northwards to and including Silali volcano. The area encompasses Paka, Silali, and Korosi volcanoes and Lake Bogoria, Lake Baringo and Arus geothermal areas. GDC conducted detailed surface studies in Silali, Paka and Korosi in 2010-2011 which resulted in the identification of priority exploration drilling sites at Silali, Paka and Korosi. The study also revealed that the geothermal area could have a capacity of more than 3,000MWe.

Occurrence of a geothermal system at Paka is manifested by the widespread fumarolic activity, hot grounds and hydro thermally altered rocks. The Paka prospect is located atop a very young volcano that is marked by recent (~10 Ka) eruptions. Results from the surveys indicate that there exists a geothermal system at Paka prospect driven by a heat source at depth and centered below the summit crater extending to the east. A 4 km wide graben structure running NNE across the volcano massif acts as the main structure controlling the reservoir permeability at the subsurface. Reservoir temperatures of between 180$^-$300^{o}C have been estimated based upon chemical geothermometry. Deep exploratory wells to confirm the geothermal reservoir have been sited.

Silali is the largest caldera volcano in the axis of the northern Kenya Rift. Detailed geoscientific studies were carried out in 2010-2011 and revealed the existence of a large geothermal reservoir under the eastern part of the volcano. Geothermometry temperatures indicate subsurface temperatures between 238-325ºC. The estimated potential of the prospect is over 1,200 MWe (GDC internal report). The prospect is the most promising in the block and the first exploration well will be drilled in the area.

Korosi and Chepchuk volcanoes in the north rift are medium size geothermal prospects with strong manifestations that include fumaroles, sulphur deposits and hot grounds. Detailed studies reveal high temperature resource at Korosi volcano and probably medium temperature geothermal system at Chepchuk; the latter being an older volcanic centre. Further studies are planned for Arus and Lake Bogoria areas to accurately determine the resource potential in these prospects.

3.0 INVESTMENT IN ENERGY SECTOR
A total investment of about US$ 7,328 million is required to implement the generation, transmission and distribution projects planned for the medium term. A broad summary of the required investment per investment category is summarized in Table 3. The amount for GDC will be for infrastructure and steam field development of Menengai and Bogoria – Silali block (field).

Table 3: Financing Requirements

	Investment Category	**Implementing Agencies**	**Approx. Investment Amount Million US$**
1	Geothermal Resource Assessment - Menengai and Bogoria Silali block	GDC	1,050
2	Generation	KenGen and IPPs	3,684
3	Transmission	KETRACO	2028
4	Distribution	KPLC	566
	Total Investment Requirements		**7,328**

4.0 PRIVATE SECTOR PARTICIPATION

The geothermal electricity generation in Kenya is still largely dominated by KenGen, which is a state utility with installed capacity of 157.5MW distributed at Olkaria (155MW) and Eburru (2.5MW). The second largest plant at 55MW is privately owned by Orpower4 Inc., a subsidiary of Ormat International and has been in operation since 2003. The government has also licensed several geothermal fields to private sector developers; however, exploration drilling is yet to be undertaken in all these areas (Table 4).

Table 4: Geothermal Fields

Field	**Licensee**	**Status**
Olkaria I. II. IV	KenGen	Generation and Production drilling
Olkaria III	Orpower4	Generation and production drilling
Oserian	ODCL	Production under steam sales by KenGen
Suswa	WalAm	Surface studies
Akira	Marine Power	Surface studies
Longonot	AGIL	Surface studies
Eburru	KenGen	Pilot generation
Menengai	GDC	Production and exploration drilling
Bogoria-Silali	GDC	Surface studies

5.0 INVESTMENT OPPORTUNITIES

The rapid expansion of geothermal generation in Kenya offers significant business opportunities in terms of consultancies, supplies, resource development and power generation.

5.1 Steam Sales Agreement

KenGen is rapidly developing steam at its Olkaria field and will soon offer 280MW development opportunity to potential investor through PPP on steam sales. KenGen will retain management authority of the reservoir and wellhead equipment while the IPP construct and operate the plant on BOT arrangement.

GDC is also offering 400MW Menengai phase one to private developers on BOOT basis. GDC will supply and manage the steam and construct steam gathering system and supply steam to power generators. GDC is currently undertaking production drilling in the field and 25MW is already on the wellhead. It is anticipated that selection of successful developers will be concluded in 2013 and power plants commissioned in 2016-2018.

5.2 Joint Development Agreement

GDC has completed detailed surface studies of the north western sector of the larger Menengai geothermal field and the studies indicate that the resource potential could be over 1,200MW. In that respect, the Company has advertised for interested private sector investors to participate in the development through PPP arrangement for 800MW for Menengai west sector. Development of Bogoria – Silali block will also be undertaken through joint development and an advertisement for interested investors is out.

6.0 OUTLOOK AND CONCLUSIONS

The Government of Kenya through it special agencies is keen to fast track geothermal development in the country through public and private sector participation. Geothermal has been identified as the least cost source of base load power and therefore rapid expansion is being undertaken at Olkaria while new areas are being explored by deep drilling. Whereas concessioning of new prospects will be rare in the future, the private sector would participate at lower risk by participating in joint development with GDC. In addition, steam sales agreements will become more common as the fast pace of steam production continues.

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