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Promoting the Economic Potential of Geothermal Direct Uses as a Catalyst for Attracting Investment in Geothermal Exploitation in Africa

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ABSTRACT

Africa is endowed with vast quantities of geothermal resources because of the presence of the East African Rift that cuts the continent from North to South and presents a source of heat for geothermal resources. The pace of exploitation of geothermal resources in Africa has been very slow over the years. One of the reasons for this slow pace is the single focus on geothermal exploitation for electricity generation. Geothermal resources for electricity generation require mainly medium to high temperature resources. Unfortunately, most geothermal resources in Africa and globally are of low temperature and have not been given attention in geothermal exploitation. This should not be the case because geothermal resources of low to high temperatures acan be utilized for commercial benefits through direct use applications. This paper proposes the promotion of the economic potential of geothermal direct uses to act as a catalyst for accelerating geothermal exploitation in many African countries that have geothermal resource potential.

1 INTRODUCTION

Africa is endowed with vast geothermal resources which are mainly located along the East African Rift System. A total of 14 countries in Africa have proven geothermal potential. The electricity generation potential of the geothermal resources in Africa is large with data showing that Kenya alone has electric generation potential of over 10,000MWe (Peter Omenda, 2010). Besides potential for electricity generation, geothermal resources have much more potential in direct use applications. Besides Kenya, the other African countries that have proven geothermal potential include Eritrea, Djibouti, Ethiopia, Sudan, Uganda, Rwanda, Democratic Republic of Congo (DRC), Tanzania, Zambia and Malawi, all lying on the African rift system. Other African countries outside the African rift such as Algeria, Tunisia, South Africa, Eswatini, Morocco, Nigeria and Egypt have thermal springs that can be exploited for direct utilization. Only a small portion of this geothermal potential has been exploited, mainly focusing on electricity generation of which about 985 MWe of electricity is produced by Kenya and 7.3 MWe by Ethiopia (Solomon et al, 2021). Despite the big economic potential for geothermal direct uses, there has been little effort towards developing direct uses of geothermal energy for economic purposes.

Geothermal energy has many direct uses of economic values that include Space heating and cooling, Snow melting in winter affected countries, Recreation purposes, Spa and Balneology, Green house heating and Drying of agricultural produce, Mineral and gas extraction and Industrial heating processes. These direct uses can generate substantial revenues for investors. In Africa, the geothermal direct use opportunities that are of economic values include; Space heating/cooling, Green house heating and fumigation, Drying of agricultural produce and Agri-processing applications, Mineral extraction and Industrial heating processes. Until now, there has been limited attempts to exploit geothermal direct use potential in Africa at economic levels. A few African countries such as Kenya, Tanzania, Tunisia and Uganda have made limited efforts of exploiting geothermal direct uses albeit in small scales. The geothermal direct uses that have been tried in Africa include; drying of farm produce, greenhouse heating and fumigation, Recreation and Mineral extraction.

This paper discusses the geothermal resources available in Africa and their potential for direct uses. Further, the paper presents the economic potential of the direct use applications and how their exploitation can serve as a catalyst for attracting investment in Geothermal utilization in Africa. A simple cost benefit analysis of the economic potential of the direct use opportunities is done using reasonable cost and revenue estimates. The result of the cost benefit analysis showed that geothermal direct uses have high potential for positive revenue earnings for investors. The paper recommends detailed studies to establish the nature and quantities of geothermal resources in African countries and screening of the direct use opportunities to enable the best

opportunities to proceed to implementation. The paper demonstrates that promoting geothermal direct uses will incentivize investors and act as a catalyst for attract investment in Geothermal exploitation in Africa.

2 GEOTHERMAL POTENTIAL IN AFRICA AND STATUS OF EXPLOITATION

There are many geothermal prospects that have been mapped along the African rift system as seen through various types of surface manifestations. About 10 countries in the eastern part of Africa have proven geothermal potential (Figure 2). Besides the countries located in the African rift systems, there are other countries outside the rift system which have signs of geothermal potential as seen by elevated ground temperatures (Figure 1). These countries include Egypt, Algeria, Tunisia, Morocco, South Africa and Eswatini among others. The geothermal potential of the African countries is discussed below.

