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GEOTHERMAL DEVELOPMENT IN KENYA-COUNTRY UPDATES

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ABSTRACT

The world is expected to experience tremendous increase in energy demand between now and the year 2025. The need to meet future energy needs of the people in the word while conserving the environment can be adequately satisfied if clean and sustainable methods of generation are adopted. In Kenya, electricity consumption is expected to grow by 23% to a minimum of 3,000 kWh by the end of 2018. To meet this demand, Kenya has scaled up renewable energy resources development with great focus on geothermal development. Kenya is highly endowed with high temperature geothermal resources that remain largely untapped. The resources are located within the Kenyan Rift Valley which forms part of the East Africa Rift System (EARS). The latter spans from Afar triple junction in Djibouti to the north, to Beira in Mozambique to the south, covering a distance of more than 4,000 km. The Kenyan Rift Valley has various volcanic centers located along its axis, extending from Barrier volcanic center in the north and ending in Lake Magadi in the south. These volcanic centers are hosts to geothermal resources. Some of these resources are well developed and in exploitation and utilization stage, whereas, others are at various stages of exploration. The developed resources include Olkaria, Eburru and Menengai. Olkaria is in the generation and monitoring stage while Eburru and Menengai are in production drilling stage. Others, namely Lake Magadi, Suswa, Longonot, Badlands, Arus-Bogoria, Lake Baringo, Korosi, Paka, Silali, Emuruangogolak, Namarunu and Barrier are at various stages of geothermal exploration. In terms of Geothermal Energy Generation, Kenya is ranked number nine worldwide with a capacity of about 690 MWe. This power is generated by Olkaria I (45 MWe), Olkaria I unit IV&V (150 MWe), Olkaria II (105 MWe), Olkaria III (155 MWe), Olkaria IV (150 MWe), Wellhead generators (83.3 MWe), Oserian (2MWe) and Eburru wellhead (2.5 MWe). To further accelerate development of geothermal resources in the country, the government of Kenya formed the Geothermal Development Company (GDC) in 2009 as a special purpose vehicle (SPV) for geothermal resource development. Presently, GDC has drilled more than forty wells with a resource potential of about 162 MWe in Menengai geothermal prospect. GDC has contracted three independent power producers (IPPs) namely Quantum East Africa Power Ltd., Orpower 22 Ltd., and Sosian Menengai Geothermal Power Ltd., to generate the first phase of 105 MWe, each expected to generate 35 MWe. Similarly, three independent power producers namely Marine Power, African Geothermal International Ltd. (AGIL) and Olsuswa Energy Ltd. have been granted licenses for geothermal exploration in Akiira, Longonot and Barrier geothermal prospects, respectively. Marine Power has

already drilled two wells in Akiira geothermal prospect. Olsuswa Energy Ltd. is currently planning for geoscientific studies in Barrier geothermal prospect to begin later in the year. The first phase is expected to produce 140 MWe. On the other hand, AGIL has planned for a 70 MWe power plant to be developed and commissioned in Longonot geothermal prospect by 2020.

1. Introduction

Kenya has a high potential for high temperature geothermal resources that remains largely untapped. These resources are located within the Kenyan Rift which, forms part of the eastern branch of the East Africa Rift System (EARS). EARS spans from Afar triple junction in Djibouti to the north, to Beira in Mozambique to the south. The Kenyan Rift Valley has various volcanic centers located along its axis, starting from Barrier volcanic center in the north and ending with Lake Magadi in the south (Figure 1). Geothermal studies carried out within the Kenyan Rift indicate a potential in excess of over 10,000 MW of geothermal resource.

