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AFRICAN DEVELOPMENT BANK GROUP
GROUPE DE LA BANQUE AFRICAINE DE DÉVELOPPEMENT

Fact sheet for geothermal development to promote Public Private Partnerships in East Africa

Kenya

Overview of electricity sector status

Commercial energy in Kenya is dominated by petroleum and electricity while wood fuel provides household energy needs for the traditional sector including rural and urban communities. 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% while others including coal accounts for less than 1%. Solar energy is also extensively used for drying and, to some extent, for heating and lighting.

Current interconnected installed electric capacity in Kenya is constituted by hydro (837 MWe), fossil fuel (646.3 MW), geothermal (907 MWe), wind (436 MWe) solar (210 MWe) and imports (200 MWe). Additionally, Kenya has an off-grid installed capacity comprising thermals (36 MWe), wind (0.6MWe), solar (2.3MWe) and geothermal (3.6 MWe). However, the off-grid installed solar capacity might be more since not all the installed solar home systems are documented. In terms of interconnected energy consumed in the country in year 2021, the largest supply came from geothermal followed by hydro, wind, thermal, imports and solar and bioenergy as shown in the Table 1. The big share from geothermal is due to the use of geothermal as baseload.

Table 1: Interconnected Electricity installed capacity in Kenya by source (2022)

Generation Source	MWe	% installed capacity
Hydropower	837	27.5
Geothermal	907	29.9
Wind	436	14.3
Thermal	646	21.3
Solar	210	6.9
Bioenergy	2	0.07
Total interconnected	3,037	

Source: (Government of Kenya, 2021), (EPRA, 2022) and sector knowledge

Kenya Electricity Generating Company PLC (KenGen), which is the largest power generator in the country currently, accounts for 64.5% of the industry's effective generation capacity. The IPPs accounts for 34.8% while isolated grid generation under the Rural Electrification Programme carried out by the Rural Electrification and Renewable Energy Corporation (REREC) accounts for 0.7% (EPRA, 2022). Electricity generation increased by 4.55% from 12,101 GWh in June 2021 to 12,652 GWh in June 2022. Hydro and geothermal were the main energy sources with a combined contribution of 65.62% while wind and solar accounted for 18%. The total generation from wind and solar increased by 352 GWh and 225 GWh respectively (EPRA, 2022).

Figure shows grid-connected installed power capacity trends in Kenya by source from 2010 to 2020. The installed capacity connected to the grid in Kenya as of 2020 was about 2,836 MW. Out of this, geothermal contributed about 863 MW, accounting for 30% of the total installed capacity. Significant growth in installed power capacity from renewable sources was recorded between 2014 and 2020, driven by growth in geothermal, wind, and solar installations. During this period, the installed hydropower capacity remained nearly constant; in turn, the fossil-fuel installed capacity increased between 2010 and 2015 but declined between 2016 and 2020.

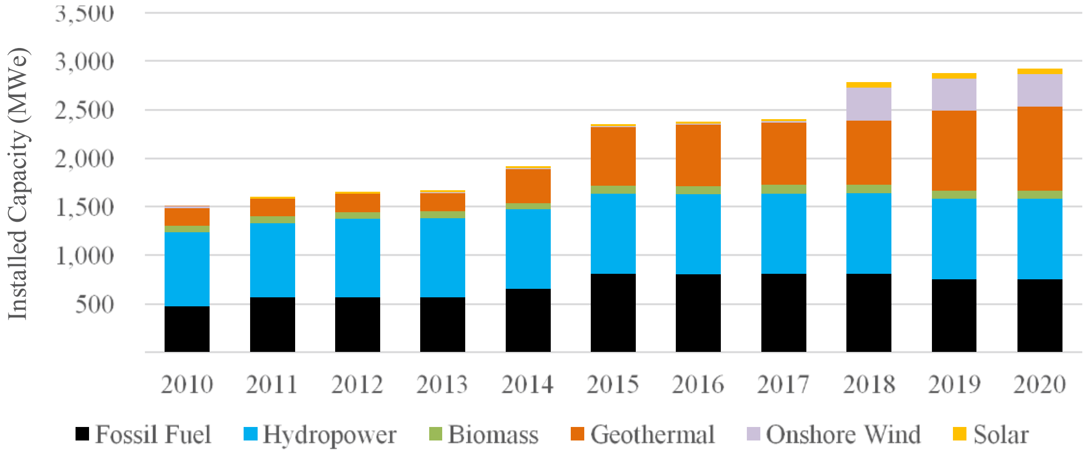

Figure 1: Grid-connected installed electricity capacity trends in Kenya by source

(Data Source: (IRENA, 2020), (KNBS, 2021)

As shown in Figure 2 electricity generation in Kenya was mainly by hydropower between 2000 and 2014, but geothermal became the foremost source of electricity generated in Kenya thereafter. In 2020, the share of electricity generated from geothermal was 43.6%, hydropower 36.5%, wind 11.5%, and fossil thermal sources 6.5%. In total, renewable energy sources contributed to about 93.5% of the electricity generated in Kenya in 2021.

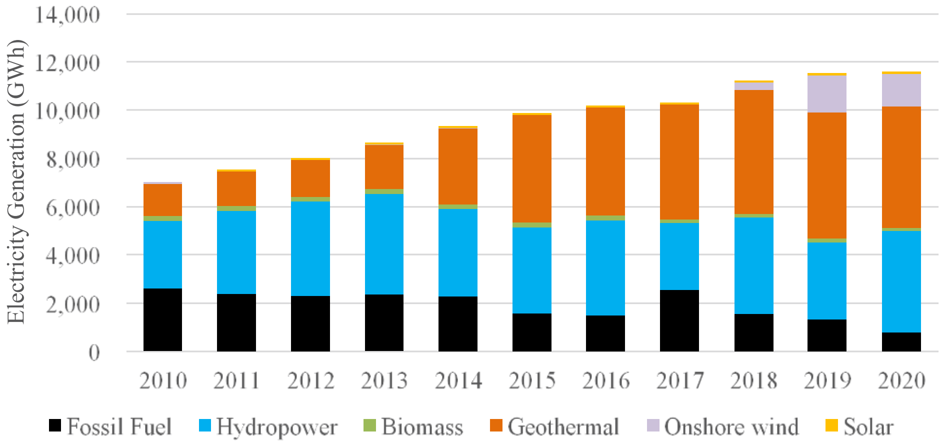

Figure 2: Grid-connected electricity generation trends in Kenya by source

(Data Source: **(IRENA, 2020)** and **(KNBS, 2021)**

According to the Energy and Petroleum Regulatory Authority (EPRA), the installed capacity increased by 102.34 MW from 2,972 MW in June 2021 to 3,074 MW in June 2022. This increment was due to addition of 120 MW and 86 MW from solar and geothermal, respectively (EPRA, 2022). New power plants that were added to the grid between 2021-2022 included Olkaria 1 unit 6 (86 MW), Selenkei

Solar plant (40 MW), Malindi Solar plant (40 MW) and Cedate Solar plant (40 MW) (EPRA, 2022). Geothermal and hydropower contribute a cumulative share of 65.62% while the generation from wind and solar are fast rising and jointly contribute to 18.69%. The focus on renewable energy develop has led to renewable energy share of total generation increase by 87% of total (EPRA, 2022). The current generation from thermal has dropped by 21.02% from 745 MW to 646 MW in the review period of 2021/2022, this was occasioned by the retirement of Tsavo Thermal Power plant whose purchase contract ended in September 2021. The phasing out of these thermal plants will help Kenya reduce environmental pollution. Installed wind capacity however, remained unchanged at 435.5 MW. However, in terms of electricity consumption, geothermal accounted for 46-50% and renewable sources accounted for more than 90%.

Ongoing & Planned Power Generation Projects

Committed power generation projects which are under construction as identified in the 2020-2030 Least Cost Power Development Plan have cumulative generation capacity of 853 MW (Government of Kenya, 2021). By the time of writing this document some of these projects had already been commissioned as indicated in (KPLC, 2022). The power plants planned for construction by 2027 include the following: Small hydro power plants of 10 MW; 50 MW of waste to energy; 589 MW geothermal and several solar power plants and battery energy storage systems. In 2023, the government and Kenya Electricity Generating Company (KenGen) signed a contract for 300 MW to be developed by an IPP for captive power where KenGen will be steam supplier.

Electricity Access

The number of connected customers in Kenya increased by 4 million at a compounded annual growth rate of 16% between 2013 - 2020. Due to government efforts to increase electricity access under the Last Mile Connectivity Program (LMCP) which started in the last seven years, as of June 2022 a total of 741,185 customers have been connected to the national grid under the LMCP program which brings the total number of connected customers in the country to 8.92 million, thus achieving over 70% of the Kenyan population with access to electricity (KPLC, 2022).