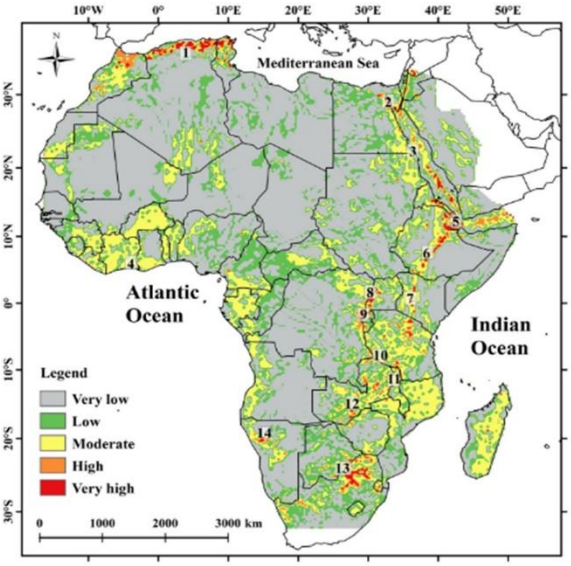


Figure 1: Satellite map of Africa showing ground temperature distribution

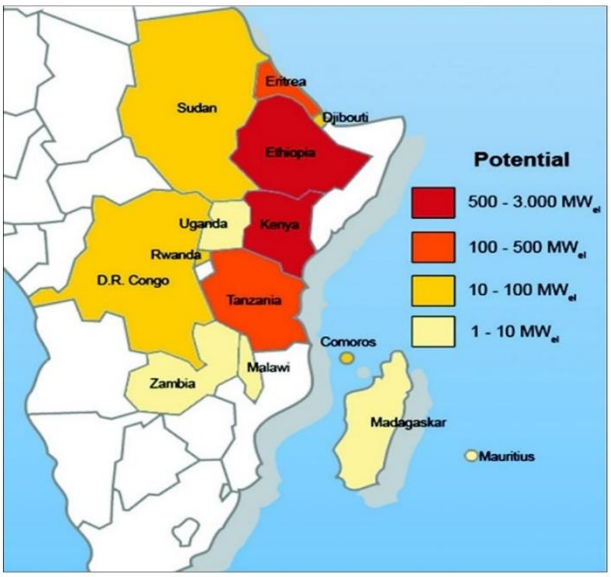


Figure 2: Countries in the eastern Africa with proven geothermal potential

2.1 Geothermal potential in Kenya

Kenya is the leader in geothermal exploitation and utilization in Africa. There are fourteen (14) geothermal prospects that have been mapped in Kenya, mostly located in the East African rift system (Figure 3). Successful drilling has been carried out in six of the prospects with three of them already under power production supporting about 985MWe in electricity production. Surface exploration that has been conducted in the geothermal prospects in Kenya estimates the country's potential for electricity production at over 10,000MWe (Omenda P, 2010). In all the drilled geothermal prospects in Kenya, it has been shown that most of them produce two-phase geothermal fluids with high to low temperatures and that the fluids contain varying quantities of minerals and gases which offer significant potential for direct uses and mineral extraction.

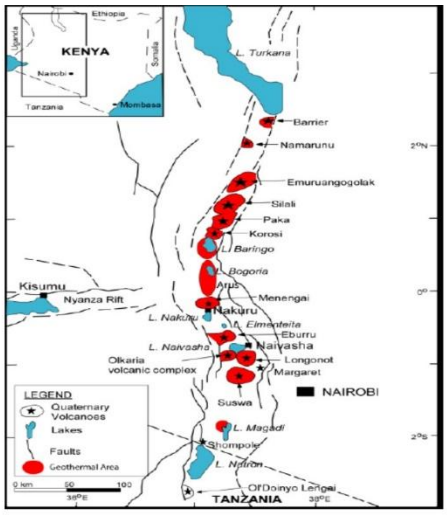


Figure 3: Geothermal Prospects along the Kenyan rift system

2.2 Geothermal potential in Ethiopia

Ethiopia comes second to Kenya in exploitation of its geothermal resources. Available information shows that there are about 25 geothermal prospects that have been mapped in Ethiopia (Solomon K. et al, 2021) with an estimated electrical potential of about 15,000MWe. The prospects extend from North to South of the country along the Ethiopian rift system (Figure 4). Of the 25 prospects in the country, Aluto-Langano geothermal field has been developed to power generation and

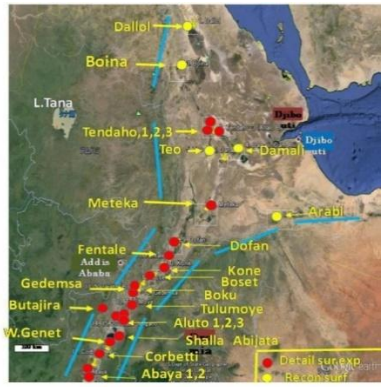


Figure 4: Map of geothermal prospects in Ethiopia.

additional wells have been recently drilled ready for additional power capacity. Drilling has also been done in Tulu Moye prospect and plans for drilling in the Corbetti and Tendaho prospects are ongoing.

