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Status of Geothermal Exploration in Zambia

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ABSTRACT

The Zambian government is making efforts to increase the share of renewable energy, apart from hydro power, in the national energy mix. The Country has relied on hydro power, which is susceptible to climate change, for a long time and currently has 2986.23 MW of installed capacity. In the 2015/2016 rain season, the country experienced drought which led to low water levels in the major rivers used for hydro power generation. As a result, the country experienced power cuts which affected production for industries and reduced availability of power for residents. It was at that time that the country doubled its efforts towards the utilization of renewable energy. Geothermal is one of the sources of energy which is being considered for exploitation both for power generation and for cascading uses. The Country has about 80 hot springs which are a manifestation of the possible source of geothermal resources which can be used for power generation. Despite having geothermal potential, the Zambia has no geothermal power plant currently running. In 1986, the Italian company working with the Zambian utility company, ZESCO Ltd, explored and constructed a 220 kW Turboden binary geothermal power plant in the Northern part of the country called Kapisya power plant. The plant has never work to evacuate power. Some of the reasons are that the nearest grid or connection point was more than 100km. The local communities in the area did not have the capacity to utilize the power therefore making the possibility of an off-grid system uneconomical. The country then did not see the benefit of geothermal energy because there was enough water hydro power generation with substantial potential which was not exploited. The plant has since deteriorated to a bad extent, however, efforts to revamp it so that it can use modern technology are being considered. Recently, a private company called Kalahari GeoEnergy has been conducting exploration activities in the Kafue Trough in the Southern Part of the Country. The kafue trough is lies at the intersection of the Zambezi mobile belt and the Mwembeshi shear dislocation zone, a previously highly active tectonic zone. So far the company has drilled exploration wells to determine the potential of finding the resource in the area. The company will be drilling more wells in September 2019 to conclude the feasibility study and the Environmental and Social Impact Assessment brief. The Ministry of Energy is supporting the company in terms of policy guidance and procedure so that the Country can benefit from the base load power that geothermal power plants provide. In addition, the Country intends to create value chains around the geothermal power plant and hotsprings which will utilize the geothermal direct applications such as the geothermal spar, aquaculture, green houses, drying etc.

1.0. INTRODUCTION

The Zambia's energy sector has for a long time been dominated by hydro generated power. Hydro has been the main source of power because of plenty water resources in the country for power generation. In fact, it is estimated that the water resources in Zambia accounts for 40% of the water in Southern Africa (WWF, 2016). Apart from the available water resources, hydro power has been advantageous because it is clean and dispatchable. The installed capacity stands at 2986.23 MW with hydro accounting for about 80.3 % of the total generation. The remainder of the generation mix is from coal (10.35%), HFO (3.8%), Diesel (3.08%) and solar (0.3%). As can be seen, renewable energy other than hydro is insignificant in terms of its contribution to the national energy mix. The mining sector consumes 51.1% of the electricity generated.

In 2014/2015 rainy season, Zambia experience drought which led to less water levels and hence reduced hydro power production. The deficit of power was about 600 MW with the mining industry recording less production as a result. This in turn prompted the mines to reduce the work force which meant job losses for the citizenly working in the mines. All other sectors were adversely affected and as a result, government decided to double the efforts channeled at increasing the share of renewable energy in the national energy mix to complement hydro which is susceptible to climate change. Some of the renewable energies under consideration were solar, wind and geothermal. Nonetheless, considering the nature of geothermal exploration and cost requirement, government chose a simpler option of solar, hence the development of the Scaling Solar Programme and REFiT Strategy. As regards, geothermal, a private company called Kalahari GeoEnergy Ltd. (KGE) has been conducting exploration drilling in the southern part of the country since 2011 with their own funds. Government has recognized the importance of the geothermal exploration activities being conducted by KGE and has been supporting in terms policy guidance. The energy from geothermal base-load and will complement hydro as well as stabilize the grid more better injection of the intermittent sources of energy.