Demand forecast and Generation Expansion Plan

The demand forecast was modelled in three scenarios i.e. reference, low and vision. Energy demand forecast was estimated to grow at 5.28% while peak load forecast was estimated at 5.38% for the reference scenarios. The same were estimated for the vision scenario at 8.20% & 8.35% and 4.78 & 4.89% for the low scenario (Government of Kenya, 2021). Energy peak demand forecast will grow at average of 5.3% in the base year from 1,972 MW to 5,526 MW between 2020-2040 under the reference scenario. Under the vision scenario peak demand with increase to 9,635 MW in 2040 growing at an average rate of 8.35%. The low scenario peak demand increases to 5,028 MW in 2040 at an average rate of 4.89% (Government of Kenya, 2020).

Generation expansion plan was conducted for different scenarios i.e. fixed case with candidate and optimized case. The reference case demand forecast scenario reflects the most likely development path hence it is used in deriving the long-term expansion plan under the fixed case with candidates and optimized case generation expansion scenarios. Under the fixed case with candidate reference demand scenario, the total interconnected capacity grows from capacity of 2,654 MW in 2020 to 8,371 MW in 2040 (Table 2). Under the optimized case reference demand scenario, the total interconnected capacity will grow from the current 3,050 MW in 2020 to 8,186 MW in 2040 in the low scenario (Government of Kenya, 2020).

Table 2: Projected power generation capacity by source

Generation type	Installed capacity (MW)							
	2022 (as at June)		2025		2030		2040	
	Units	%	Units	%	Units	%	Units	%
Hydropower	837	27.5	848.8	24.05	1499.5	29.11	1813.9	22.16
Geothermal	940	29.9	976.6	27.67	1411.6	27.4	2586.8	31.60
Solar	210	6.9	250.3	7.09	454.3	9.0	404.0	4.93
Wind	435.5	14.3	475.5	13.47	771.4	20.0	731.0	8.93
Cogeneration	2	0.07	71.44	2.02	197.4	3.83	239.8	2.93
Thermal	646	21.2	506.4	14.35	417.8	8.11	-	-
Biogas	-	-	-	-	-	-	-	-
Biomass	-	-	-	-	-	-	-	-
Imorts			200.0	5.67	200	3.88	200.0	2.44
Gas Turbines (LNG)	-	-	200.0	5.67	200	3.88	480.0	5.86
Coal	-	-	-	-	-	-	981.0	11.98
Natural Gas	-	-		-	-	-	750.0	9.16
Nuclear	-	-	-	-	-	-	-	-
Total	3037.5	100	3,529	100.0	5,152	100	8,186.5	100

*This excludes 45 MWe Olkaria I power plant which was retired for rehabilitation in March 2023.
Data source: (EPRA, 2022); (Government of Kenya, 2020)

Feed in Tariff (FiT)

The publication of FiT policy was done for 2008 for wind, biomass and small hydro projects. This was revised in 2010 to adjust wind and biomass and also include geothermal, biogas and off-grid solar projects. The second revision of the 2008 FiT policy was done in 2012 to include grid-connected solar projects and was in force till 2021. The tariffs are applicable for 20 years from plant commissioning dates. In 2021 new feed-in-tariff rates were introduced (Table 3). The currently effective electricity feed-in-tariff rates approved in 2021 as published by EPRA in the Kenya Gazette notice Vol. CXXIII-No. 238 of 2021 are as follows (Energy & Petroleum Regulatory Authority, 2021).

Table 3(a): Electricity Feed-in-tariff (FiT) set in 2021

Technology	0.5 MW-10 MW	10 MW-20 MW	Escalable Component
Small hydro plants	9.0 US cents/kWh	7.6 US cents/kWh up to a maximum of 20MW otherwise to be competitively procured)	8%
Biomass	9.5 US cents/kWh	9.5 US cents/kWh up to a maximum of 20MW otherwise to be competitively procured)	15%
Biogas	9.5 US cents/kWh	9.5 US cents/kWh up to a maximum of 20MW otherwise to be competitively procured)	15%

Table 3(b): Electricity Feed-in-tariff (FiT) set in 2021

Technology	Tariff	Capacity
Wind	5.97 US cents/kWh	To be determined during auction
Solar	5.75 US cents/kWh	To be determined during auction
Small hydro plants	5.6 US cents/kWh	Above 20 MW
Biomass	8.4 US cents/kWh	Above 20 MW
Biogas	8.4 US cents/kWh	Above 20 MW
Geothermal	6.5 US cents /kWh (guide)	To be determined during procurement

Overview of geothermal development status

Geological setting

The Kenya Rift is part of the EARS that extends from the northern border with Ethiopia and northern Tanzania. Development of the EARS began in the north and migrated southward with initial development in Kenya during the Oligocene (Dunkley, Smith, Allen, & Darling, 1993). Compared to the Main Ethiopian Rift where extension is more than 3-7 mm/year reaching more than 3-4 cm in Afar, opening rate in Kenya is much reduced and measuring less than 2 mm/year. Formation of the graben structure in Kenya started about 5 million years ago and was followed by fissure eruptions in the axis of the rift to form flood lavas by about 2 to 1 million years ago. During the last 2 million years, volcanic activities became more intense within the axis of the rift due to increased extension. During this time, large shield volcanoes, most of which are geothermal prospects, developed in the axis of the rift. The volcanoes include Suswa, Longonot, Olkaria, Eburru, Menengai, Korosi, Paka, Silali, Emuruangogolak and Barrier. Homa hills is a geothermal prospect in the Nyanza Tertiary rift in western Kenya while Mwananyamala is a geothermal area associated with faulted Permo-Triassic sandstones of the coastal Kenya (Figure 3).

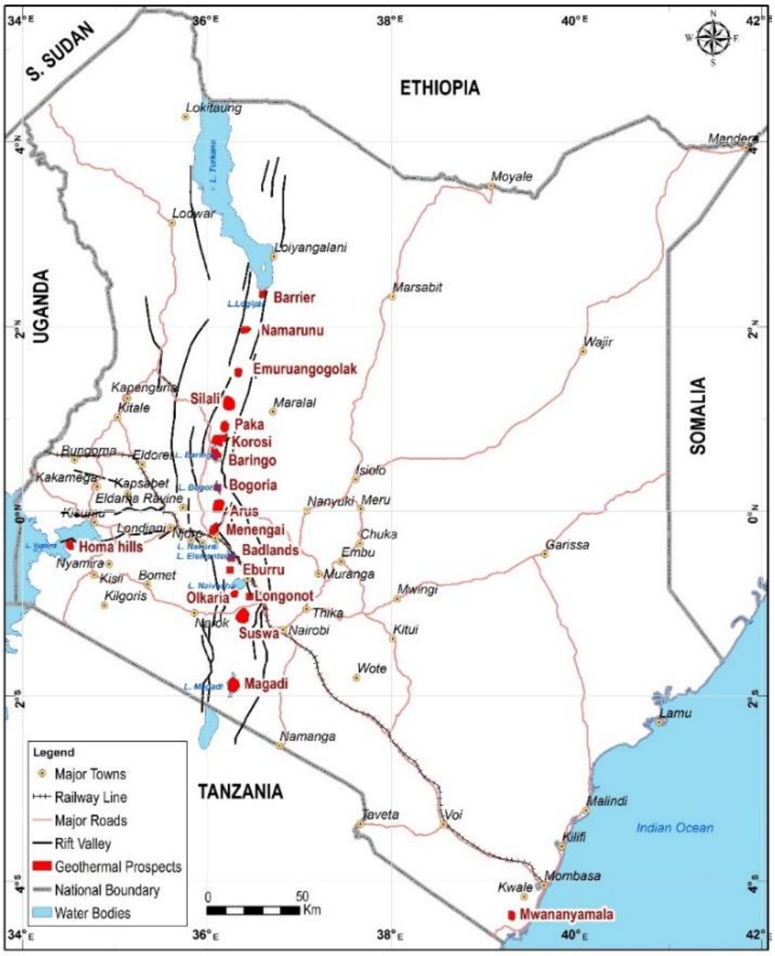

Figure 3: Map of Kenya showing locations of the geothermal fields and prospects

Geothermal field and prospects

- **Olkaria geothermal field**

The Olkaria geothermal field is located within the axis of the rift with a bias towards the Mau escarpment to the west. The rock outcrops are dominated by rhyolite flows and pyroclastics of which the youngest is the Ololbutot rhyolitic obsidian flow that erupted at 180 ± 50 yr B.P., (Clarke, Woodhall, Allen, & Darling, 1990), (Figure). Fault systems at Olkaria are dominantly in three directions: NW-SE, N-S and NE-SW. The latter two are younger affect even the Holocene flows while the NW trending faults are older and often associated with the rift graben formation. On the sub surface, the volcanic complex has been divided into the east and west with the divide being the fault zone that runs through Olkaria Hill (Omenda, 1998). The lithology in the western sector is dominated by the Mau Tuffs but minor trachyte, rhyolite and basalt occur within the formation. The Greater Olkaria geothermal field has been divided into seven fields for ease of development and management, namely, Olkaria East, Olkaria West, Olkaria NW, Olkaria NE, Olkaria Central, Olkaria SE, and Olkaria Domes (Figure 4).

