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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. These resources are largely untapped. The resources are located within the Kenyan Rift Valley which forms part of the East Africa Rift System (EARS). 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. Geothermal exploration in Kenya began in 1952. Currently, Kenya is ranked number nine worldwide as regards to geothermal energy production with an aggregate capacity of about 690 MWe. Further, to accelerate development of the enormous geothermal resources in the Country, the government formed Geothermal Development Company (GDC) in 2009 as a special purpose vehicle (SPV) for geothermal resource development. Similarly, three independent power producers namely Marine Power, African Geothermal International Ltd. (AGIL) and Olsuswa Energy Ltd. have been granted license

for geothermal exploration in Akiira, Longonot and Barrier geothermal prospects, respectively.

Various financial partners have played a key role in the development of geothermal resources in the Country. They include; Government finance, multilateral development banks, bilateral development agencies, special purposes finance (green funds), commercial banks and private equity. Some of the Direct Utilization steps made by Kenya include recreational purposes, fish farming, heating and fumigation of green houses, milk pasteurization and drying of crop harvests. Kenya has also faced a fair share of challenges in geothermal development especially during the early stages of development. Geothermal energy has been proven to be benign, sustainable and reliable with a high availability factor. The Kenyan government is focusing on having 2,500 MWe geothermal contribution in the country's energy mix by 2025.

1. Introduction

Kenya's electricity consumption is projected to grow from 1,860 MWe in 2017 to 3,348 MWe in 2022 (Least Cost Power Development Plan, 2013). During this period, the installed capacity is projected to increase from 2,333 to 5,122 MWe consisting of; 917 MWe from hydropower, 1,565 MWe from geothermal, 506 MWe from wind, 185 MWe from biomass, 442 MWe from solar, 560 MWe from thermal, 327 MWe from coal and 400 MWe import. The reserve margin is projected to range between 19 and 45%. The surplus capacity will be available for regional power trade as the various interconnector projects under construction will be completed. The interconnected system installed capacity as per May 2018 was 2.370 GW (KPLC, 2018). Out of this, geothermal contributes about 690 MWe, hydropower 823 MWe, thermal has a total of 776 MWe and wind has 25.5 MWe, while cogeneration contributes 28MWe. Apart from the interconnected system, Kenya has an off-grid system in areas away from the interconnected system. As at February 2018, the off-grid installed system was 27.52 MW and consisted of diesel, solar and wind power plants. The off-grid thermal is at 26.33 MWe, wind is at 0.5550 MWe, while solar is 0.64 MWe. The power percentage rate as per consumption is 47% geothermal, 39% hydropower, 13% thermal and 0.4 % wind. The Kenyan government heavily relied on hydropower for electricity generation in the past. However, fluctuating climatic conditions makes hydropower an unreliable mode of generation. It is for this reason that the government shifted focus and invested resources in the exploration and development of geothermal resources beginning 1970s. Table 1 gives a summary of the current installed capacity by mode of generation, projects onto which funds have been committed and those under construction, while Table 2 shows the projects under construction and those onto which funds have been committed but not yet under construction.

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**

Geothermal Power plants are touted to 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.

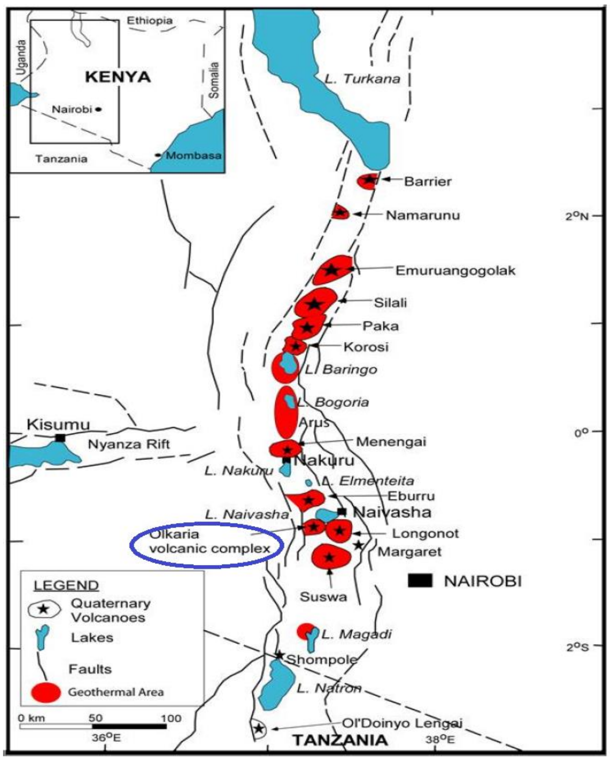

Figure 1: Location of geothermal fields and prospects along the axial region of the Kenyan rift.