1.1. Structure of the Ministry of Energy

The Ministry of Energy is responsible for energy development in the country and is guided by the National Energy Policy of 2008. It is mainly in charge of policy formulation and strategic interventions to ensure the sector develops to respond to the current and projected power demand to ensue economic growth. The Ministry has its implementation agencies, that is, The Energy Regulation Board, ZESCO Ltd and the Rural Electrification Authority (REA).

ZESCO Ltd is the electricity utility company. They manage the major power generating plants in the Country and the national grid from generation, transmission to distribution. There are a number of Independent Power Producers with a wide generation mix and all of their own on-grid power generated is injected into the national grid.

The Energy Regulation Board regulates the energy sector, that is, both the power and petroleum sub sectors. They ensure security of supply of energy services and products, providing a level playing field in the sector, setting cost reflective prices and safeguarding consumer interests.

The Rural Electrification Authority (REA) was established by an act of parliament due to the need for increased efforts in rural electrification to increase electricity access. In addition, Government needed to make the utility company commercially viable as opposed to taking electricity where the returns will not match the investment. REA receives grants from the Government to implement projects in rural areas which range from grid extension, on-grid power generation plants and off-grid systems with energy source which may be hydro, solar or wind.

2.0. GEOTHERMAL ENERGY RESOURCES AND POTENTIAL IN ZAMBIA

Zambia has about 80 known hot springs across the country. The hot springs indicate the potential for possible extraction of the heat for power generation since they serve as a manifestation of the presence of geothermal energy resources in an area.

Table 2.1. Below is a list of major hot springs in Zambia and their temperatures

HOTSPRINGS IN ZAMBIA			
Area	Geothermal field	Hotspring	Temp. ℃
Northern	Northern	Kapisya	85
		Kaputa	51
		Kalaya	51
Eastern	North Luangwa	Chongo	87
		Nabwalya S.	67
	South Luangwa	Musaope	74
		chikoa	64
South Eastern	Lusaka East	Chinyunyu	61
		Chongwe	54
	Lukusashi	Musenseshi	54
		Mafwasa	65
Southern	Lochninvar	Gwisho	72
		Bwanda	94
	Kariba	Chibimbi	58
		Kariba	78.5
Western/ Copperbelt	Copperbelt	Kasho	80
	North Kafue	Lupiamanzi	73
		Lubungu	76
	South Kafue	Longola	70
	Kasempa North	Kaimbwe	52

Figure 2.1 indicates the positions of the hot springs across the Country. The ones indicated are the known ones and others are not named and Zambia being a vast Country, more could be discovered if a comprehensive study was to be conducted. Moreover, the map indicated was developed more than 25 years ago and has not been updated and temperatures require verification.

Kapisya hot spring was the first to exploit for possible generation of electricity. It is located at the west coast of Lake Tanganyika in Northern Province and the temperature of the hot spring is about 85℃. in 1986, a pilot plant power was built at Kapisya hot spring with a capacity to generate 220KW but the ground temperature of 85℃ was too low for the design temperature of the power plant. Additionally, the agreement did not include the construction of the power transmission line. The nearest grid connection point at that time was more a 100 km. The nearest population to the power plant is villages with very low power consumption potential and scattered settlements. Constructing an off-grid system for the nearby villages is therefore not economically viable. It is because of these reasons that the power plant is not functioning up to this time. This could indicate that the feasibility study for the project was poorly done and the project only benefitted the developer.