1) Olkaria East field

The Olkaria SW field is home to the Olkaria I power plant which was the first geothermal power plant in Kenya, the first unit (Olkaria I Unit 1) having been commissioned in 1981. The second (Olkaria I Unit 2) and third unit (Olkaria I Unit 3) were installed in November 1982 and March 1985 respectively. Each of the units is of 15 MW each hence a total installed capacity of 45 MWe.

The power plant has been decommissioned and is undergoing rehabilitation and upgrade to 63 MWe by 2025 (Figure 6). To fully utilize steam realized after further appraisal drilling of the Olkaria East field, additional units (AU) consisting of 2x75 MWe (Olkaria IAU4 and Olkaria IAU 5) plants were developed and commissioned in 2014 and a further unit of 86.8 MWe (Olkaria IAU 6) power plant was commissioned in June 2022. This is the largest single geothermal turbine in Kenya and also the one with the lowest steam consumption.

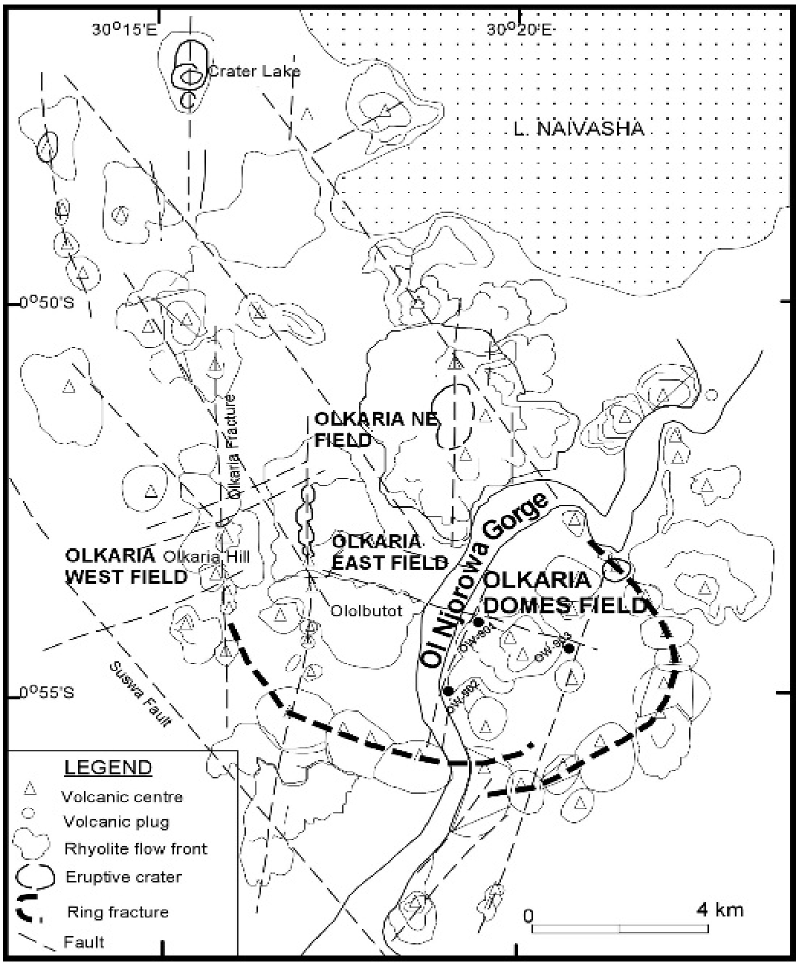

Figure 4: Structural map of Olkaria geothermal field

2) Olkaria Wellhead Power Plants

83.3 MW of wellhead power plants have been installed in Olkaria at about four locations. The power plants vary in sizes from 2.5-5 MWe for individual units (Figure 7). The power plants are condensing type designed by Green Energy Group of Iceland. The power plants have been operating successfully from 2011, however, their steam consumption rate (>10 t/hr/MWe) much higher than the large conventional power plants installed at Olkaria (<7.5t/hr/MWe). The power plants have been installed at Olkaria East field and Domes fields.

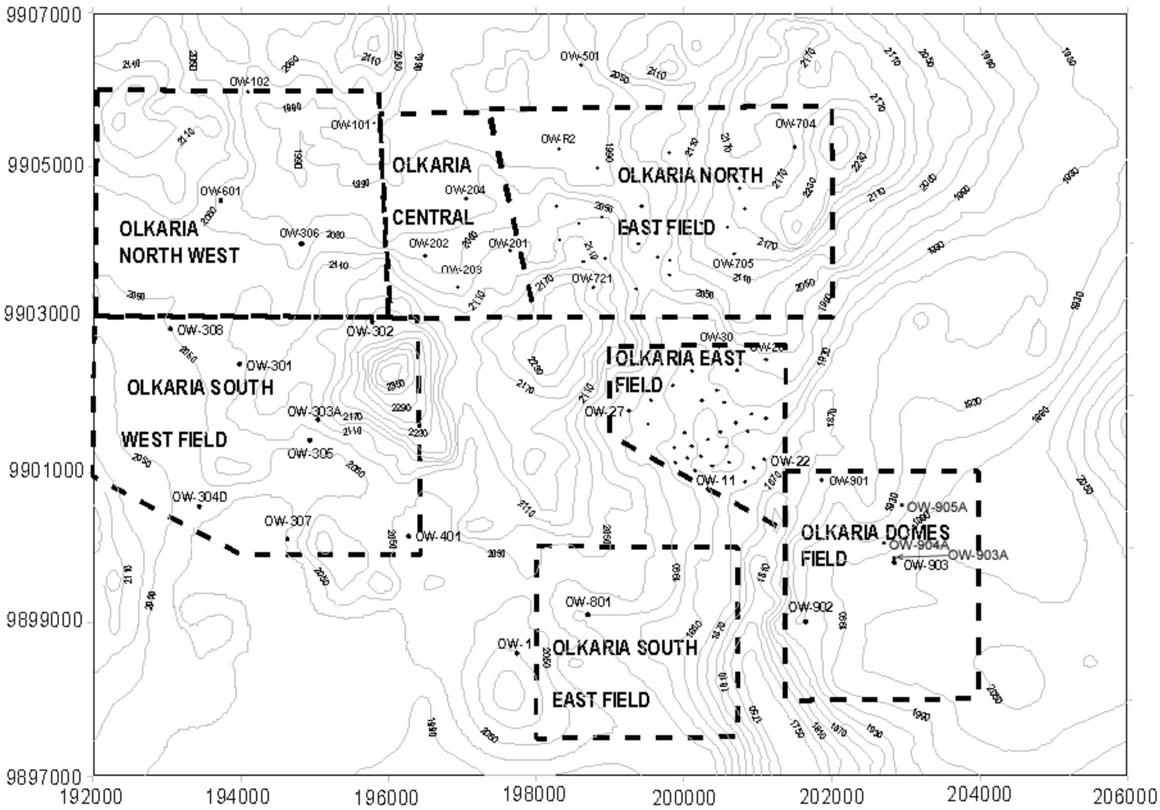

Figure 5: Map of the Greater Olkaria geothermal area showing the locations of the fields

Figure 6: A view of Olkaria 1 power plant located in the Olkaria East production field

Figure 7: Wellhead power plants at Olkaria geothermal field

3) Olkaria North East field

This field hosts the Olkaria II power plant. The plant consisting of 2X35 MWe units was commissioned in 2003. A third 35 MWe unit was commissioned in 2010 (Figure 8). The current total installed capacity at Olkaria II is 105 MWe. Production drilling is ongoing in the field with intention of increasing the capacity of the field by 140 MW. Feasibility study for the expansion has been commissioned. At the field is also developed a geothermal hot bath and spa which is the largest in Kenya.

Figure 8: Photo of Olkaria II, 105 MWe Power Plant at Olkaria

4) Olkaria Domes field

Surface exploration was carried out in 1993 and three exploration wells drilled in 1999. Appraisal drilling was undertaken in 2006 and 2007 and paved way for production drilling that has continued to date. 2x75 MWe Olkaria IV power plant was completed and commissioned in December 2014 (Figure 9). 37.8 MWe wellhead units have been installed in Olkaria Domes field.

Figure 9: Photo of Olkaria IV, 150MWe Power plant

The eastern sector of the field houses the Olkaria V power plant rated at 173.2 MWe power station which was commissioned in 2019 (Figure 10). The power plant houses 2x86.6 MW turbines with inlet pressure of 4.8 bar. This is the largest geothermal power plant in Kenya and have the second largest single turbine after Olkaria I AU 6.

Figure 10: Photo of Olkaria V, 173.2 MW Power Plant commissioned in 2019

5) Olkaria Central field

Olkaria Central field is located between Olkaria West and Olkaria North East fields. All the wells drilled in this field have relatively lower outputs resulting from lower reservoir temperatures and lower permeability. Oserian Development Company (ODC), a flower farm, constructed two power plants with installed capacity of 2.5 and 1.8 MWe utilizing Organic Rankine Cycle (ORC) (Figure 11Figure 1) and back pressure technologies (Figure 12), respectively. The plants use steam from wells leased from KenGen. The plants which were commissioned in 2004 and 2006, respectively provide electricity for private use. ODC also utilizes geothermal heat for greenhouses from a 1.28 MWe well also leased from KenGen. Plate heat exchangers are used to heat fresh water which is then used to heat the greenhouses and sterilize soil. Separated CO_2 is used to enrich the CO_2 levels in the green house. The use of geothermal heat has resulted in drastic reduction in operating costs in the flower farm.