Reconnaissance and surface exploration has been conducted in all the geothermal prospects in the country. The geothermal prospects that have been mapped in Ethiopia have different surface manifestations that include thermal pools, hot springs, fumaroles, geysers, steaming grounds, steam vents among others. The wells drilled in the Aluto-Langano field produce two-phase geothermal fluids of low to high temperatures and some of the fluids are rich in carbon dioxide (CO_2) gases and other minerals. The geothermal fluids and the geothermal manifestations are great resources for direct use applications. The high CO_2 encountered in the fluids of Aluto-Langano wells could present a potential of CO_2 extraction and use in the beverages industry, among other direct uses.

2.1 Geothermal potential in Djibouti

Djibouti is third in Africa after Kenya and Ethiopia in efforts of exploiting its geothermal potential. Information available show that Djibouti has 7 geothermal prospects that have been mapped (Figure 5) with an estimated electric potential of 1,000MWe.

Initial exploration and drilling around the lake Asal prospect was conducted in the 1970s and proved an existence of high temperature resource which produced high temperature geothermal fluids but with very high salinity which limited their utilization. Further exploration drilling was conducted in the 1980s in the Hanle-Gaggade area which intercepted geothermal resources of low temperatures (Aboulkader and Fouad, 2012). In 2023, one shallow well was drilled in the Galla Koma region of the Hanle prospect but although the well encountered high temperatures, it lacked permeability. Available information show that plans to drill more exploration wells in the Hanle area are currently ongoing.

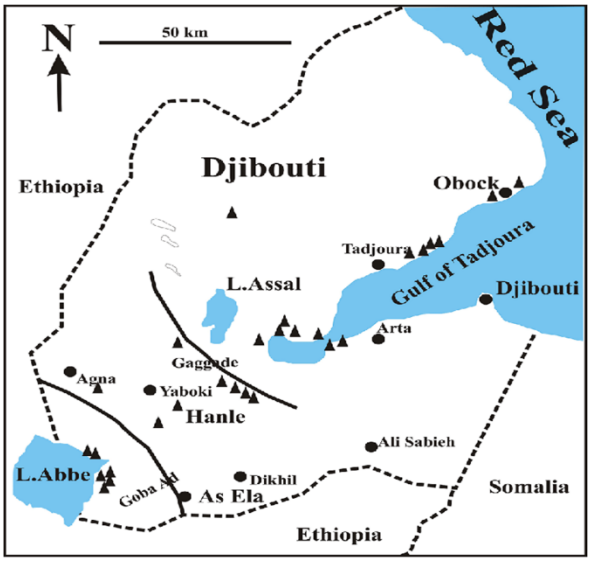


Figure 5: Map of geothermal prospects in Djibouti

2.2 Geothermal potential in Uganda

The western branch of the east African rift traverses the western side of Uganda and is the reason for the geothermal potential in the country. There are 28 geothermal prospects mapped in Uganda but only 4 have been studied by surface exploration and some temperature gradient wells drilled (Ariya, 2021).

Available information show that preliminary studies estimate the geothermal potential of Uganda to be in the range of 450-1500MW in electricity generation. Preliminary studies show that the geothermal resources in Uganda are mainly formed in a sedimentary, fracture dominated system as opposed to a magmatic system and its geothermal fluids can have high mineral content that may be suitable for mineral recovery that include salt, silica, zinc, lithium, manganese and a range of other rare Earth elements. Salt is presently mined at the Katwe

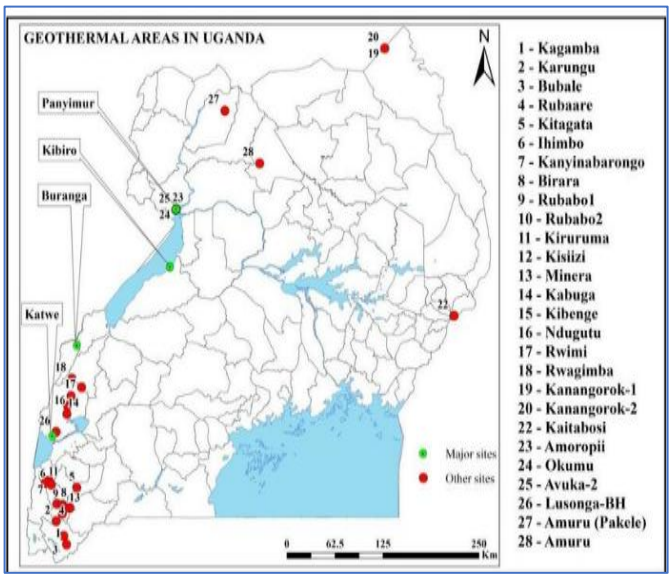


Figure 6: Map of geothermal prospects in Uganda

prospect. The abundance of low temperature geothermal resources in Uganda is a good opportunity for direct uses.