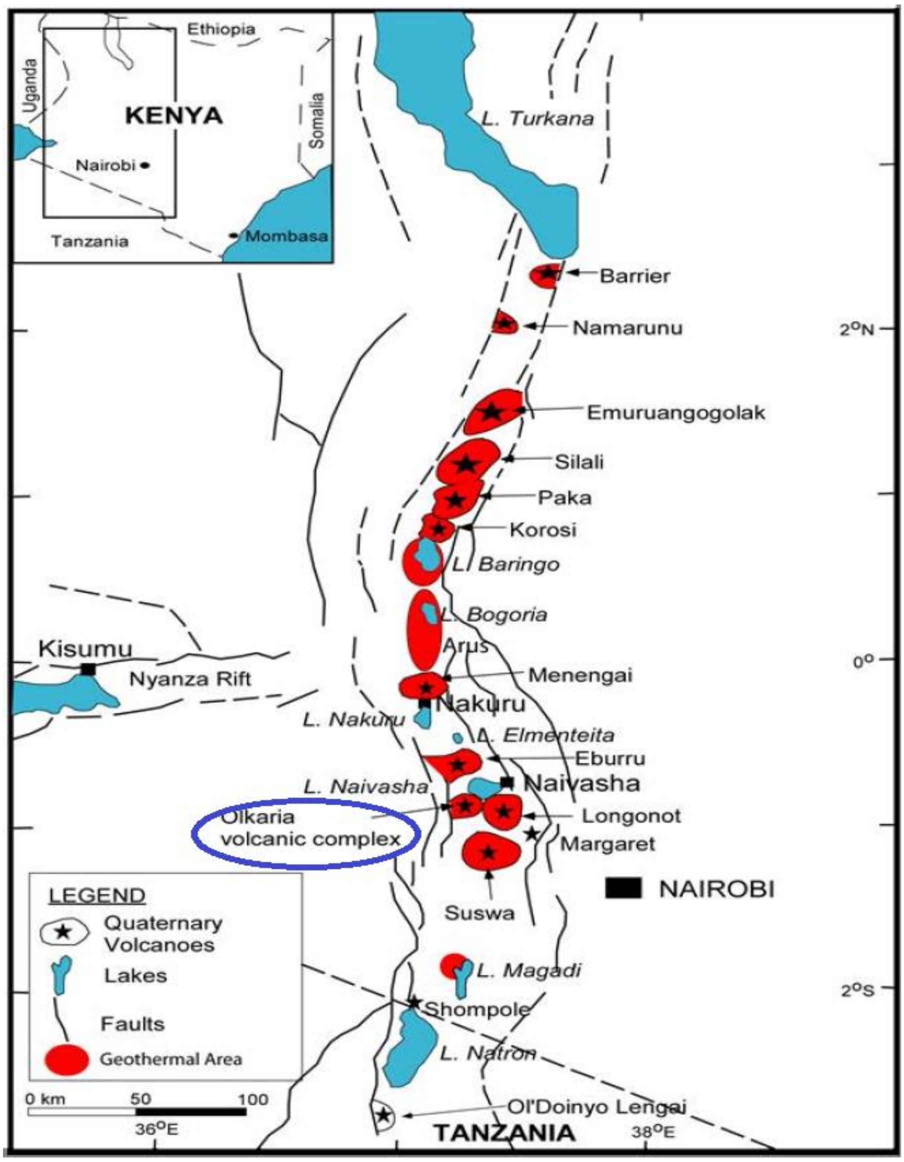

Figure 1: Location of geothermal fields and prospects along the axial region of the Kenyan rift.

Geothermal Power plants have the lowest unit cost with a high availability factor, hence suitable for base load (Ondraczek, 2014). This is well captured in the Least Cost Power Development Plan (2013-2035) prepared by Government of Kenya. For instance, the current Olkaria geothermal power plants have operated as base loads with more than 95% availability. Power generation is anchored on an efficient and effective transmission and distribution network system. In Kenya, the Kenya Power and Lighting Company (KPLC) is tasked with transmission and distribution of the generated power to customers. KPLC has launched various projects aimed at attaining efficient and effective power distribution (KPLC, 2017). These include; the Last Mile Connectivity Project (LMCP) aimed at increasing electricity access to Kenyans especially the low income group, the Kenya Electricity Modernisation Project (KEMP) aimed at enhancing the electricity network in readiness for the anticipated 5000+MW generation by 2030, and the Global Partnership on Output Based Aid (GPOBA) electrification project, a partnership between World Bank and KPLC aimed at preventing commercial losses by reducing cases of electricity theft while providing convenient services to customers through prepaid metering.

Table 1: Present and planned electricity production.

	Geothermal		Fossil Fuels		Hydros		Other Renewables		Total	
	Capacity Mwe	Gross Prod. GWh/yr	Capacity Mwe	Gross Prod. GWh/yr	Capacity Mwe	Gross Prod. GWh/yr	Capacity Mwe	Gross Prod. GWh/yr	Capacity Mwe	Gross Prod. GWh/yr
In operation	690	6,044	776	6,798	823	7,209	56	491	2,345	20,542
Under construction	358	3,136	-	-	-	-	310	2,716	668	5,852
Funds committed but not yet under construction	185	1,620.60	1,000	8,760	-	-	120	1,051	1,305	11,432
Estimated total projected use by 2020	2,765	24,221	3,753	32,876	1,310	11,477	679	5,948	8,507	74,523

Table 2: A breakdown of projects under construction and those which funds have been committed.

Project	Mode of generation	Status	Company	Capcity	
				Capacity Mwe	Gross Prod. GWh/yr
Turkana project	Wind	Under construction	Lake Turaka Wind Power Ltd	310	2,716
Menengai Project	Geothermal	Under construction	GDC	100	876
Baringo-Silali	Geothermal	Under construction	GDC	100	876
Olkaria V	Geothermal	Under construction	KenGen	158	1,384.08
TOTAL				**668**	**5,852**
Meru project	Wind	Funds comitted	KenGen	80	701
Lamu project	Fossil fuel	Funds comitted	Centum Investment/Gulf Energy	1,000	8,760
Gitaru	Solar	Funds comitted	KenGen	40	350
Olkaria 1AU6	Geothermal	Funds comitted	KenGen	70	613
Wellheads	Geothermal	Funds comitted	KenGen	108	946
Olkaria 1 Upgrade	Geothermal	Funds comitted	KenGen	7	61
TOTAL				**1,305**	**11,432**

2. Geothermal Development in Kenya

Geothermal exploration in Kenya began in 1952 (KPLC, 1992). This was carried out by a consortium of several companies including, East African Power & Lighting Company Ltd (EAPL), Power Securities Corporations Ltd, Associated Electrical Industries Export Ltd, and Babock and Wilcox Ltd. The study indicated the potential of geothermal resource with a high potential located within the central Kenyan Rift Valley, particularly Olkaria. The study resulted in the siting of two wells X1 and X2 in 1956 (KPLC, 1992). The two wells, drilled to a total depth of 950 m and 1200 m, respectively recorded a measured downhole temperature of about 235 °C. Unfortunately, the wells were not able to discharge. This led to the abandoning of geothermal research and development until 1970s. From 1971 to 1972, a joint geothermal exploration exercise between the Government of Kenya and the United Nations Development Program (UNDP) was carried out from Olkaria to Lake Bogoria and Eburru geothermal prospects. The work involved geological mapping, hydrogeological surveys, gravity studies and infra-red imagery surveys.