Figure 11: Photo of Oserian 2.5 MWe geothermal ORC power plant

Figure 12: Photo of Oserian Back Pressure, 1.8 MW Gross power plant

6) Olkaria West field

The Olkaria West field hosts the OrPower4 power plant owned by Ormat International. In 2000, ORMAT through its local subsidiary OrPower 4, Inc. commissioned an 8 MWe combined cycle pilot plant called Olkaria III after winning an international tender (Figure 13). This was later increased to 12 MWe. In 2009, OrPower 4 further commissioned a 35 MWe generating unit, followed by a 36 MWe in 2013, 26 MWe generating unit in 2014, 29.6 MWe unit in 2016 and 15 MWe in 2018 bringing the total to 170 MWe (Gross). OrPower4 uses the combined cycle plant technology to generate the 155 MWe (LCPDP (2021).

Figure 14: Orpower4 Power Plant at Olkaria III

- **Eburru Geothermal Field**

Eburru geothermal field is located to the north of Olkaria at the foot of the Mau escarpment. Detailed surface studies were concluded in 1990 and culminated in the drilling of six exploration wells between 1989 and 1991. One of the six exploration wells (EW-01) produce high pressure steam (Omenda & Karingithi, 1993). Wells EW-04 and EW-06 produce low enthalpy single-phase fluids; the remaining three wells are unproductive. A 2.40 MWe condensing pilot plant was constructed and commissioned in 2012 (Figure 15). KenGen in 2022 commenced drilling of appraisal wells in the field with plans to expand the generation capacity to 25 MWe.

Figure 15: Photo of Eburru 2.4 MWe back pressure geothermal plant

- **Menengai geothermal field**

Menengai geothermal field is hosted by the Menengai Caldera volcano within the axis of the central segment of the Kenya Rift. The volcano has been active since about 0.8 Ma. The volcano is built of trachyte lavas and associated intermediate pyroclastics. Post caldera activity (< 0.1 Ma) occurred inside the caldera with eruption of thick piles of trachyte lavas from various eruption centres. Appraisal and production drilling have proved existence of high temperature geothermal reservoir. Exploration drilling commenced in Menengai in 2011 and now over 40 deep production wells of depths varying from 2,100 m to 3,200 m have been drilled with >160 MWe of steam realized (Figure 16). Reservoir temperatures of up to 400°C at 2000 m have been encountered in several wells with four of the wells encountering magma at 2100-2300 m depth. The reservoir at Menengai has proved complicated with possible existence of discrete reservoirs of which some have low production but others good. For example, Wells MW-01A produces steam of about 30 MWe on full discharge (Figure 17).

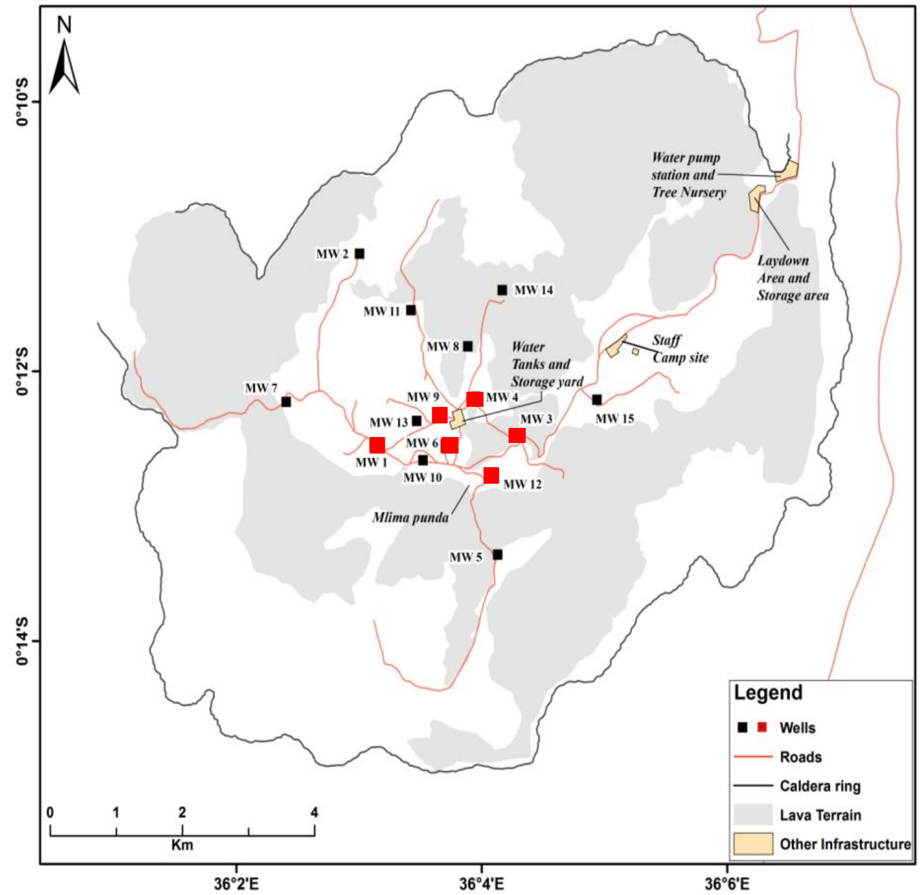

Figure 16: Map of the Menengai Geothermal field

Figure 17: Discharge testing of Menengai well MW-01A producing 30MWe.

Production drilling at the Menengai geothermal field has proved steam equivalent to about 170 MW on the wellhead. Three IPPs have entered into a steam sales agreement with GDC for power generation of 35 MWe each. The IPPs are Globeleq-Quantum Power East Africa Ltd., OrPower 22 Ltd and Sosian Menengai Geothermal Power Ltd (SMGPL). The development of Menengai geothermal power plant is under the Project Implementation and Steam Supply Agreement (PISSA) which mandates GDC to provide steam and manage the reservoir during generation while the IPPs to finance, design, construct, install, operate and maintain the plants on a Build-Own-Operate basis for 25 years. The 35 MWe Sosian Menengai Geothermal Power (SMGPL) was commissioned in August 2023 (Figure 18). SMGPL, is one of the IPPs selected by GDC to develop, design, finance, construct and install a 35 MW Geothermal Power Plant in Menengai Geothermal Field. The Power Plant design uses two Kaishan geothermal Steam counterpressure screw expanders (2x11MWe) which discharge their exhausts into three Organic Rankine Cycle (3x11MWe) units, all equipped with the necessary auxiliaries and balance of plant equipment, respectively. This is the first geothermal screw expander power plant in Kenya. Globeleq/Quantum Power commenced construction of their 35 MWe power plant in June 2023 and is due for commissioning in 2025 while Orpower22/Symbion Power project is still awaiting some approvals after its takeover by Kaishan.

- **Suswa prospect**

Suswa is the southernmost of a series of Quaternary caldera volcanoes in the Kenya Rift. The volcano has two nested calderas: outer and inner with diameters of 10 and 4 km, respectively. Volcanism at Suswa started during late Pleistocene and continued to less than 1,000 years ago, (Omenda P. , 1997). The volcanic products comprised trachytes, phonolites and their pyroclastic equivalents. Results from detailed surface studies suggest reservoir temperatures of >300°C based on gas geothermometry. Seismic and gravity studies show that the heat source under the caldera is at about 6 km depth. Resistivity (MT) indicates an anomaly centered below the inner caldera and extending to the northeast out of the inner caldera. Exploratory drilling is expected to commence in year 2017. Prefeasibility studies indicate a reservoir potential of 200 MW and GDC plans to commence exploration drilling in 2024 after many years of delay.

Figure 18: Photo of Sosian 35MWe power plant at Menengai. The plant uses Kaishan screw expander and ORC turbines

- **Longonot prospect**

Longonot is a large caldera volcano within the floor of the southern Kenya Rift adjacent to Olkaria Geothermal field. The volcano comprises of a large trachyte caldera of about 11 km diameter and a resurgent activity on the caldera floor that formed a central volcano with a crater at the summit. The caldera floor is filled, to a large extent, by trachytic ashes from the central volcano. The youngest activity (<300 years BP) at Longonot was of mixed Trachyte-basalt composition and erupted within the crater floor and on the northern flank of the central volcano. Geothermal surface manifestations are mainly fumaroles and hot grounds within the central crater. The geochemical survey revealed high radon and CO_2 gas discharges with gas geothermometry indicating geothermal reservoir temperatures of more than 300°C (KenGen, 1998). Combined MT, gravity and seismic indicate that the heat source is at 6 km deep with the shallowest portion directly under the central volcano, (Alexander & Ussher, 2011). Geothermometry indicates that a high temperature geothermal system >250°C exists under the volcano. The prospect was licensed to African Rift Geothermal Limited (AGIL) for at least 140 MWe. Exploration drilling activity has delayed due to several factors including financing challenges and suspension of PPA negotiations by the government in 2021. The company now plans to undertake exploration drilling in 2023/2024.