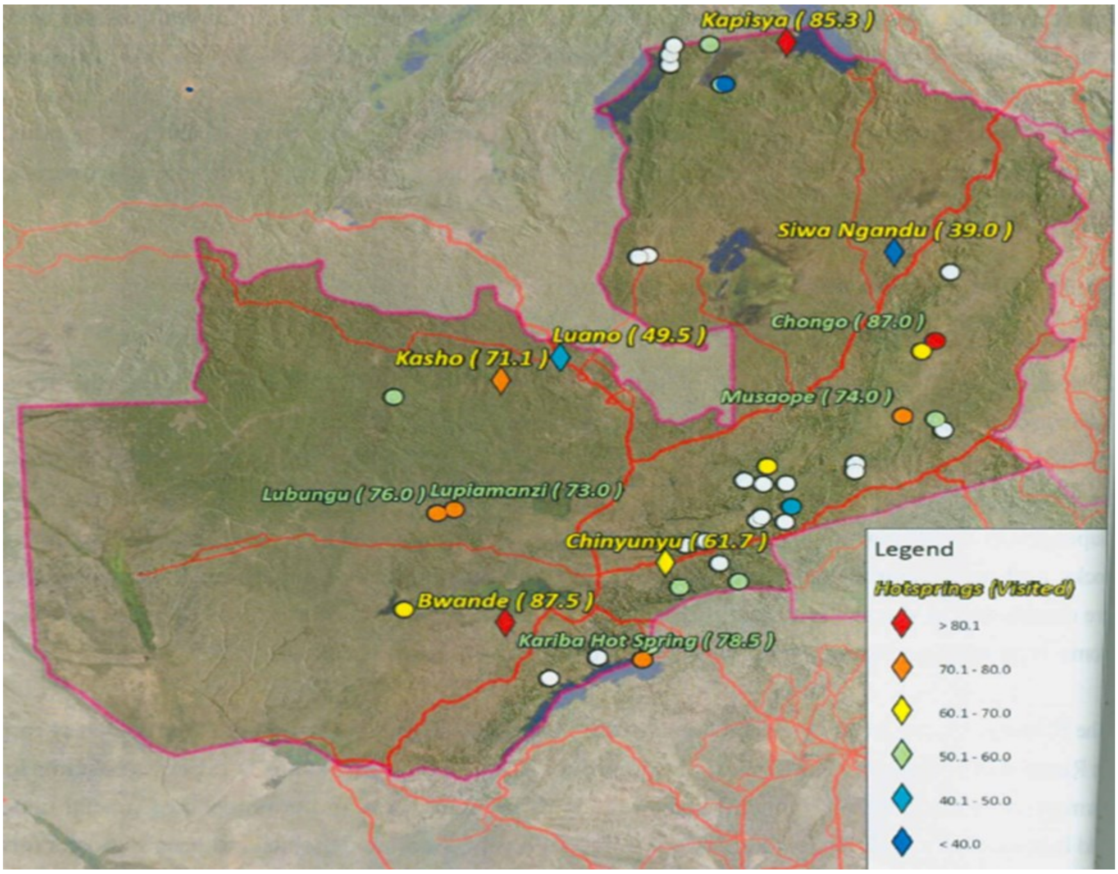

Figure 2.1: Geothermal hot springs in Zambia

However, further survey and investigations of Kapisya hot springs were done by ZESCO Ltd. with technical assistance from Kenyan Power Generating Company (KenGen) of Kenya. For every water point that was sampled, four different types of elements were analysed, including the conservative constituents Cl, B, HCO3 and F. Acidified samples were collected for the analysis of metal species (Na, K, Ca, Mg, Li, Cu, and Fe) The Kapisya geothermal field has an estimated reservoir sodium-potassium ratio and quartz temperature solute geothermometer temperatures of about 124°C (low-enthalpy resource) at that time depth of production (Omenda et al., 2007). However, further works beyond the investigation has not conducted because the report indicated a negative resource which was not viable for revamping the project.

3. GEOTHERMAL UTILIZATION

Currently, exploration drilling is going on at Bwanda and Gwisho hot springs. These hot springs lie in Lochinvar National Park in Southern Province of Zambia. Kalahari GeoEnergy Ltd, the company drilling the exploration wells estimates the potential of the geothermal resource in the area to be enough to produce in access of 50 MW of electric power. Apart from the exploration happening at Bwanda and Gwisho hot springs, there are no other hotsprings which are being exploited for possible power production. Most of the hotsprings are used as heritage sites 9 tourism purposes) and there is a small fee charged for some of them to have access. The most visited is the Chinyunyu site which has been fenced by the National Heritage of Zambia.