2.3 Geothermal Potential in Tanzania

Tanzania has the two arms of the African Rift System cutting through the country which provides potential for geothermal resources. Although Tanzania has not reached the geothermal power production stage, a lot of efforts have been put to realize geothermal utilization in the country. Currently, slim hole drilling is ongoing at Ngozi geothermal prospect as part of exploration of the field.

Available reports indicate that Tanzania has mapped 27 geothermal prospects in four regions of the country namely the South-Western and Northern volcanic region, coastal sedimentary basins, central part of the country and the Western rift systems (Figure 7). The geothermal electricity potential of Tanzania is estimated at 5,000MWe comprising of low to high temperature resources (Shakiru, 2021). Online information show that several geothermal direct use technologies including drying of crops and vegetables, fish drying, hatchery, milk pasteurization, tea processing, balneotherapy and greenhouse heating are being considered for socio-economic use at Kiejo-Mbaka and Songwe geothermal prospects (Shakiru, 2021). This demonstrates that there are abundant opportunities for economic utilization of geothermal direct uses in Tanzania which can be used as a catalyst to open up investment in geothermal exploitation in the country.

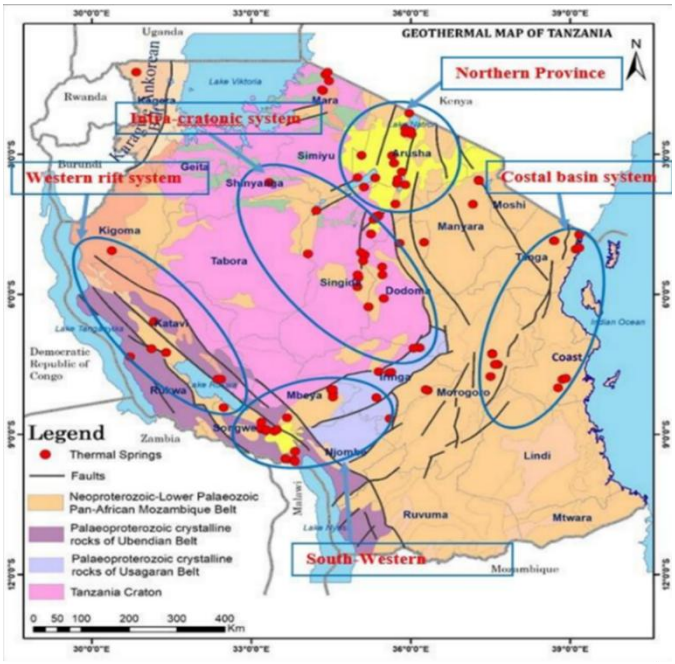


Figure 7: Map of geothermal prospects in Tanzania

2.4 Geothermal Potential in Other African Countries

Other African countries that have proven geothermal potential include Tunisia, Morocco, Algeria, Sudan, Democratic Republic of Congo (DRC), Rwanda, Zambia, Eswatini, South Africa and Malawi. Whereas the geothermal potential in Sudan, Democratic Republic of Congo (DRC), Rwanda, Zambia and Malawi is associated with the African rift system, the ones in Eswatini, South Africa, Tunisia, Morocco and Algeria related to Continental Intercalaire aquifers. The geothermal potential in these countries is described below;

In Tunisia, geothermal energy is mainly used for direct use applications because of the low temperature of the resources, which are localized in the southern part of the country (Mouldi, 2010). The established uses include Oasis irrigation, greenhouse heating and cooling, swimming, and bathing among other direct uses. In Sudan, reconnaissance studies have shown that the country has geothermal potential as manifested by presence of hot springs in several parts of the country. Available information estimates the geothermal potential of Sudan at 400 MWe of power generation. So far, there are 5 sites with geothermal potential in the country with some gradient wells and oil wells registering high temperatures. In the DRC, the western arm of the African rift traverses the eastern sector of the country and has several active volcanoes with geothermal systems present. Despite the limited research on the geothermal potential in the country, the presence of volcanic systems signifies presence of heat sources more so in the Eastern part (Goma and Environs). In Rwanda, significant exploration for geothermal resources have been undertaken including drilling of two deep wells which did not produce. However available information shows that there are geothermal manifestations in the form of hot springs and distinct geological features with three main geothermal prospect areas having been demarcated for further exploration.