- **Korosi Geothermal prospect**

Korosi volcano is located in the northern part of Kenya rift valley and lies north of Lake Baringo and Paka volcano to the north east. Detailed surface studies were undertaken between 2005 and 2012. The latest volcanic activity associated with Korosi volcano was of basaltic composition and occurred a few hundred years ago while the last trachytic volcanism occurred about 100 Ka. The MT resistivity surveys indicate an anomaly below the Korosi massif. Gas geothermometry indicates reservoir temperatures of more than 250°C. Three exploratory wells have been completed with poor results. GDC is undertaking further evaluation of the prospect to identify new exploration targets.

- **Paka prospect**

Detailed surface studies of Paka volcano was undertaken in 2006. Paka is a relatively small shield volcano constructed largely by trachyte lavas and pyroclastic deposits and located just to the north of Korosi volcanic complex. The structure of Paka is dominated by a broad zone of normal faulting 7.5 km wide graben bound by the eastern and the western fault boundaries respectively. Surface geothermal activity is widely developed at Paka particularly within the summit craters and the northern flanks where fumaroles at >97°C are common. GDC in 2019 commenced exploration drilling at the summit of the volcano within the caldera floor. Ten wells have been completed with and additional two progressing. So far, the thirteen drilled wells have a steam equivalent of about 38 MWe on the wellhead. GDC has tendered for feasibility study consultant which is expected to be undertaken in 2023/2024.

- **Silali prospect**

The Suswa geothermal field is one of the geothermal prospects in the southern segment of the Kenyan Rift Valley. Suswa is a large Quaternary caldera volcano south of Olkaria and Longonot volcanic complexes. It has an outer and inner caldera with a resurgent dome in the middle of the inner caldera. The volcanic products include early shield building trachytes which were superseded by post caldera phonolites and pyroclastic flows. Geothermal manifestations are abundant in the prospect and most of which are located within the along the moat of the inner caldera, along the outer caldera rim and along fault lines within the main caldera floor. The fumaroles occur at more than 95 ^{o}C and are often associated with sulphur deposits. The estimated geothermal potential of the field is estimated at 750 MWe using volumetric assessment. GDC plans to commence exploration drilling in the prospect by 2024.

- **Other Geothermal prospects in Kenya**

The other licensed prospects under surface studies evaluation are Barrier, Emuruepoli, Emuruangogolak, Namaurunu, Arus, Elementeita, Lake Magadi and Homa Hills. Among these prospects, only Barrier has had detailed surface studies undertaken and well sites selected in 2019. The prospect development was affected by the moratorium placed by the government in 2021 which has since been lifted. The other prospects are at planning stages for detailed surface studies.

Geothermal utilization technologies

The geothermal power plants in Kenya deploy the following technologies (Table 4): Flash condensing plants with turbines from Mitsubishi, Toshiba and Fuji (Figure 19). High efficiency has been noted with the newer machines with steam consumption better than 6.3 t/hr/MW compared to those installed earlier in 2003 which had a steam rate of 7.5t/hr/MW. These power plants use wet cooling tower and both brine and condensate are reinjected.

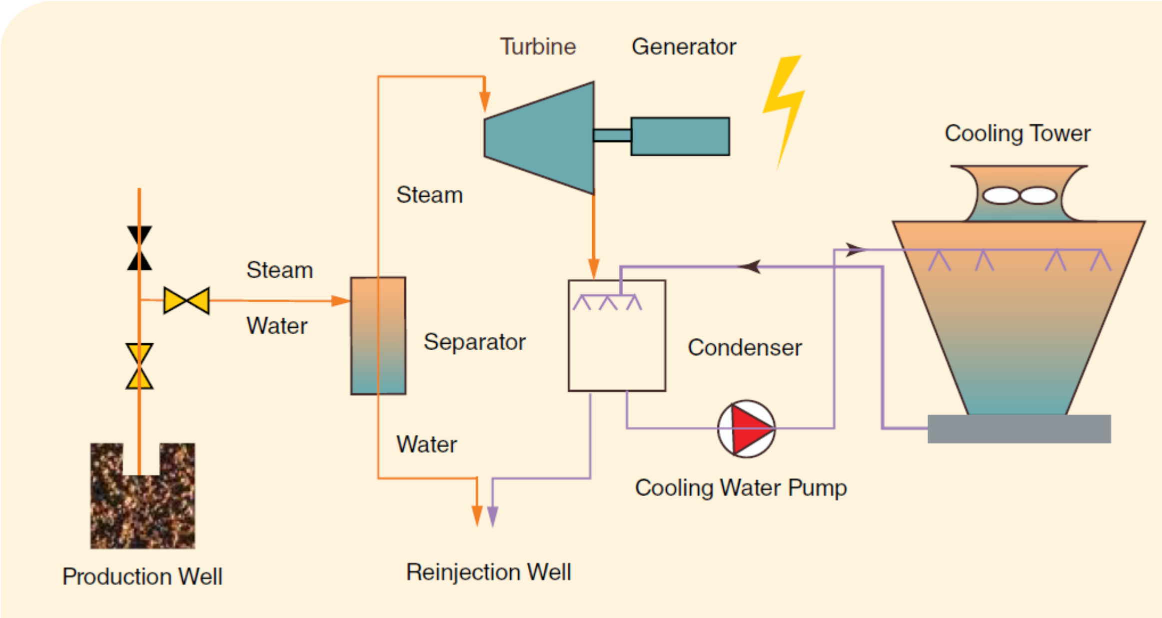

Figure 19: Flow diagram of single flash power plant similar to KenGen power plants

From (ESMAP, 2012)

At Olkaria, only about 50% of the fluid extracted from the ground is reinjected and this has resulted in negative impact on the reservoir. KenGen, therefore, has been considering changing the cooling systems to hybrid or other alternatives to ensure higher water recovery for reinjection but the right technology has not been identified. The other flash plants are used with wellhead power plants at Eburru and Olkaria. The Olkaria units were developed by Green Energy Group (GEG) units of Iceland while the one at Eburru was developed by Geothermal Development Associates of Reno Nevada. However, the wellhead units are not efficient due to many reasons and have very high steam consumption rates, typically more than 10 t/hr/MW.

ORC plants are mainly installed at Orpower4 where they use Ormat Energy Converter (OEC) Units for the entire 170 MW gross generation. Binary plants typically operate with liquid dominated systems with temperatures of at least about 120°C but can operate with steam at temperatures of more than 160°C (Figure 20). For example, the binary plants operated by Orpower4 in Kenya operate with high temperature steam. However, the efficiency is a little comprised resulting in higher steam consumption rate than that of flash plants. The Oserian ORC plant also uses OEC unit. Binary plants, however, are more environmentally cleaner with no emissions since it is a closed loop system.

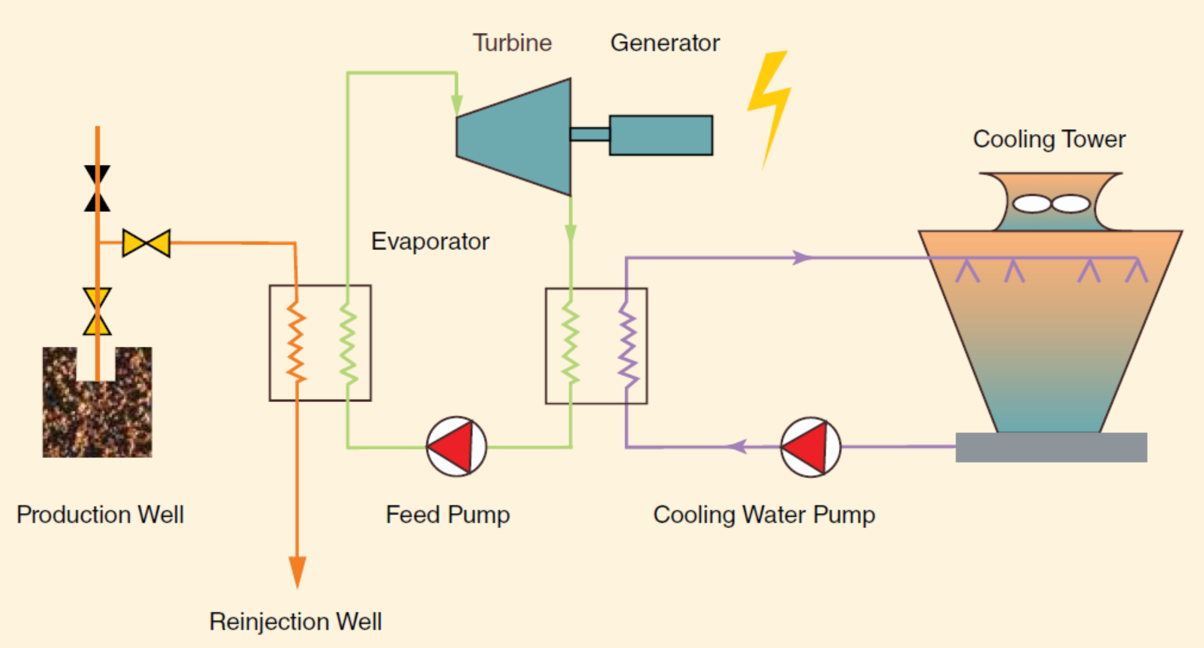

Figure 20: Flow diagram of binary power plant

From: (ESMAP, 2012)

A different technology was introduced lately into the Kenyan generation space and that is the use of combined screw expander and ORC turbines at the Sosian Menengai Geothermal plant. The high-pressure steam is passed through two stages of screw expander (high P and Low P) and ORC as bottoming cycle. The technology is interesting as all steam condensate in the steam fraction is condensed and reinjected without any emissions to the environment, thus ensuring reservoir and environmental sustainability.