Geothermal energy is benign, reliable with high availability and therefore, stands to play a big role in realizing Kenya's vision 2030 energy objectives. The government targets a total of

5,000 MWe power generation from geothermal sources by 2030 (Micale et al., 2015). Hence, the government has embarked on an ambitious geothermal expansion plan in order to meet the set geothermal power share in the country's energy mix.

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). These volcanic centers are hosts to geothermal resources. Some of these resources are well developed and in generation and monitoring stage while others are at various stages of exploration. Geothermal studies carried out within the Kenyan Rift indicate a potential in excess of over 10,000 MW of geothermal resource.

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 work 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 mainly 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. The latter was found to be the most prospective. A technical review committee was constituted and in their discussions recommended drilling of four deep wells of approximately 2,200 m deep. This commenced in 1973 with funds from UNDP. The drilling was done by a rig owned by the East Africa Power Lighting (EAPL) company. 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. This study provided promising results. The study recommended the development of a 2x15 MWe power station. After the completion of the feasibility study, UNDP pulled out of the project. Active drilling for a 30 MWe power plant continued. Geothermal Energy New Zealand Limited (GENZL) was engaged to supervise all drilling operations.

From 1977, additional wells were drilled to provide enough steam for the generation of electricity, and in June 1981 the first 15 MWe generating Olkaria 1 unit 1 power plant was commissioned. By November 1982, the drilling had gathered enough steam to generate additional 15 MWe. This was commissioned in November 1982. 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, exploration work has continued in the Olkaria geothermal field. 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. In 1990's, the field was divided into seven sectors for ease of management and exploitation. A summarized breakdown of the geothermal power plants' development in Olkaria geothermal field is as explained below.

2.1 Olkaria Geothermal field

Olkaria geothermal field is the only most explored field in Kenya. Currently, about 690 MWe is being generated from the field. Additionally, 30 MWt from the Olkaria field is being utilized for flower farming and recreational purposes in the Oserian green houses and Olkaria geothermal spa, respectively. The proven resource in Olkaria geothermal field is more than 1,200 MWe. The field has been divided into seven segments for the purpose of easy management (Figure 2). The highest single producing well in Africa, well OW-921A is located in this field with a capacity of 30 MWe. KenGen has also set up a natural geothermal Spa in Olkaria field. Additionally, Olkaria geothermal field is the pioneer field in which Wellhead generators have successfully been installed and operated.

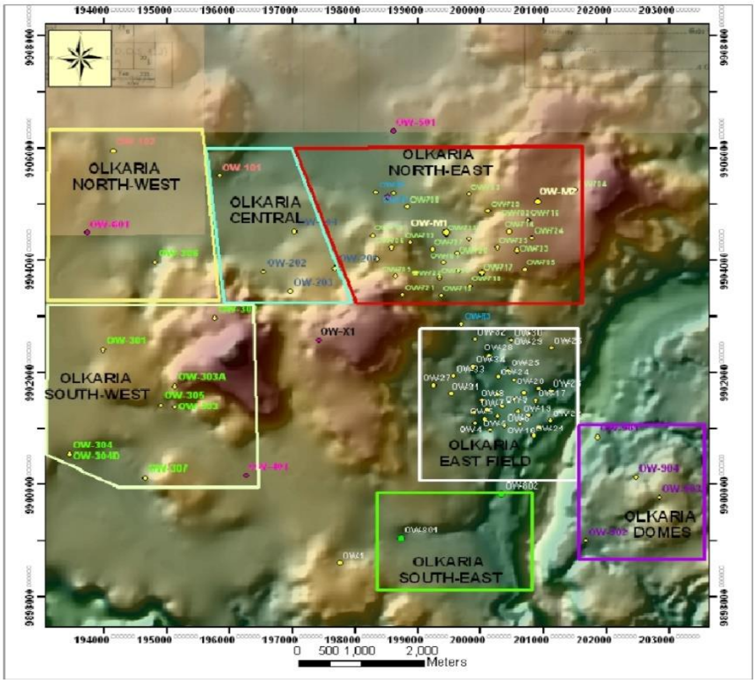

Figure 2: The seven segments of Olkaria geothermal field.