Apart from exploitation for possible power generation, there is an opportunity for geothermal direct use applications for most of the hotsprings because of low temperature levels as compared to sites in East Africa. The Ministry of Energy working with the Ministry of Commerce and KGE have started a deliberate programme to begin preparations for direct use application of geothermal when the KGE sets up a power plant.

The two Ministries working with other stakeholders have developed a concept paper that makes an initial case for a proposed Industrial Park and outlines value chains enterprise potential that could utilise geothermal direct heat in the industrial park in Monze. The concept is suited to the kind of life in the area which is cattle heading and crop agriculture. It further identifies possible economic sectors that could be targeted for investment in the park, outlines a financing plan and makes recommendations through a multi-year implementation plan that lists activities that need to be undertaken leading to the establishment of the proposed Industrial Park.

4. OPPORTUNITIES FOR GEOTHERMAL HEAT DIRECT APPLICATION

Some of the activities which will utilize excess heat from the geothermal power plant to be established by Kalahari GeoEnergy Limited were identified as follows:

4.1. Animal Husbandry

The key to a dairy processing would be the availability of product and the interest of the local community in the project. It is estimated that there are more than 90,000 head of traditionally managed cattle in the Monze-Namwala Lochinvar area. Little milk from these herds reaches the market as collection points are scarce. It is estimated that milk yields from traditional cattle are very low ranging from 1 to 2 liters per day from a milking cow. However, with relatively inexpensive supplements, better managed grazing and plentiful water, milk production from these traditional cows can rise to 10 liters per day from one milking cow. Assuming that 20% of herds are milking and assuming only half the milk could be collected, it is possible that there could be the basis of a viable processing industry.

4.2. Pasteurization

Geothermal brine can be used as a heating liquid for a Milk pasteurization unit either by directly use of the brine to heat up the raw milk, or by heating secondary fresh water. Pasteurization is a mild (as opposed to frying, baking or roasting) heat treatment which aims to fulfill two purposes, to remove pathogenic bacteria from foods, thereby preventing disease, and to remove spoilage (souring) bacteria to improve its keeping quality. Pasteurization can be done to various kinds of food and beverage products, such as tomato juice, honey, ice cream mix, and including milk. Each food has different temperature and time for pasteurization process.

4.3. Horticulture

The use of geothermal energy to provide controlled heating for greenhouses is being increasingly implemented globally. A good example is Kenya where significant volumes of roses and vegetables such as peppers are grown in greenhouses adjacent to and heated by the Olkaria power plants. The growing and ripening times are reduced by an average of 30%.

4.4. Aquaculture

The aim of geothermal aquaculture is to heat water to the optimum temperature for aquatic species. This involves the raising of freshwater or marine organisms in a controlled environment to enhance production rates. The geothermal water is commonly used to heat water in raceways, ponds and tanks. The water temperature depends on the species involved, ranging from 13 to 30°C. By controlling the rearing temperature the growth rate of the fish can be increased by 50 to 100%, thus increasing the number of harvests per year.

4.5. Geothermal Spa

Spas and hot baths associated with geothermal are another common application. Examples include the man-made Blue Lagoon in Iceland which has been created from the outflow of the Svartenji Geothermal power plant, and the Olkaria Spa associated with KenGen's Olkaria power plants in Kenya. These can include restaurants, accommodation and other amenities, which make them popular tourist destinations. Such a spa could be developed at Lochinvar within the proposed Industrial Park as part of the improvement of the Park for tourism purposes.

Figure 2.2: Kapisya Geothermal Plant

Figure 4.1: Nteme Milk Co-operative, 10Km North of Monze (and 35km from Lochinvar), the nearest milk collection point

Figure 4.2. Olkaria hot Spa in Kenya.

4.6. Water Filtration

The local communities draw water from drilled wells with hand pumps and hand dug scraps. Sampling suggests that those wells at Lochinvar Lodge and in the Lupiamanzi and Namulula areas are contaminated either or both by brines and pathogens. Kalahari GeoEnergy has drilled two water wells and has instituted research into possible filtration processes including slow bed filtration to remove pathogens and the future possibility of using geothermal energy either in forward osmosis or multiple effect distillation. Certainly, any commercial development will require potable water that could also be supplied to the community.