Table 4: Installed and planned geothermal power plants in Kenya

Power Plant	Commissioned year	Licensee	Technology	Installed capacity (MW)	Status
Olkaria I	Unit 1 (1981)	KenGen	Single Flash	15	Decommissioned 2023
	Unit 2 (1982)			15	Decommissioned 2023
	Unit 3 (1985)			15	Decommissioned 2023
	Unit 4 (2014)			75.2	Operating
	Unit 5 (2015)			75.2	
	Unit 6 (2022)			86.8	
	Total			237.2	
Olkaria II	Unit 1 (2003)	KenGen	Single Flash	35	Operating
	Unit 2 (2003)			35	
	Unit 3 (2010)			35	
	Total			105	
Olkaria III	Unit 1 (2000)	OrPower4	Binary	52.8	Operating
	Unit 2 (2009)			39.6	
	Unit 3 (2014)			17.6	
	Unit 4 (2016)			45	
	Total			155	
Olkaria IV	Unit 1, Unit 2 (2014-2015)	KenGen	Single Flash	2 x 74.8	Operating

Power Plant	Commissioned year	Licensee	Technology	Installed capacity (MW)	Status
Olkaria V	2019	KenGen	Single Flash	2 x 86.7	Operating
Olkaria Wellhead Leasing	2028 (estimated)	KenGen-PPP (commercial)	Mixed ORC and flash	58	Contract signed
Olkaria-FFI	2025 (estimated)	KenGen-PPP (commercial)	Flash	300	Feasibility Study ongoing
Olkaria Wellheads	2012- 2016 (16 units)	KenGen	Single Flash	81.1	Generation
Oserian	2003	ODLC	Binary	2.5	Steam from OW-306
Oserian	2004	ODCL	Back Pressure	1.8	Operating using steam sales agreement with KenGen
Eburru Wellhead	Unit 1 (2012)	KenGen	Single Flash	2.4	Pilot generation operating
	Unit 2	-	Not decided	25	Appraisal drilling ongoing
Menengai (Phase 1)	2025 (estimated to be completed)	GDC & IPPs	-	-	Steam field development completed
Menengai 1-I	2025 expected	Orpower22/Symbion/ Kaishan	Binary	1 x 35 net	CPs ongoing
Menengai 1-II	2025 estimated	Globeleq	Single flash	1 x 35 net	In construction
Menengai 1-III	2023 scheduled	Sosian Energy SMGPL	Screw expander +ORC	35 net (mixed and with several units	Operating

Power Plant	Commissioned year	Licensee	Technology	Installed capacity (MW)	Status
Olkaria I and IV uprating	2025	KenGen	Efficiency upgrade	40	Contract signed for construction
Wellhead Leasing	2028	Rentco Africa	Mixed ORC/Flash	58	Contract signed
Steam sales	2027	FFI		200	FS in progress
Longonot	2030 (estimated)	AGIL		140	Surface exploration done; drilling awaited
Paka	2030 (estimated)	GDC & IPP		100	Production drilling. Feasibility study tendered
Akiira	2032 (estimated)	AGL			Surface exploration completed. Two exploration wells failed
Suswa	2030 (estimated)	GDC & IPP		150	Surface exploration completed; drilling awaited

Direct use applications

Direct use of installed capacity and energy use of geothermal resources in Kenya currently stands at 18.5 MWth and annual use of 601.9 Tj/y (Omenda, et al. 2020; Table Table 5). Bathing, swimming, and greenhouse heating have become the main direct use of geothermal resources in Kenya. Development of direct use facilities in Kenya follows the Lindal Diagram which shows the type of applications that are suitable for particular temperature ranges (Figure 21).

Table 5: Direct use installed capacity and energy use in 2019 in Kenya

Use	Installed Capacity (MWt)	Annual Energy Use (Tj_t/y)
Greenhouse heating	5.3	185
Agricultural drying	0.3	9.9
Fish farming	0.2	6.5
Bathing and swimming	8.7	275.5
Other uses (laundry operations and milk pasteurization)	4.0	125
Total	18.5	601.9

Source: (Omenda, Mangi, Ofwona, & Mwangi, 2020)

- **Oserian Greenhouse Heating**

Oserian Development Company Limited (ODCL), a privately-owned farm located in Naivasha within the Great Olkaria Geothermal field, has been utilizing geothermal energy for agriculture since 2003. Cut rose flower greenhouses of 50 hectors in total are heated using geothermal energy (Figure 22). Through a system of loops, hot geothermal fluid heats fresh water which is used as a heat transport medium to the greenhouse. Greenhouse heating assists in controlling relative humidity within the greenhouse especially the early morning hours when humidity tends to rise to 100%. Reducing relative humidity to below 85% eliminates fungal infection and the use of chemical fungicides. Heated water is also used to sterilize the fertilized water-reducing fertilizer waste and costs. Carbon dioxide from the well is piped to the greenhouses in order to enhance photosynthesis. Therefore, the use of geothermal energy has resulted in reducing operational costs and increasing productivity and market share due to the use of environmentally and eco-friendly practices.

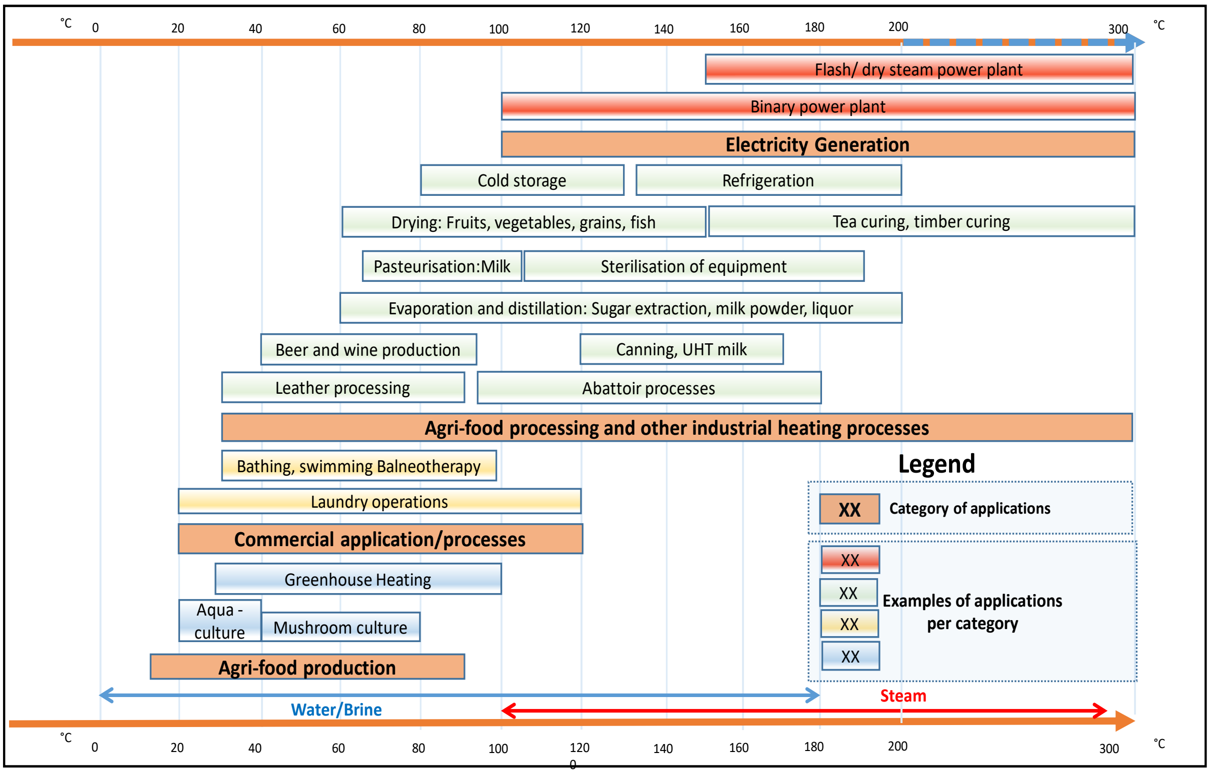

Figure 21: The modified Lindal diagram

Source: (IRENA, 2020)

Figure 22: Geothermally heated greenhouse in Kenya. The white pipes carry hot water

A study showed that the Oserian flower farm reduced costs of heating by 70% by adopting geothermal heating in greenhouses (Land-O-Lakes, 2013) and by 85% on fungicides (Mburu, 2014). In addition, the farm was able to cultivate two famous flowers “Sweet Vuvuzela” and “Queen of Africa” which would have been uneconomical to farm without geothermal energy. According to the consultation with ODCL in 2022, ODCL sold the flower business and is still in the transition stage with plans to focus on industrial parks and power generation.