The research narrowed down to an area of about 80 km^2 in Olkaria geothermal field, recommending the drilling of four (4) deep wells of approximately 2,200 m deep. Financed by the UNDP, the drilling exercise commenced in 1973 with funds from UNDP. By 1976, six exploratory wells had been drilled. Using data from the drilled wells, a feasibility study was done by SWESCO, Stockholm and VRKIR Consulting Group Ltd. The study focused on reservoir assessment, steam utilization for power generation, effluent disposal, by product use and environmental impact of the geothermal power development. This study provided promising results. The study recommended the development of a 2x15 MWe power station. Additional wells were thereafter drilled to provide enough steam for the generation of electricity. In June 1981 the first 15 MWe generating Olkaria 1 unit 1 power plant was commissioned. By November 1982, enough steam to generate additional 15 Mwe had been realized. By the end of 1984, a total of 33 wells had been drilled in the Olkaria East field with steam capacity enough to generate a total of 45MWe from this field. This resulted in the commissioning of the third 15 MWe generating unit in March 1985. Since then, the concession area has since been expanded and a total of about 302 wells have been drilled to date in the larger Olkaria geothermal field. A summarized breakdown of the geothermal power plants' development in Olkaria geothermal field is provided below.

2.1 Olkaria Geothermal field

The Olkaria geothermal field is the most explored field in Kenya. Currently, about 690 MWe is generated from the field. Additionally, 30 MWt from the Olkaria field is being utilized for flower farming and recreational purposes at the Oserian green houses and Olkaria geothermal spa, respectively. The proven resource in Olkaria geothermal field is more than 1,200 MWe. The highest single producing well in Africa, well OW-921A is located in this field with a capacity of 30 MWe. The Olkaria geothermal field is home to the geothermal Spa, a natural spa and recreation centre utilizing brine directly sourced from a well. The field is composed of over 300 wells drilled so far and enough steam generated to support power generation in five power plants so far. For ease of management, the field is divided into seven sections, the Olkaria North West, Olkaria Central, Olkaria North East, Olkaria South West, Olkaria East, Olkaria South East and the Olkaria Domes field.

2.1.1 Conventional Power Plants at Olkaria geothermal field

The Olkaria 1 power plant is the oldest plant of all the plants within Olkaria, generating 45 MWe from steam tapped from 24 out of the 33 drilled wells assigned to this plant. One of the 33 wells is being used for re-injection, two have been retired while the rest serve as standby wells. Currently the field has steam capable of generating an additional 25 MWe. In 1986, drilling was expanded beyond Olkaria East field. By 1992, a total of 30 wells had been drilled in the Olkaria Northeast field. This wells had steam enough to produce 105 MWe. This was however followed by a period of political instability that led to stallment of geothermal development until 1999. In 2003, a 70 MWe Olkaria II (units 1 and 2) were commissioned. A third unit generating 35 MWe was commissioned in May 2010. The Olkaria II power plant produces a total of 105 MWe using 22 of the 30 drilled wells supplying steam to the three units that make up the plant.