4.7. Fuel Synthesis

KGE is interested in determining the feasibility of using geothermal power for sustainable fuel synthesis, including production of hydrogen and other commercial gases by electrolysis. The fuel cell industry which uses hydrogen as a fuel is slowly gaining momentum globally. Such utilization of geothermal power would be appropriate if the plant were to be utilised as a spinning reserve to the grid during peak production by variable energy sources and so provide secondary revenue streams.

The direct use applications mentioned are not limited to the geothermal heat in Lochnivar National Park, other hotsprings can also be used for the same application. One program that could be used to develop direct use application is the Scaling up Renewable Energy Programme (SREP). The program has the Implementation Plan (IP) which recognizes geothermal direct application as one important use of renewable energy for a number of economic activities stated in the preceding section.

5.0. DISCUSSION

The obvious reason why geothermal has not been exploited is the high cost and a perception of low temperature hotsprings. It is perceived that the failure of the Kapisya Geothermal Plant has affected possible investment which could have come if the plant was successful. Another reason is the availability of less risky and low investment power generating options.

Since the KGE exploration is the first exploration being conducted after the Kapisya, it is difficult to determine the tariff that can be reached at the point of power production. The tariff being charged for hydro power being produced is not cost reflective, comparatively cheap in the Southern African region. And the recently solar power plants that have been developed under the Scaling solar project are US Cents 6.015/kWh for the 54MW Bangweulu project and US Cents 7.84/kWh for the 34MW Ngonye Solar project. Another solar program called the Global Energy Feed in Tariff (GETFiT) with a total of 120MW segregated into 20MW each has produced even lower tariffs of US Cents 4.99 /kWh. The tariff for geothermal energy would need to be specially categorized as it may not beat the tariffs stated but has way more bigger capacity factor and many other advantages that the solar power plants. In view of the above, the tariff that will be arrived at would need to put into consideration the advantages of geothermal energy as compared to other renewable energies particularly solar.

The National Energy Policy recognizes geothermal as one of the renewable energy which can be used to be increase the national energy mix. Other programs are the SREP and the Sustainable Energy for all but all are not specific to geothermal energy. The policy and regulatory framework is therefore not adequate to support the nature of geothermal exploration. It is however expected that success of the KGE project would bring considerable change and consideration to the policy intervention so that it is adequate to support the risk associated with geothermal exploration.

6.0. CONCLUSION

The interest that geothermal energy keeps attracting in Zambia is positive for its development. Other stakeholders are getting involved and ready to explore opportunities beyond power generation.

It is envisaged that the Lochinvar National park will change significantly because of the geothermal activities in the park. As it stands, there has been excessive poaching in the park and virtually no game still exists. Looking at the Kenyan situation in Olkaria region, the number of animals increased after the power started operating due to increased security around the park. We are also hoping for a similar situation. The benefits of geothermal will therefore extend to tourism.

In general, Zambia has demonstrated the need to explore geothermal energy through its inclusion in the SREP IP and the support being rendered to KGE. The establishment of the power plant may attract more investment in other geothermal fields in the Country thereby creating benefits beyond stable generated power.

7.0. ACKNOWLEDGEMENTS

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Table 1. Present and planned production of electricity

	Geothermal		Fossil Fuels		Hydro		Nuclear		Other Renewables (specify)		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	Capacity MWe	Gross Prod. GWh/yr
In operation in December 2019	0	0	358	1,409,238	2,469	11,477,557	0	0	88	154,176	2,881	13,040,971
Under construction in December 2019												
Funds committed, but not yet under construction in December 2019												
Estimated total projected use by 2020												

Table 2. Utilization of geothermal energy for electric power generation as of 31 December 2019.