- **Eburru Geothermal Field**

The first recorded direct-use application in Kenya was the pyrethrum dryer built in 1939 in Eburru for use in drying pyrethrum flowers and grains. KenGen designed a water harvesting and a drying unit on commercial scale that would benefit the community at Eburru (Ngethe, 2020),. The drier is supplied with geothermal water from a well at 95°C adjacent to the drying chamber at about 43°C (Figure 23). The community pays per weight of materials to be dried as co-share for maintenance of the facility (Mangi, 2013). Well EW-01 is currently connected to the Eburru pilot power plant.

Figure 23: Pyrethrum and grain dryer at Eburru geothermal field

- **Menengai Direct Use Pilot Projects**

In 2015, in order to showcase the technical and financial viability of direct uses, the GDC set up a direct use pilot facility at Menengai geothermal field in Nakuru County. The facility, harnessing heat from Menengai well 3 (MW-03), includes a milk pasteurizer, a heated greenhouse, heated aquaculture ponds, a laundry unit, and a later-added experimental grain drier (Currently the system uses steam from well MW-12 after well MW-03 developed output problems). The 150-liter capacity milk processing demonstration unit takes about four hours to pasteurize one batch of milk and could be effectively used if there were greater amounts of raw milk available (Figure 24). Since this plant is located in an agriculturally rich environment, it can be utilized for milk processing for the majority of dairy farmers in the region. The GDC is currently seeking the possibility of procuring milk from local dairy cooperatives to ensure continuous processing of milk by using this geothermally heated pasteurizer.

Figure 24: The milk-processing unit. (Source: GDC)

Cascading has been demonstrated by redirecting the water already used for milk pasteurization and from the geothermally heated dryer to the fishponds. Water exits at the system at around 65°C and is therefore reusable in the fishponds since they require temperatures between 24°C and 29°C. Tomatoes and capsicum are grown on media in the greenhouse developed by GDC. Wastewater from the fishponds is filtered, added with additional nutrients in fertigation tanks, and fed to the crops through drip irrigation. During the night, early morning, and wet seasons, geothermal heated water at a temperature range of 50°C–55°C is circulated in galvanized pipes to raise the temperature and lower the relative humidity inside the greenhouse. Temperatures are maintained at 28°C–30°C and relative humidity at less than 85%. This in return ensures less fungal infections and consequently realization of bigger production with less use of agricultural chemicals. GDC also developed technology for agricultural crop drying and its feasibility was demonstrated through the steam-heated cereal drying pilot facility depicted in Figure 25 (Kinyanjui, 2013). This constitutes another GDC's geothermal heat direct use flag-project implemented in Menengai and the dryer can be used for crops such as maize, wheat, barley and sorghum.

Figure 25: Grain dryer utilizing geothermal steam at Menengai (Source: GDC)

- **Olkaria Spa and Bath**

KenGen established the Geothermal Health Spa and Demonstration Centre nearby the Olkaria II power plant. This center showcases geothermal direct use applications such as hot and warm water bathing for balneological effects, sauna, steam bathing, cooking, drying of fruits and vegetables, refrigeration, irrigation of crops, and fish farming. In addition, the Lake Bogoria Spa and Hotel located in the same area operates a swimming pool that utilizes water from a nearby hot spring. The Geothermal Spa (Figure 26) has three cascaded lagoons. The first lagoon is a receiving pond of hot brine at more than 90°C that is gathered from various wells in the Olkaria geothermal field. The second lagoon is an overflow from the first lagoon and offers temperatures of 35-50°C. Designed in an aesthetic manner, this lagoon has both shallow and deep ends (KenGen, 2020).

Figure 26: The Geothermal Spa (source: KenGen)

Policy, regulatory and institutional framework for development of geothermal resources

Institutional framework

The energy sector in Kenya comprises of various government Ministries and agencies (Figure 27). This structure is the result of a series of restructuring since 1997 following government policies touching on the sector.

- **The Ministry of Energy and Petroleum**

The Ministry of Energy and Petroleum (MoEP) is responsible for overseeing the electricity sector in Kenya. It provides policy guidance, vision and strategy towards the creation of an enabling environment for efficient operation and growth of Kenya's energy sector. The Ministry is also charged with the responsibility to license and manage geothermal concessions.

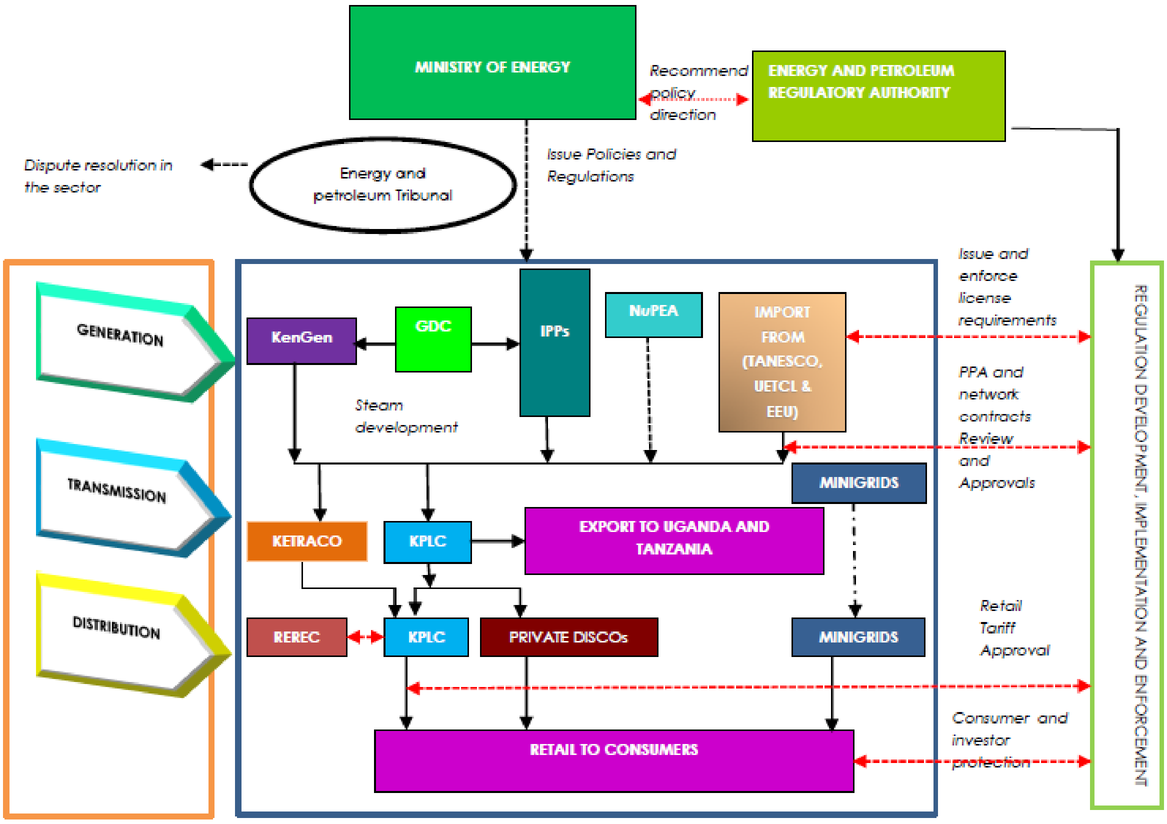

Figure 27: Institutional setup of the Energy sector (LCPDP 2021-2040).

- **Kenya Electricity Generating Company**

KenGen as a corporate identity was adopted on 2nd October, 1998 and is charged with all publicly owned power generating plants. The Government of Kenya holds 70% of shares while 30% is owned by the public. KenGen is charged with electricity generation in the country from geothermal, hydro, solar, wind and hydrocarbons. KenGen produces about 80% of electricity consumed in Kenya.

- **Geothermal Development Company**

The GDC was incorporated in the year 2008 to speed up the development of geothermal resources in Kenya. It is fully owned by the Government of Kenya and its main role is to de-risk geothermal fields and promote development of direct use applications. GDC would achieve its mandate by developing geothermal resources and either selling steam to IPPs or partnering with IPPs to develop in the post exploration stages of geothermal projects through joint development agreements.

- **Kenya Electricity Transmission Company**

Kenya Electricity Transmission Company (KETRACO) is a State Corporation charged with high voltage transmission from the generating stations to the load centres. The transmission of electricity was previously part of the mandate of the KPLC until the incorporation of KETRACO in the year 2008. The mandate of KETRACO is to plan, design, and construct, own, operate and maintain new high voltage electricity transmission infrastructure in Kenya.