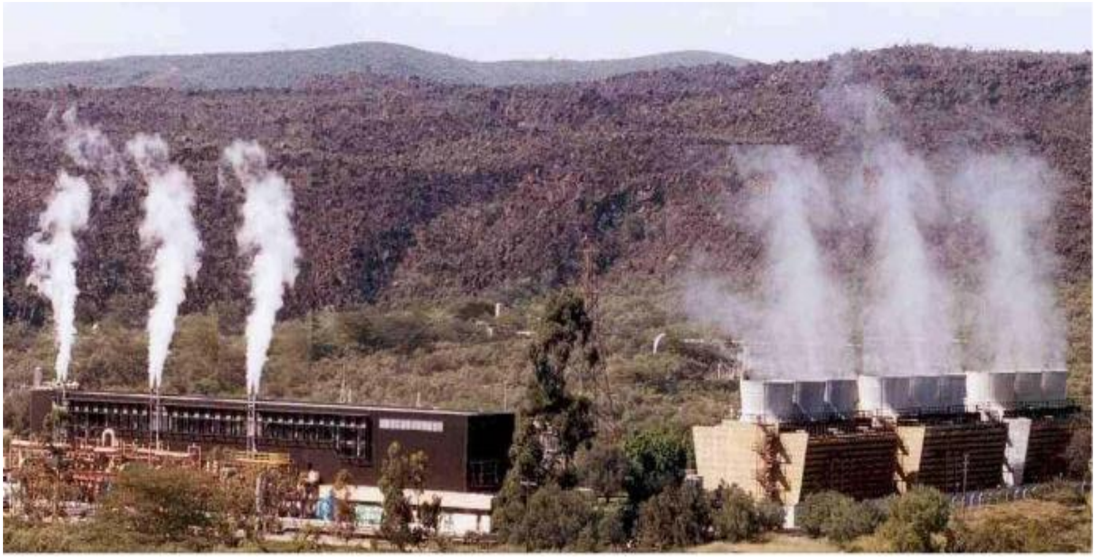

Figure 2: A view of Olkaria 1 Power plant, the oldest geothermal plant in Kenya

The Olkaria 300 MWe project comprises the Olkaria IV and the Olkaria I additional units 4 and 5. Each of the two power plants has an installed capacity of 150 MWe. Olkaria I units 4 and 5 draw steam from Olkaria East and partly Northeast sectors. Construction works on the each of the 150 MWe power project for Olkaria I units 4&5 and, Olkaria IV began in March 2012 and 23rd July 2012, respectively. Olkaria IV power plant was commissioned in October 2014, while Olkaria I, Units 4 and 5 were commissioned in February 2015 each with an installed capacity of 150 MWe. The four power plants, inclusive Olkaria I, II, IV and I AU are owned and operated by KenGen.
ORMAT International was licensed in the year 1997 to explore and generate power from the Olkaria Northwest field, referred to as Olkaria III. In August 2000, ORMAT, through its local subsidiary OrPower 4, commissioned an 8MWe plant that was later increased to 12 MWe from a combined binary cycle pilot plant, the first geothermal plant to use binary technology in Kenya. In January 2009, a new 35 MWe plant was installed as an additional unit to the plant. Production at the field has continued to increase through the years and installed capacity now stands at 155 MWe. The Olkaria III power plant is owned and operated by Ormat International. Commissioned in July 2004, the Oserian geothermal power plant is a binary power plant owned and operated by the Oserian Development Co. Ltd. Drawing leased steam from the Olkaria central field, the plant generates 4MWe.

2.1.2 The Wellhead Technology

The wellhead technology is a new power generating technology that involves tapping steam from wells which are undergoing discharge tests or waiting to be connected to a conventional power plant. The steam is directed into a small power generator for power generation. The main aim of this technology is to ensure return on investment from early generation as it only takes 6 months to construct and commission. With the realization of the efficiency in terms of the short duration required to have power on the grid, KenGen accelerated the installation of wellhead generators in 2014-2015. Currently, KenGen has installed 16 wellhead generators with an aggregate capacity of 83.5 MWe.

2.2 Eburru geothermal field

Eburru volcanic complex is located approximately 40 km to the north of Olkaria. Six exploration wells were drilled between 1989 and 1991. The total output from one of the wells (EW-1) that was able to discharge was 2.4 MWe. Combined geophysical survey data and downhole data from the drilled wells indicated that Eburru field had geothermal potential of about 50-100 MWe. In 2011, KenGen commissioned a 2.4 MWe wellhead unit. KenGen continues to carry out more detailed exploration studies in the larger Eburru-Badlands-Elementaita area aimed at identifying drill sites for appraisal and production wells.

2.3 Menengai geothermal field

Detailed surface exploration in Menengai, Arus-Bogoria, Koros-Chepchuk and Paka began in 2004. Menengai caldera is the most recently discovered geothermal field in Kenya. The detailed studies done in 2004 were the basis of siting and drilling of two exploration wells in Menengai field in 2011, carried out by the Geothermal Development Company (GDC). The mapped potential area in Menengai is over 80 Km^2 with an estimated resource potential of 1,600 MWe. So far, over 40 wells have been drilled successfully with an estimated resource potential of about 162 MWe. Production drilling is on-going in the field using seven high capacity drilling rigs. The rapid development of the Menengai geothermal field is as a result of financial support by different financial players. Key among them is the Government of Kenya (GoK). Amongst the financiers is the African Development Bank (AfDB), French Development Agency (AFD), UK Government, World Bank, Scaling-up Renewable Energy Program (SREP) and others. This assistance ranges from purchase of drilling rigs and materials, consultancies, capacity building initiatives and infrastructural development.

2.4 The Arus-Baringo-Silali Project

The Arus-Baringo-Silali block in this paper refers to the Arus-Bogoria, Korosi, Chepchuk, Paka and Silali geothermal prospects. This block has an estimated potential of 3,000 MWe. GDC has been tasked with the development of this resource in phases. Phase I targets to generate 100 MWe of electricity. This phase is funded by the Government of Kenya and KfW, a German government owned development bank. The Government of Kenya is funding the construction of access roads and community engagement while KfW has given GDC a concessional loan of Ksh. 8 billion for the drilling of 15-20 wells. GDC has already completed a 70 km access road to open up the area for drilling.

2.5 Suswa Geothermal Project

The Suswa Geothermal prospect is situated at the intersection of Narok, Kajiado and Nakuru Counties. Detailed geoscientific studies carried out between 1992 and 1993 rated the field as having a good potential for geothermal development. The project has an estimated potential of over 750 MWe. A shallow heat source exists under the caldera at a depth of about 10 Km. So far, three wells have been sited on the main caldera floor, estimated to have a potential of about 200 MWe.