N = Not operating (temporary), R = Retired. Otherwise leave blank if presently operating.									
1F = Single Flash B = Binary (Rankine Cycle)									
2F = Double Flash H = Hybrid (explain)									
3F = Triple Flash O = Other (please specify)									
D = Dry Steam									
Electrical installed capacity in 2019									
Electrical capacity actually up and running in 2019									
Locality	Power Plant Name	Year Commissioned	No. of Units	Status[1)]	Type of Unit[2)]	Total Installed Capacity	Total Running Capacity	Annual Energy Produced 2019	Total under Constr. or Planned
						MWe[3)]	MWe[4)]	GWh/yr	MWe
Total									

Table 3. Utilization of geothermal energy for direct heat as of 31 December 2019 (other than heat pumps).

[1] I = Industrial process heat
C = Air conditioning (cooling)
A = Agricultural drying (grain, fruit, vegetables)
F = Fish farming
K = Animal farming
S = Snow melting
H = Individual space heating (other than heat pumps)
D = District heating (other than heat pumps)
B = Bathing and swimming (including balneology)
G = Greenhouse and soil heating
O = Other (please specify by footnote)

[2] Enthalpy information is given only if there is steam or two-pha

[3] Capacity (MWt) = Max. flow rate (kg/s)[inlet temp. (°C) - outlet temp. (°C)] x 0.004 ($MW = 10^6$ W)
or = Max. flow rate (kg/s)[inlet enthalpy (kJ/kg) - outlet enthalpy (kJ/kg)] x 0.001

[4] Energy use (TJ/yr) = Ave. flow rate (kg/s) x [inlet temp. (°C) - outlet temp. (°C)] x 0. ($TJ = 10^{12}$ J)
or = Ave. flow rate (kg/s) x [inlet enthalpy (kJ/kg) - outlet enthalpy (kJ/kg)] x 0.0

[5] Capacity factor = [Annual Energy Use (TJ/yr)/Capacity (MWt)] x 0.031
Note: the capacity factor must be less than or equal to 1.00 and is usually less,
since projects do not operate at 100% of capacity all

Note: please report all numbers to three significant figures.

			Maximum Utilization					Capacity[3]	Annual Utilization		
Locality		Type[1]	Flow Rate	Temperature (°C)		Enthalpy[2] (kJ/kg)			Ave. Flow	Energy[4]	Capacity
			(kg/s)	Inlet	Outlet	Inlet	Outlet	(MWt)	(kg/s)	(TJ/yr)	Factor[5]
Northern	Kapisya			85							
	Kaputa			51							
	Kalaya			51							
North Luangwa	Chongo			87							
	Nabwalya S.			67							
South luangwa	Musaope			74							
	chikoa			64							
Lusaka East	Chinyunyu			61							
	Chongwe			54							
Lukusashi	Musenseshi			54							
	Mafwasa			65							
Lochninvar	Gwisho			72							
	Bwanda			94							
Kariba	Chibimbi			58							
	Kariba			78.5							
Copperbelt	Kasho			80							
North Kafue	Lupiamanzi			73							
	Lubungu			76							
South Kafue	Longola			70							
Kasempa North	Kaimbwe			52							
TOTAL											

Table 4. Geothermal (ground-source) heat pumps as of 31 December 2019.

This table should report thermal energy used (i.e. energy removed from the ground or water) and report separately heat rejected to the ground or water in the cooling mode. Cooling energy numbers will be used to

rejected to the ground in the cooling mode as this reduces the effect of global warming.

1) Report the average ground temperature for ground-coupled units or average well water or lake water temperature for water-source heat pumps

2) Report type of installation as follows: (TJ = 1012 J)

V = vertical ground coupled

H = horizontal ground coupled

W = water source (well or lake water)

O = others (please describe)

3) Report the equivalent full load operating hours per year, or = capacity factor x 8760

4) Thermal energy (TJ/yr) = flow rate in loop (kg/s) x [(inlet temp. (oC) - outlet temp. (oC)] x 0.1319

5) or = rated output energy (kJ/hr) x [(COP - 1)/COP] x equivalent full load hours/yr

6) Cooling energy = rated output energy (kJ/hr) x [(EER - 1)/EER] x equivalent full load hours/yr

Note: please report all numbers to three significant figures

Due to room limitation, locality can be by regions within the country.