- **Kenya Power and Lighting Company**

Kenya Power and Lighting Company (KPLC) is a State Corporation in which the Government of Kenya has a shareholding of 50.1%. The private shareholding amounts to 49.9%. Kenya Power purchases electrical energy in bulk from KenGen and other Independent Power Producers and sells to consumers. It owns some high voltage transmission lines and distribution lines.

- **Energy and Petroleum Regulatory Authority**

The EPRA was established as an energy sector regulator under Section 4 of the Energy Act, 2019. It is charged with the responsibility of economic and technical regulation of electric power, renewable energy, and downstream petroleum sub-sectors. Its functions also include tariff setting, review, licensing, enforcement, dispute settlement and approval of power purchase and network service contracts.

- **Rural Electrification and Renewable Energy Corporation**

The Rural Electrification and Renewable Energy Corporation (REREC) was established under Section 66 of the Energy Act No 12 of 2006. With mandate to manage the Rural Electrification Programme Fund; develop and update rural electrification master plan as well as implement and source additional funds for the rural electrification programme, among other functions. With mandate conferred by the Energy Act, 2019, RECEC has an expanded mandate of spearheading Kenya's green energy drive, in addition to implementing rural electrification projects. Nuclear Power and Energy Agency (NuPEA) is responsible for the promotion of nuclear electricity generation development, including research, capacity-building and programme implementation. Energy & Petroleum Tribunal: independent legal entity mandated to determine disputes and appeals in accordance with the Constitution of Kenya, Energy Act 2019, and other relevant laws.

- **The National Treasury**

To encourage investment in geothermal development for electricity generation, Government of Kenya/The Treasury through the National Treasury's Legal Notice 91 of 2015 puts in place tax incentives, including tax exemptions on interest on loans advanced from foreign sources, provided the funds are utilized for investment in infrastructure. Legal Notice 106 of 2015 grants an exemption from stamp duty on the registration of security documents relating to loans from foreign sources utilized in investing in geothermal infrastructure. The government/Ministry of Finance also provides for 10-year tax holiday for geothermal plants of at least 50 MW, seven years for plants in the range of 30-49 MW, and five years for plants of capacities between 10-29 MW (Kiptanui & Mwai, 2018).

Policy and regulatory framework

As summary, Kenya has comprehensive policy framework for geothermal development, such as a clear geothermal development plan, FiT policy, Tax and other financial incentives for geothermal power plant. However, financial incentives for direct use application have not existed yet in Kenya and other targeted countries. Kenya also has comprehensive regulation for geothermal development starting from regulation for geothermal ownership, exploration license and authority, royalty, to regulation for electricity market liberalization.

- **National Energy Policy 2018**

The National Energy Policy provides a comprehensive description of the current state of the energy sector and of the policy framework as of 2018 and contains policy recommendations for various subthemes: coal, renewable energy (including geothermal and hydro in particular), electricity, energy efficiency and conservation, land, environment, health and safety, energy services, energy financing, pricing, and socioeconomic issues. In particular, the policy has clear directions to promote geothermal generation and utilization as a low cost, environmentally sustainable source of electricity for Kenya.

- **The Integrated National Energy Plan (INEP)**

The INEP is an intergovernmental document intended to guide the energy sector on short-, medium-, and long-term energy requirements based on evolving economic, social, politic, and technical issues. In accordance with the Energy Act of 2019, the cabinet secretary, in collaboration with other stakeholders, is mandated to develop an INEP every three years in respect of coal, renewable energy, and electricity so as to ensure delivery of reliable energy services at the least cost. INEP will consolidate all national energy service provider plans and country energy plan. County governments are charged with the preparation of county energy plans incorporating petroleum, renewable energy, and electricity master plans. They are also required to undertake physical planning relating to energy resource areas such as dams, geothermal sites, solar and wind farms, as well as the facilitation of energy demand by planning for industrial parks and other energy-consuming activities.

- **The Energy Act 2019**

Kenya adopted the Energy Act No. 1 of 2019 (the Energy Act) to, among other objectives, promote the generation of renewable energy in Kenya. The Energy Act mandates the Cabinet Secretary for the Ministry of Energy and Petroleum to develop, publish, and review energy plans in respect of renewable energy to ensure delivery of reliable energy services and to, at a minimum, cost and develop a conducive environment for the promotion of investments in energy infrastructure development. In an effort to promote energy investments, national and county government are required to facilitate the acquisition of land for energy infrastructure development.

The Energy Act 2019 established the Renewable Energy Resource Advisory Committee under the Ministry of Energy and Petroleum with the mandate of advising the cabinet secretary on the licensing and management of renewable energy projects, excluding geothermal. The Act also established the

EPRA as the regulator of the energy sector, giving license for geothermal power plant projects and other power projects. Regarding with royalties from extraction of geothermal resources, this Act adopted the provisions of the bill despite the protestations relating to the amount of the royalty charged on licensees, i.e., between 1% to 2.5% to be paid during the first 10 years of production and between 2% and 5% for the following years. It has also retained the provisions on the division of the royalty by the three stakeholders, i.e., the local communities will receive 5%, the county government 20%, and the remaining 75% will be taken by the national government.

- **Geothermal Resources Act No. 12., 1982 (repealed)**

This is the act under which most of the IPPs on geothermal were licensed prior to the enactment of the Energy Act 2019. The act regulates access to and exploitation of geothermal resources for power generation. It vests all geothermal resources in the government and empowers the minister responsible for energy to authorize geothermal exploration and grant geothermal licenses. According to this act, a geothermal resources license may be granted for a period not exceeding 30 years, subject to certain set terms and conditions, and can be for the whole or part of a geothermal resource area. It may be renewed for a period not exceeding five years. The license confers upon the licensee the right to explore, drill, extract, and use and do all those things that are reasonably necessary for conducting all those operations. Most of the current geothermal exploration licenses issued in Kenya were granted under the Geothermal Resources Act, no. 12 of 1982.

- **PPP Act No. 14 of 2021**

PPPs in Kenya were established under PPP Policy Statement 2011, and later revised in Act 15 of 2013 and replaced by the Public Private Partnership Act, no 14 of 2021. The Public Private Partnership Act, 2021 provides for the participation of the private sector in the financing, construction, development, operation or maintenance of infrastructure or development projects through public private partnerships. The act provides for the participation of the private sector in the financing, construction, development, operation and maintenance of public infrastructure projects through concession and other contractual arrangements; and institutions that regulate, monitor, and supervise the implementation of project agreements relating to infrastructure or development projects.

Subsequent to the PPP Act, several key enabling regulations and guidelines have been put in place or are in the process of being finalized. These include PPP Regulations 2014, Project Facilitation Fund Regulations 2017, draft PPP (Amendment) Bill 2016, draft County PPP Regulations 2015, and draft Petition Regulations 2015. The PPP Unit, which is housed in the National Treasury, became operational in 2010 and has been strengthened with technical, legal, safeguards, procurement, PPP, and financial expertise. The Kenya government considers geothermal projects to be some of the infrastructure projects that are eligible and well suited for PPP arrangements. Olkaria III Geothermal Power Plant was the first geothermal power plant developed under a public-private partnership (PPP).

- **Regulation for Environmental Impact Assessment**

The Environmental Management and Co-ordination Act No. 8 of 1999 act provides for the establishment of an appropriate legal and constitutional framework for sustainable management of the environment and natural resources in Kenya. It outlines environmental impact assessment procedures, environmental audits, monitoring procedures, transmission, and environmental quality standards. The act is administered by the National Environmental Council (NEC) under the chairmanship of the Cabinet Secretary and implemented by the National Environmental Management Authority (NEMA).

Kenya has many laws which relate to environmental and social considerations. These laws and regulations are sector specific. Some of those governing geothermal development in Kenya are: Kenya Vision 2030, Kenya National Climate Change Response Strategy, The Sessional Paper No. 4 of 2004 (The Energy Policy Document), Constitution of Kenya 2010, Environmental Management and Co-ordination Act 1999, Cap 8, The Environmental Impact (Assessment and Auditing) Regulations, 2003, The Environmental Management and Co-ordination (Water Quality & Waste Management) Regulations, 2006, The Environmental Management and Coordination (Noise and Excessive Vibration Pollution Control) Regulations 2009, The Geothermal Resources Regulations Act, 1990, Energy Act Cap. 12, Local Authority Act Cap. 265, Physical Planning Act Cap. 286, Water Act, 2002, The Way Leaves Act, Cap 292, Land Acquisition Act 295, Occupational Safety and Health Act, 2007, Public Health Act, Cap. 242 and The Wildlife Conservation and Management Act, Cap 376. Some of the International Law and conventions include World Bank Safeguard 4.01-Environmental Assessment, World Bank Operational Policy BP 17.50 - Public Disclosure, Convention on Biological Diversity, United Nations Framework Convention on Climate Change (UNFCCC), World Heritage and Fossil Sites Convention.

Most of the work undertaken during geothermal surface exploration do not require approval of an ESIA report since they do not alter the environment except when drilling of thermal gradient holes are required. Prior to drilling and development of subsequent stages of a geothermal project, a comprehensive environmental and social impact assessment report must be approved by NEMA.