2.6 Longonot geothermal project

The Longonot geothermal prospect lies east of the Olkaria Geothermal field. Geological, geochemical and geophysical surveys were carried out in the prospect in 1988. Results from these surveys were used to site two exploratory wells. The prospect concession area is more than 132 km^2 and is capable of supporting 200 MWe power generation. In 2009, the Ministry of Energy in Kenya granted the African Geothermal International Ltd. (AGIL) a license to explore and develop the Longonot prospect for a period of 30 years.

2.7 Akiira Geothermal prospect

Surface exploration studies were carried out at the Akiira geothermal prospect in the 1990's. The studies indicated a resource potential of over 70 MWe. In the year 2015, Marine Power drilled two exploratory wells. The wells could not sustain discharge due to low pressure. However, temperatures of about 200 °C were recorded in one of the wells. Plans are underway to carry out more detailed surface exploration before conducting further drilling activities.

2.8 Barrier Geothermal prospect

The Barrier geothermal prospect covers an area of 136 km^2 and is located in Turkana County, south of the iconic Lake Turkana. Reconnaissance survey by the British Geological Survey (BGS) in 1993 indicated occurrence of surface manifestations, signifying a hydrothermal system. Further, surface studies conducted in 2011 by GDC revealed a high temperature area covering approximately 60 km^2 with sub-surface temperatures of about 281° C and an estimated resource potential of 750 MWe. Olsuswa Energy Ltd. has been granted a license to carry out exploration and development in this prospect area. In April 2018, the Company signed a Memorandum of Understanding (MoU) with the Turkana County government involving geothermal exploration and development in Barrier geothermal complex. Plans are currently underway to carry a detailed geo-scientific (geological, geochemical and geophysical) exploration exercise set to commence before the end of the year 2018.

2.9 Other geothermal prospects

Other geothermal prospects include Emuruangogolak, Namarunu, Lake Magadi and Elementaita. Reconnaissance studies carried out in these prospects indicate sub-surface temperatures of above 200 °C. Further detailed studies are planned for in future in the prospect areas.

3. Kenya's Future geothermal power development plans

The country's National Geothermal Strategy serves as a guide on the future of geothermal development plans in Kenya. The National Geothermal Strategy is anchored on Kenya's Vision 2030, the National Development Blueprint. The main objective for vision 2030 is transformation of Kenya into an industrialized nation with the ability to provide quality life to all its citizens. To achieve this objective under Kenya's Vision 2030, the Ministry of Energy has put up plans to accelerate geothermal drilling and steam development. A total of 282 geothermal wells will be drilled with a steam equivalent of 1,520 MWe. The planned execution of this plan is based on enhancing and accelerating efforts in geothermal steam generation, geothermal drilling and geothermal steam development. The tables below indicate the government's short-term plans to increase steam generation and development.

GEOTHERMAL GENERATION												
Programmes /Projects	Objectives	Expected Outcome/ Output	Performance Indicators	Implementing Agencies	Time Frame	Source of Funds	Total Cost (in KShs million)		Budget (in KShs million)			
								2017/18	2018/19	2019/20	2020/21	2021/22
Olkaria V	To increase power capacity and lower cost of power	158 MW	158 MW installed	KenGen	2015-2019	KenGen	44,544	31,180	8,909	4,455	-	-
Olkaria I Unit 6	To increase power capacity and lower cost of power	70 MW	70MW installed	KenGen	2015-2019	KenGen, JICA, EIB	22,724	2,272	13,634	4,546	2,272	-
Olkaria VI	To increase power capacity and lower cost of power	140MW	140MW installed	KenGen	2016-2020	PPP	44,544	-	4,454	26,726	8,909	4,454
Olkaria I & IV Upgrade & Top-up	To increase power capacity and lower cost of power	47MW	47MW installed	KenGen	2016-2019	KenGen KfW	6,722	672	4,706	1,344	-	-
Wellhead Modular Plants	To increase power capacity and lower cost of power	47MW	47MW installed	KenGen	2016-2019	KenGen	10,300	1,030	6,180	2,060	1,030	-
Olkaria I Refurbishment	To increase power capacity and lower cost of power	6MW	MW installed	KenGen	2020	KenGen	7,434	2,493	4,198	743	-	-
Menengai Phase I 105 MW (Sosian, Quantum & Orpower 22)	To increase power capacity and lower cost of power	105MW	MW installed	GDC	2019	IPP	25,793	13,897	11,897	-	-	-
Menengai Phase II 60 MW	To increase power capacity and lower cost of power	60MW	MW installed	GDC	2021	PPP	13,596	-	-	6,798	6,798	
Orpower 4	To increase power capacity and lower cost of power	60MW	60MW installed	IPP	2022			2,102	4,204	6,307	6,307	2,102
Orpower 4	To increase power capacity and lower cost of power	10MW	10MW installed	IPP	2017							
Marine Power Akiira	To increase power capacity and lower cost of power	70MW	70MW installed	IPP	2022			2,453	4,905	7,358	7,358	2,453
Agil	To increase power capacity and lower cost of power	140MW	MW installed	IPP				4,905	9,810	14,716	14,716	4,905