2.1.1 Olkaria I power station

Olkaria I power plant is owned and operated by KenGen. It taps its steam from the Olkaria East field. The power station generates 45 MWe tapping steam 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. Figure 3 shows the aerial view of Olkaria I plant. Currently the field has steam capable of generating an additional 25 MWe.

2.1.2 Olkaria II power station

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. However, the political agitation and inflation experienced in the country from 1990 to 1997 dissuaded financiers from investing in the country. This led to stalling 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, bringing the total installed capacity for Olkaria II power plant to 105 MWe (Figure 4). 22 of the 30 drilled wells supply steam to the three power generating units. Olkaria II is owned and operated by KenGen.

2.1.3 Olkaria III power station

In 1996, the government of Kenya initiated reforms in the Energy sector. Part of these reforms was the opening up of the power generation to Independent Power Producers. In 1997, ORMAT International was licensed by the Kenya Government to explore and generate power from the Olkaria Northwest field. This was referred to as Olkaria III. In August 2000, ORMAT, through its local subsidiary OrPower 4, commissioned 8 MWe that was later increased to 12 MWe from a combined binary cycle pilot plant. This was the first geothermal plant to use binary technology. As part of its first phase of development, OrPower 4 drilled nine directional wells to further appraise the Olkaria Northwest sector.

In January 2009, a new plant was installed adding another 35 MWe to the plant's capacity. Later, 36 MWe production unit was installed in 2013. The fourth generation unit at Olkaria III, with capacity of 26 MWe was commissioned in 2014. The fifth unit with a capacity of 29.6 MWe was commissioned in February, 2016, bringing the total capacity at the plant to 139.6 MWe. Further, an additional 15 MWe was added to the national grid in early 2018, bringing the aggregate installed capacity to about 155 MWe. This power plant draws its steam from the Northwest sector of the Olkaria geothermal field.

2.1.4 The Olkaria 300 MWe Project: (Olkaria IV & Olkaria 1 AU)

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&5 draws steam from Olkaria East and partly Northeast sectors. In 1999, KenGen drilled three exploratory wells in the Domes field. The data analysis from the drilled wells indicated resource potential in this field. In 2006, the government of Kenya funded appraisal drilling in the Domes field. In 2007, the government signed a six production wells' drilling contract with the Chinese owned Great Wall Drilling Company (GWDC). The field proved to be more successful and more production and re-injection wells were drilled. With improved drilling technology, deeper and directional wells extending down to a total depth of 3,000 m were drilled in Domes area. In 2009, the first optimization study for the entire Olkaria geothermal resources was done by WestJec. This confirmed the capability of Olkaria geothermal field to sustain additional production of 150 MWe for the Olkaria IV power plant and 150 MWe for the Olkaria I unit IV&V units. 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 on 17th October2014, while Olkaria I, Units 4 and 5 were commissioned on 19th February 2015. The two power plants each generate 150 MWe.

2.1.5 The Wellhead Technology

KenGen is the pioneer of the Wellhead Technology. 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. Conventional power plants take between 24 to 36 months to construct and commission. The well head power plant on the other hand takes approximately 6 months. Wellhead Technology was initiated to address the increase in power demand in the country. The first Wellhead generator was commissioned in Eburru in the year 2011 with a generation capacity of 2.4 MWe. The second Wellhead generator was commissioned in June, 2012 in Olkaria East field. This has a generation capacity of 5 MWe. With the realization of the efficiency in terms of the time taken to have power on the grid, KenGen accelerated the installation of wellhead generators in 2014-2015. By June 2018, KenGen had installed 16 wellhead generators with an aggregate capacity of 83.5 MWe. 15 of the wellheads units are located in Olkaria geothermal field, while one unit is located in Eburru geothermal field.

2.1.6 Oserian power plant

This is a binary power plant owned by Oserian flower farm. It was commissioned in July 2004. Its steam is leased from KenGen. It generates 4 MWe. It draws steam from Olkaria Central sector of Olkaria geothermal field.

2.2 Eburru geothermal field

Eburru volcanic complex is one of the volcanic centers that have geothermal resource potential. It is located approximately 40 km to the north of Olkaria. Detailed surface studies were carried out between 1987 and 1990 by KenGen. Six exploration wells were drilled between 1989 and 1991. 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. The total output from one of the well that was able to discharge (EW-1), was 2.4 MWe. Further infill MT surveys done in 2006 revealed that Eburru field is able to support up to over 70 MWe power generation. The combined MT data and 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 condensing pilot power plant (wellhead unit). In 2016 and 2017, KenGen carried out more detailed exploration studies in the larger Eburru-Badlands Elementaita area. Currently, plans are underway to drill appraisal and production wells to build a high capacity power plant.