Locality		Ground or Water Temp.	Typical Heat Pump Rating or Capacity	Number of Units	Type[2]	COP[3]	Heating Equivalent Full Load	Thermal Energy Used[5]	Cooling Energy[6]
		(°C)[1]	(kW)				Hr/Year[4]	(TJ/yr)	(TJ/yr)
Northern	Kapisya	85							
	Kaputa	51							
	Kalaya	51							
North Luangwa	Chongo	87							
	Nabwalya S.	67							
South luangwa	Musaope	74							
	chikoa	64							
Lusaka East	Chinyunyu	61							
	Chongwe	54							
Lukusashi	Musenseshi	54							
	Mafwasa	65							
Lochninvar	Gwisho	72							
	Bwanda	94							
Kariba	Chibimbi	58							
	Kariba	78.5							
Copperbelt	Kasho	80							
North Kafue	Lupiamanzi	73							
	Lubungu	76							
South Kafue	Longola	70							
Kasempa North	Kaimbwe	52							

Table 5. Summary table of geothermal direct heat uses as of 31 December 2019.

1) Installed Capacity (thermal power) (MWt) = Max. flow rate (kg/s) x [inlet temp. (°C) - outlet temp. (°C)] x 0.004184
or = Max. flow rate (kg/s) x [inlet enthalpy (kJ/kg) - outlet enthalpy (kJ/kg)] x 0.001
2) Annual Energy Use (TJ/yr) = Ave. flow rate (kg/s) x [inlet temp. (°C) - outlet temp. (°C)] x 0.1319 (TJ = 1012 J)
or = Ave. flow rate (kg/s) x [inlet enthalpy (kJ/kg) - outlet enthalpy (kJ/kg) x 0.03154
3) Capacity Factor = [Annual Energy Use (TJ/yr)/Capacity (MWt)] x 0.03171
Note: the capacity factor must be less than or equal to 1.00 and is usually less, since projects do not operate at 100% capacity all year
4) Other than heat pumps
5) Includes drying or dehydration of grains, fruits and vegetables
6) Excludes agricultural drying and dehydration
7) Includes balneology

Use	Installed Capacity[1]	Annual Energy Use[2]	Capacity Factor[3]
	(MWt)	(TJ/yr = 10^{12} J/yr)	
Individual Space Heating[4]			
District Heating [4]			
Air Conditioning (Cooling)			
Greenhouse Heating			
Fish Farming			
Animal Farming			
Agricultural Drying[5]			
Industrial Process Heat[6]			
Snow Melting			
Bathing and Swimming[7]			
Other Uses (specify)			
Subtotal			
Geothermal Heat Pumps			
TOTAL			

Table 6. Wells drilled for electrical, direct and combined use of geothermal resources from January 1, 2015 to December 31, 2019 (excluding heat pump wells).

1) Include thermal gradient wells, but not ones less than 100 m deep

Purpose	Wellhead Temperature	Number of Wells Drilled				Total Depth (km)
		Electric Power	Direct Use	Combined	Other (specify)	
Exploration[1]	(all)					
Production	>150° C					
	150-100° C					
	<100° C					
Injection	(all)					
Total						

Table 7. Allocation of professional personnel to geothermal activities (Restricted to personnel with University degrees).

(1) Government
(2) Public Utilities
(3) Universities
(4) Paid Foreign Consultants
(5) Contributed Through Foreign Aid Programs
(6) Private Industry

Year	Professional Person-Years of Effort					
	-1	-2	-3	-4	-5	-6
2015	5	3				
2016	5	3				
2017	5	3				
2018	6	3				
2019	6					
Total	6					

Table 8. Total investments in geothermal in (2019) US$

Period	Research & Development Incl. Surface Explor. & Exploration Drilling	Field Development Including Production Drilling & Surface Equipment	Utilization		Funding Type	
			Direct	Electrical	Private	Public
	Million US$	Million US$	Million US$	Million US$	%	%
1995-1999						
2000-2004						
2005-2009						
2010-2014						
2015-2019						