Table 3: Indicating the Governments' geothermal development plans

GEOTHERMAL STEAM DEVELOPMENT												
Programmes /Projects	Objectives	Expected Outcome/ Output	Performance Indicators	Implementing Agencies	Time Frame	Source of Funds	Total Cost (in KShs million)	Budget (in KShs million)				
								2017/18	2018/19	2019/20	2020/21	2021/22
Olkaria IX	To increase electricity generation capacity from geothermal sources	140 MWe	140MWe installed	KenGen	2022	PPP	44,544	-	4,454	26,726	8,909	4,454
Menengai Phase II	To increase electricity generation capacity from geothermal sources	60 MWe	60MWe installed	GDC	2022	GoK, AFD, AfDB, EIB,	4,470	1,490	1,490	1,490		
Menengai Phase III	To increase electricity generation capacity from geothermal sources	100 MWe	100MWe installed	GDC	2022	GoK, AFD, AfDB, EIB,	7,107		1,800	1,800	1,800	1,707
Korosi Phase I	To increase electricity generation capacity from geothermal sources	100 MWe	100MWe installed	GDC	2022	GoK, AFD, ELLIPSE, GRMF, KfW,	7,107	1,421	1,421	1,421	1,421	1,421
Paka Phase I	To increase electricity generation capacity from geothermal sources	100 MWe	100MWe installed	GDC	2022	GoK, ELLIPSE, GRMF, KfW,	7,107	1,421	1,421	1,421	1,421	1,421
Suswa Phase I	To increase electricity generation capacity from geothermal sources	100 MWe	100MWe installed	GDC	2022	GoK, ELLIPSE, GRMF, India EXIM, KfW,	7,107		1,800	1,800	1,800	1,707

Table 4: Geothermal Steam Development plans for various prospects

GEOTHERMAL DRILLING												
Programmes /Projects	Objectives	Expected Outcome/ Output	Performance Indicators	Implementing Agencies	Time Frame	Source of Funds	Total Cost (in KShs million)	Budget (in KShs million)				
								2017/18	2018/19	2019/20	2020/21	2021/22
Menengai Phase III	Exploration and Appraisal Drilling to support 100 MW geothermal generation	35 Wells	35 Geothermal Wells drilled	GDC	2018-2022	GoK, AFD, AfDB, EIB,	19,055	523	7,688	8,048	2,796	
Korosi Phase I	To increase electricity generation capacity from geothermal sources	35 Wells	35 Geothermal Wells drilled	GDC	2018-2022	GoK, AFD, ELLIPSE, GRMF, KfW,	19,055	1,399	4,712	3,500	8,224	1,220
Paka Phase I	To increase electricity generation capacity from geothermal sources	35 Wells	35 Geothermal Wells drilled	GDC	2018-2022	GoK, ELLIPSE, GRMF, KfW,	19,055	1,399	3,500	5,400	7,880	876
Silali Phase I	Exploration and Appraisal Drilling to support 100 MW geothermal generation	9 Wells	9 Geothermal Wells drilled	GDC	2018-2022	GoK, ELLIPSE, GRMF, India EXIM, KfW,	5,665	59	2,060	2,060	1,486	
Suswa Phase I	To increase electricity generation capacity from geothermal sources	35 Wells	35 Geothermal Wells drilled	GDC	2018-2022	GoK, India EXIM, Italian Dev. C, AFDB, UK Export Finance	19,055		10,926	4,120	2,060	1,949
African Geothermal Centre of Excellence	To enhance and expand geothermal energy capacity building for the country and the region	Established and equipped Centre of Excellence	Equipped Geothermal Centre of Excellence	GDC	2018-2022	GOK, ICEIDA, NDF, UNEP, GRMF	1,710	342	513	855	-	-

Table 5: Geothermal Drilling plans for various prospects

3.1 Kenya's Geothermal Field Development Plan

The National Geothermal Strategy aims at attracting private sector investment and maintaining electricity affordability to consumers. Under the National Geothermal Strategy, the proposed geothermal field development plan is based on three principles. These include Portfolio exploration, Stepwise expansion and Parallel development. Under Portfolio exploration, multiple fields are explored and evaluated simultaneously, thereby increasing the probability of having at least one viable prospect for development at any given time while reducing the chances of overlooking significant development opportunities. Stepwise expansion involves cautious incremental step development determined by reservoir data. This prevents the risk of reservoir depletion and pressure drops. On the other hand, Parallel development involves development of fields selected from the Portfolio exploration and simultaneously developing them hence speeding up development. In efforts geared towards ensuring that the National Geothermal Strategy is achieved, the Strategic Geothermal Planning Unit (SGPU) has been set up to provide strategic leadership on matters to do with Geothermal Power development.

3.1.1 The Strategic Geothermal Planning Unit (SGPU)

The SGPU is tasked with sector coordination, definition and implementation of geothermal policies and strategies proposed by the Ministry of Energy. The SGPU specific tasks include:

- ✓ Coordination of geothermal development in line with power development and transmission planning
- ✓ Define the sequencing of geothermal field development
- ✓ Review and simplify the legal and regulatory framework for geothermal energy

- ✓ Formulate a strategy for private sector involvement in the geothermal sector that unifies the regulatory structure for geothermal development consistent with the Strategic Vision
- ✓ Determine the business model to be applied in development of the various fields
- ✓ Determine the timing for tendering of de-risked geothermal fields
- ✓ Oversee tender process for award of geothermal license to IPPs including defining the technical and financial specifications by which an IPP partner will be selected
- ✓ Formulate conditions for award of geothermal resource licenses for greenfield projects
- ✓ Determine the pricing policy for Greenfield projects.