2.3 Menengai geothermal field

Detailed surface exploration in Menengai, Arus-Bogoria, Koros-Chepchuk and Paka began in 2004. Menengai caldera is the most recent discovered geothermal fields in Kenya. The detailed studies done in 2004 were the basis of siting and drilling of two exploration wells in Menengai field in 2011. The drilling was underateken by the Geothermal Development Company (GDC). GDC is a Special Purpose Vehicle (SPV), fully owned by the Kenyan government and formed with main aim of speeding up geothermal development. 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.

GDC has contracted three IPPs to construct three power plants under phase 1 of Menegai development. The three Independent Power Producers (IPPs) will generate the first 105 MWe from Menengai geothermal field. These are Quantam East Africa Power Ltd., Orpower 22 Ltd., (a consortium of Ormat, Civicon and Symbion) and Sosian Menengai Geothermal Power Ltd., (SMGPL). Each of the IPPs will install a 35 MWe power plant in Menengai. GDC and the IPPs have signed a Project Implementation and Steam Supply Agreement (PISSA). The agreement stipulates that the IPPs will finance, design, construct, install, operate and maintain the plants on a Build-Own-Operate (BOO) basis. The IPPs have also signed a steam sale agreement with Kenya Power who will off-take the power generated by the IPPs. 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 % equity arrangement.

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 KES. 8 billion for the drilling of 15-20 wells. GDC has contracted Hong Kong Off-Shore Oil Services Limited (HOOSL) to drill the 15-20 geothermal wells under this phase. Additionally, it has already done 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. There is a shallow heat source under the caldera at a depth of about 10 Km. Three wells have been sited on the main caldera floor. The caldera floor is estimated to have a potential of about 200 MWe. A 70 MWe power plant is programmed for development and commissioning by end of 2018. A private investor has been licensed to carry out further survey and subsequent development, subject to a specific time bound programme.

2.5 Longonot

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 believed to be more than 132 km^2 and is capable of supporting 200 MWe power generation. In 2009, the Ministry of Energy in Kenya granted African Geothermal International Ltd. (AGIL) a license around Mt. Longonot prospect for exploration and production for 30 years. A 70 MWe power plant will be developed in Longonot and commissioned by 2018. An additional 70 MWe power plant will be developed in the field for commissioning by 2020.

2.6 Akiira Geothermal prospect

Surface exploration studies were done in Akiira area in 1990s. 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.

2.7 Barrier Geothermal prospect

The Barrier geothermal prospect is the north most geothermal prospect along the Kenya Rift axis. The prospect covers an area of 136 km^2 and is located in Turkana County, south of iconic Lake Turkana. Reconnaissance survey by the British Geological Survey (BGS) in 1993 indicated strong occurrence of strong 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 geothermal resource license (No. 1/2016) as per the geothermal act (1982). In April2018, the Company signed a Memorandum of Understanding (MoU) with the Turkana County government involving geothermal exploration and development in Barrier geothermal complex. Currently, the Company is planning for the upcoming geo-scientific (geological, geochemical and geophysical) to be executed in the area later in the year.

2.7 Other geothermal prospects

Other geothermal prospects include Emuruangogolak, Namarunu, Lake Magadi and Elementaita. Reconnaissance studies carried out in these prospects indicate temperatures of above 200 °C.

3. Future geothermal power development plans

The future geothermal development plans are based on the National Geothermal Strategy. On the other hand, the National Geothermal Strategy is anchored on the main objective of 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 high quality life to all its citizens. The expansion of renewable, sustainable, competitively priced and affordable energy is key to achieving this. Furthermore, the National Geothermal Strategy is based on the Least Cost Power Development Plan (LCPDP) 2015 through 2035.

Table 3: Geothermal Generation

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

To achieve the high share of renewable energy in Kenya's Vision 2030 energy mix, the Ministry of Energy has put plans to undertake geothermal drilling and steam development. A total of 282 geothermal wells will be drilled with a steam equivalent of 1,520 MWe. Execution of this plan will follow three key steps; Geothermal Generation, Geothermal Steam Development and Geothermal Drilling.