3.1.2 Other key steps taken to enhance geothermal development

Apart from setting up the Strategic Geothermal Planning Unit (SGPU), the government has also put up a raft of other steps aimed at accelerating geothermal power development in Kenya. This include:

(i) Enhancing public-private partnership (PPP"s). Steps have been taken by the government to attract private investors

(ii) The recently enacted mining act stipulates the maximum period a lease can be held. Failure to develop a lease through geothermal exploration or development work leads to the lease being lost and issued to active investors with the financial capability of developing these prospects.

(iii) Capacity building initiatives. Plans to set up a Geothermal Centre of Excellence in the country are at an advanced level. This is aimed at enhancing the skills and knowledge of local professionals in the geothermal sector.

4. Progress made in direct utilization of geothermal resources

Globally, direct utilization of geothermal energy has increasingly gained popularity due to its economic, environmental and energy efficiency benefits. Its applications vary widely from agricultural applications, crop drying, space heating and industrial processes. In Kenya, direct utilization of geothermal resources dates back to early 19th century.

Within the Olkaria geothermal field, Oserian Development Company Ltd. uses geothermal energy in the heating and supply of carbon dioxide required for photosynthesis to the greenhouses (Figure 6). Greenhouse heating assists in controlling relative humidity within the greenhouse especially the early morning hours when humidity tends to rise to about 100%. Reducing relative humidity to below 85% eliminates fungal infection and hence eliminates the use of chemical fungicides. Heated water is also used to sterilise the fertilised water, reducing fertiliser wastage and hence reducing cost. Carbon dioxide from the well is piped to the greenhouses in order to enhance photosynthesis. In 2015, GDC set up a direct use demonstration project in Menengai to scale up direct utilization of geothermal resources. The direct use demonstration centre is aimed at showcasing how geothermal by-products can benefit communities through their use in green houses, leather tannery, dairy milk preservation, fish farming, meat processing and development of spas among others.
An idea to construct a geothermal spa at the Olkaria Geothermal Field was conceptualised in the year 2010. The spa utilizes natural geothermal water from a drilled well. The water is obtained from the well at 100 °C. From the well, it's pumped into a pool where it's allowed time to cool to 70 °C. It is

again transferred to another pool where it's cooled further to 35 °C before flowing to the main pool where visitors enjoy their warm bath (Figure 7). The geothermal Spa started operations in 2013 and is the only natural spa in Africa. Lake Bogoria hotel have utilized hot springs for use in a swimming pools. The hot springs are directed into a swimming pool where residents and visitors enjoy a warm bath.

Figure 3: A view of the Olkaria Geothermal Spa.

5. Key players in geothermal sector

Apart from KenGen, there exists a number of other key players in the geothermal sector, all aiming at exploring and developing the vast resource existing within the Kenyan rift. GDC was incorporated in December 2008 as a Government Special Purpose Vehicle (SPV) to undertake surface exploration of geothermal fields through exploration, appraisal and production drilling. Established as a limited company owned by the government of Kenya under the ten Ministry of Energy & Petroleum, the company commenced its operations in 2009. OrPower 4 Inc., a subsidiary of the Ormat Technology operates a Geothermal Power Station on the South western slopes of Olkaria hill through a 20 years Power Purchase Agreement (PPA) with KPLC. The company recently commissioned its 5th generator, hence achieving a total installed capacity of about 155 MWe.

Other than OrPower 4 Incl., other licensed Independent Power Producers (IPP) include; (Mt Longonot geothermal field), Olsuswa (Barrier field) and Marine Power Generation (Akiira geothermal field), all tasked with exploration and development of Geothermal resources in respective fields.

6. Challenges to geothermal development and their remedies

Geothermal resource development, like many other renewable energy sources is not devoid of its own challenges. These challenges range from environmental and social, policy and legislative, technological and financial (Malafeh & Sharp, 2014). The county has face these and other challenges in its strides for geothermal energy resource development. Some of the challenges are discussed hereunder;

6.1 Financial challenges

Exploration, appraisal and production drilling in geothermal development requires large up-front financial investment. Funding for geoscientific surface studies and exploratory drilling is done by the government while appraisal drilling is partially funded by the government and the private sector. The huge capital investment required has resulted in overreliance to donor funding. The speed of geothermal resource development in Kenya has hence been determined by the availability of donor funds. For instance, the withdrawal of donor funding in the 1990s saw a considerable slowdown of geothermal activities in Kenya.

6.2 Technological and Human capacity challenges

During the early times of geothermal development, Kenya lacked the required expertise to handle this new technology. Inadequate human capacity slowed down geothermal development. This was compounded by the overreliance on foreign experts which raised the cost of development. On the other hand, technological challenges negatively affected geothermal development. Low capacity drilling rigs unable to drill to depths beyond 2000m led to much of the resource remaining untapped.

6.3 Environmental and Socioeconomic challenges

Kenya’s geothermal resources, like most of the geothermal resources, are located in remote scenic, wild and protected areas. The key socioeconomic impact associated with developing these resources include loss of wildlife habitat and intrusion in scenic tourist areas. Communities living within these areas also have to be displaced due to unconducive environmental conditions that come with geothermal power development. For example, Olkaria geothermal field is located within the Hells Gate national park.