Each of the three steps is elaborated in Tables 3, 4 and 5.

Table 4: Geothermal Steam Development

GEOTHERMAL STEAM DEVELOPMENT												
Programmes /Projects	Objectives	Expected Outcome/ Output	Performance Indicators	Implementing Agencies	Time Frame	Source of Funds	Total Cost	Budget (in KShs million)				
							(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 5: Geothermal Drilling

GEOTHERMAL DRILLING												
Programmes /Projects	Objectives	Expected Outcome/ Output	Performance Indicators	Implementing Agencies	Time Frame	Source of Funds	Total Cost	Budget (in KShs million)				
							(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	-	-

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. This speeds up development.

There are two scenarios for geothermal power development. The first scenario is the reference scenario and the second is Vision scenario. Electricity consumption is forecasted to grow in the long term by 7.3 or 9.6% per year under the reference and vision scenario, respectively. Peak demand is expected to increase to 6,700 MWe under the reference scenario and 10,200 MWe under the vision scenario by 2035. The share of geothermal on the national grid is forecasted to be 2,849 MWe under the reference scenario and 3,589 MWe under the vision scenario (Table 6) by 2035. The geothermal share is expected to be contributed by public and private entities either through joint ventures or concessions.

Table 6: Geothermal share and the Capital Investment required by 2035

	Scenario	Reference Scenario	Vision Scenario
Geothermal Expansion up to 2035	MW	2,849	3,589
	Capital requirements	$6.683B	$8.158B

To achieve the National Geothermal Strategy, six business models for geothermal development have been proposed. The Strategic Geothermal Planning Unit (SGPU) has also been set up to provide strategic leadership and prescribe business models.

3.1.1 The proposed six Geothermal Development Business Models

A summary of the business models is shown in Table 7 while the advantages and limitations of each of these models is presented in Table 8.

Table 7: A summary of the proposed six geothermal development business models

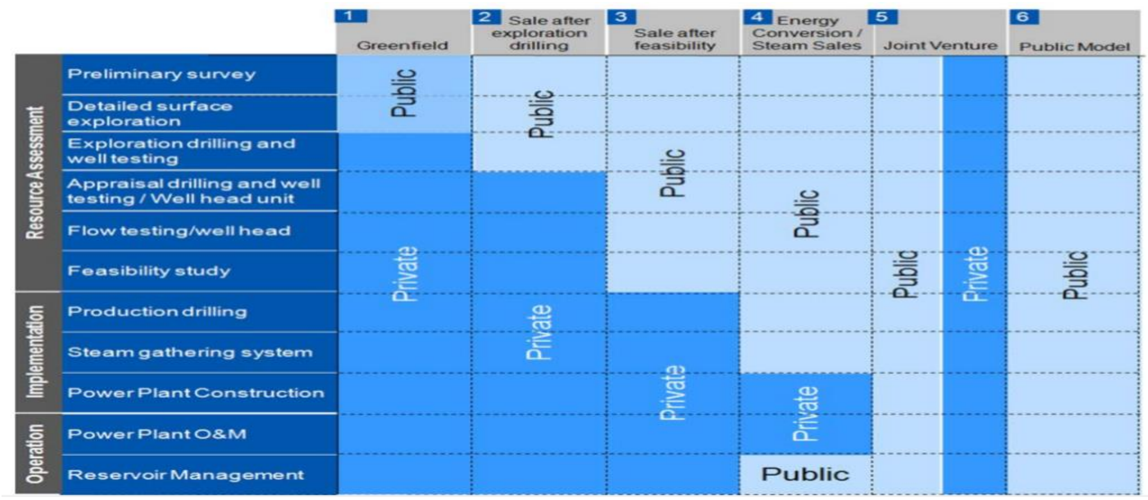

Table 8: Advantages and Limitations of the proposed six geothermal development business models

Model	Advantages	Limitations
Model 1: **Greenfield**	. Leverages most amount of private funding. . Private sector carries the resource risks. . Makes significant use of private sector expertise.	. High risk premium will result in a high generation tariff. . No debt without proven geothermal resource. Equity requirement may result in slow development. . License speculation possible.
Model 2: **Sale after exploration drilling**	. Proves the existence of reservoir . Leverages significant private sector funds . Simultaneous field development.	. High remaining resource risks . The private sector may still be unable to source for commercial funding . License speculation possible
Model 3: **Sale after feasibility**	. The existence, capacity and characteristic of the resource are proven . Several fields can be simultaneously developed	. All processes and data from exploration drilling needs to be produced according to global best practices
Model 4: **Steam sales**	. Generation tariff is lower compared to BM1, BM2, BM3 . May attract traditional IPP's (non-geothermal) . Private sector has easier access to commercial funding	.Significant up-front public sector investment . Private sector requires steam sale guarantee (under steam sales) . Significant need of public assets and human resources
Model 5: **Joint venture**	. Several parastatals can participate as shareholders in a SPC . Public sector can use previous investment of fields as equity in the SPC.	. Private sector will require to be the majority shareholder with management rights . Conflicting interests among the different parties may arise.
Module 6: **Fully public**	. Geothermal tariffs lowest of all potential business models	. Increase government liabilities . High funding requirements may be impossible to meet

3.1.2 The proposed 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.

Apart from the elaborated measures, the government has also put in place key steps to enhance geothermal development. They include:

- ➢ Enhancing the public-private partnership. Steps have been taken by the government to attract greater private investment. The formation of GDC to undertake geothermal well exploration and drilling then lease out steam to IPPs is one of such measures.
- ➢ The recently enacted mining act sets up the maximum period a lease can be held with no geothermal exploration or development work going on. This will open up geothermal prospects to able investors who are otherwise locked out by lease holders who lack the financial capability of developing these prospects.
- ➢ The plans to set up a Centre of Excellence in the country is aimed at enhancing local capacity building.

4. Progress made in direct utilization of geothermal resources

In Kenya, direct utilization of geothermal resources dates back to early 19th century. The Maasai community for instance is known to have used red ogre associated with the hot springs and altered ground to decorate their faces. Additionally, they used the hot springs for bathing. The early English settlers also applied direct utilization of geothermal resources in drying of crop in Eburru. In 1939, they built a geothermal drier to dry pyrethrum and white corn.

Oserian Development Company Ltd. took direct utilization of geothermal to a higher scale in 2000. It leased one well in addition to already two leased wells for power production. This well is used in the heating and supply of carbon dioxide required for photosynthesis to the greenhouses. In 2010, KenGen took the idea of direct utilization of geothermal resources a notch higher. An idea to construct a geothermal spa was conceptualized. The spa utilizes natural geothermal water from a drilled well. The water is obtained from the well at 100 °C. 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 pool. The hot springs are directed into a swimming pool where residents and visitors enjoy a warm bath.

In 2015, GDC set up direct use demonstration project in Menengai to scale up direct utilization of geothermal resources. The direct use demonstration centre is aimed at showing 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. Four demonstration projects have been set up in Menengai. They include geothermal powered dairy unit, geothermal heated aquatic ponds, geothermal heated greenhouse and geothermal powered laundry unit. Pilot plants have been set up for use in these projects.

5. Key players in geothermal sector other than KenGen

GDC was incorporated in December 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. The company commenced its operations in 2009. GDC was established as a limited company owned by the government of Kenya with the National Treasury and Ministry of Energy & Petroleum as the shareholders.

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. Other than OrPower 4 Incl., other licensed Independent Power Producers (IPP) include; WalAM Geopower Inc. (IPP) for exploration and development of Suswa geothermal field, AGIL (IPP) for exploration and development of Mt Longonot geothermal field, Olsuswa (IPP) for exploration and development of Barrier field and Marine Power Generation (IPP) for exploration and development of Akiira geothermal field.

6. Barriers 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 challenges tend to slow down the utilization of geothermal resources. Kenya has also faced these challenges in its strides for geothermal energy resource development. Some of the challenges include financial, technical and human capacity, environmental and socio-economic and policy and legislative challenges. However, the government has established various mechanisms for addressing these challenges. They include; setting aside research fund to facilitate exploration studies, formation of GDC to fast track development of green fields, taking scientists and engineers abroad to undergo training and enactment of Environmental Impact Assessment policies among others.

7. Financing of geothermal projects in Kenya

Contradictory as it may appear, it is true that in financing of projects, money is not the main problem. There is a lot of money chasing after very few promising projects. The issue is mainly whether the projects are bankable. Both 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. Geothermal projects have long economic life of at least 20 years and typically 25 to 30 years with payback period of about 10 to 15 years. 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,

8. Conclusion

Geothermal power has proved to be cheap and reliable source of energy to the Kenyan power consumer. For the country to realize clean, reliable and affordable energy, more efforts are being put in fast tracking the development of geothermal energy. 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.

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