6.4 Legislative and Policy challenges

Before 1998, electricity generation and distribution was tasked to Kenya Power Company (KPC). KPC was a state owned corporation under the Ministry of Energy. This made the development of geothermal resource a solely government affair. Owing to the limited government resources, this monopoly considerably slowed down geothermal development. The government set up on a fundamental reform process within the energy sector in 1996. A policy paper on economic reforms set out the governments intentions to separate the regulatory and commercialize functions of the sector, facilitate restructuring and promote private-sector investment. Consequently, the Electricity Power Act of 1997 reduced the government’s mandate, through the Ministry of Energy, to policy formulation while devolving its regulatory mandate to Electricity Regulatory Board (ERB). KenGen was formed through an act of parliament enacted in 1996 and was established in 1997 with a mandate to generate electricity. The act allowed Independent Power Producers (IPPs) to enter electricity generation industry, enhancing geothermal exploration and development in the country.

7. Financing of geothermal projects in Kenya

Geothermal development in Kenya has relied on various sources of funds in financing geothermal projects. The sources include government financing, multilateral development banks, bilateral development banks, special purpose financing, commercial banks and private equity. The key challenge as regards financing of geothermal projects proving the bankability of a project. Investors and financiers put their resources into a project with the hope of recovering their investment at a profit over the life of the investment, hence must be convinced that a project is bankable before they invest in it.

7.1 Government Financing of Initial Stages

The government assumes the high upfront risks associated with geothermal resource exploration and appraisal by provision of financing for the initial development phases. A multi-disciplinary surface exploration approach is employed in the initial exploratory stages of geothermal resource. Detailed scientific studies are carried out by the government aimed at confirming the existence of a resource. The only sure way to confirm the existence of a resource is by appraisal drilling, also conducted by the government. The government finances these phase through taxes, ordinary and infrastructure bonds. Once the existence of a resource is confirmed, other players in the industry come in at the next less-riskier stages of productive well drilling and development. Confirmation of the existence of a resource considerably reduces the risks involved hence prepares projects for financing by other financial players.

7.2 Financing of Latter stages

Once the existence of a resource has been proven through detailed surface studies and appraisal drilling conducted, a host of other financing partners are willing to invest in production drilling and development of the geothermal resources. The risks involved at this stages are drastically reduced hence the willingness by various partners to invest. Major sources of funds at this stage include multilateral development agencies, bilateral development agencies, special purpose finance (green fund donors), commercial funds and private equity. The participation of all these players in the geothermal sector has greatly contributed and accelerated resource exploration, appraisal drilling, production drilling and development of related infrastructure within the sector.

8. Conclusion

Geothermal power has proven to be an affordable and reliable source of energy to the Kenyan power consumer. For the country to realise clean, reliable and affordable energy, concerted efforts geared at fast tracking the development of geothermal resources in Kenya have been embraced. There is great focus on geothermal development by both the Kenyan government and private sector. The government aims at having more than 50% of power supply coming from geothermal by the year 2025. This will provide least cost power to the various sectors of the economy, expected to spur rapid economic development in the country.

REFERENCES

Corti, G., 2011: Evolution and characteristics of continental rifting: Analog modelling-inspired view and comparison with examples from the East Africa Rift System, Tectonophysics, doi:10.1016/j.tecto.2011.06.010.

Dunkley, P. N., Smith M., Allen D. J., and Darling W. G., (1993): "The geothermal activity and geology of the northern sector of the Kenya Rift Valley", British Geological Survey (BGS), Research report SC/93/1, pp 202.

Geothermal Development Company Ltd., (2011): Geothermal resource assessment of the Barrier volcanic complex. Internal Report.

Japan Geothermal Energy Association, Brief on Geothermal development in Kenya: Status as at August 1992.

Kenya Power and Lighting Company (1992). Internal Report.

Kenya Power and Lighting Company (2017). Company Profile. http://kplc.co.ke/img/full/EIV7U2cM86jl KPLC%20Corporate%20Profile May%202017.pdf.

KPLC ,2018

Lesage, D., & Van de Graaf, T. (2016). Global energy governance in a multipolar world. Routledge.

Least Cost Power Development Plan (2013): A report by the Ministry of Energy.

Malafeh and Sharp. (2014). Geothermal Development: Challenges in a Multiple Access Scenario.

Micale, V., Trabacchi, C., & Boni, L. (2015). Using Public Finance to Attract Private Investment in Geothermal: Olkaria III Case Study, Kenya. Climate Policy Initiative, Venice, Italy.Available:http://climatepolicyinitiative.Org/wpcontent/uploads/2015/06/150601_Final_Olkaria_ForWeb. Pdf.

Omenda, P. (2014). Geothermal Country Update Report for Kenya, 2014. Presented at Short Course IX on Exploration for Geothermal Resources, at Lake Bogoria and Lake Naivasha, Kenya, Nov. 2-24, 2014.

Ondraczek, J. (2014). Are we there yet? Improving solar PV economics and power planning in developing countries: The case of Kenya. Renewable and Sustainable Energy Reviews, 30, 604-615.

S. Bwire, 1981 Olkaria Geothermal Field: History and Future plans.