To the southern part of Africa, information show that Zambia, Malawi and Eswatini have geothermal potential manifested by widespread occurrence of hot springs. In Zambia, efforts to harness energy from the hot springs and shallow boreholes culminated in installation of a pilot binary power plant at Kapisya which was not successful. Further work is being undertaken towards realization of geothermal energy use in the country. In Malawi, indicators of geothermal resources are mainly the presence of hot springs which are linked to the rift faults. Detailed research has not been conducted and therefore the country's geothermal potential is still

uncertain. In Eswatini, recent scientific exploration showed that the country has potential for low temperature geothermal resources which are being considered.

Other Africa countries that have manifestations of geothermal potential include Algeria, Egypt, Morrocco, Comoros and Mozambique.

3 OPPORTUNITIES FOR INVESTMENT IN GEOTHERMAL DIRECT USES IN AFRICA

3.1 Introduction to Geothermal Direct Uses

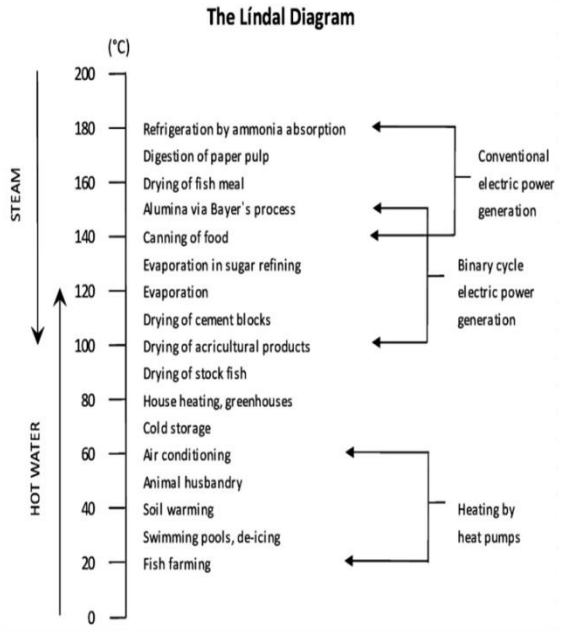


Figure 8: Lindal diagram showing possible direct use applications at various temperatures.

Geothermal direct use refers to the application of geothermal energy for heating, extraction of gases and minerals, recreation and medicinal uses and other uses besides generation of electricity.

Most geothermal direct uses utilize resources of low to moderate temperatures (20 - 120°C) which are abundant in many parts of the world. Low to moderate temperature resources have been used for many years for bathing, heating, water harvesting, mineral extraction and greenhouse farming among many. Direct use of moderate to high temperature resources have also been seen in industrial heating, hot water production, drying of farm produce and milk pasteurization. In recent years, extraction of minerals from geothermal fluids have shown commercial viability.

The type of use of a geothermal resource depends on the resource temperature and the chemistry of the fluids. The Lindal diagram (Figure 8) shows how use of geothermal resources is classified based on the resource temperatures.

3.2 Geothermal resources available for direct uses in Africa

Geothermal resources in its entirety have potential for direct uses. Below is a description of the geothermal resources found across the African continent and the potential direct uses of the resources.

3.2.1 Geothermal manifestations and related geological features

The areas in Africa with geothermal potential are also endowed with interesting surface manifestations and associated geological features which can be utilized for eco-tourism and educational purposes. The manifestations include hot springs, fumaroles, geysers, steaming grounds, ground alterations and many others. The associated geological features include volcanoes, caldera systems, rift systems, fissures, gorges among others. Available information show that these features are found in many regions of Africa that have geothermal potential. In Kenya, surface manifestations like steaming grounds, hot springs, altered grounds, rift



Figure 9: Longonot mountain in Kenya, a typical volcanic mountain in geothermal rich area



Figure 10: Image of a typical geothermal hot spring popular for tourism

escarpments, fissures are found in all parts with geothermal resources. This is similarly abundant in other African countries like Ethiopia, Tanzania and Uganda. In Eritrea and Djibouti, features such as steam vents are common. On the same note, geological features associated with geothermal rich areas are common in all prospects. The photos below show some of the natural manifestations and geological features found in Africa.

3.2.2 Geothermal steam



Figure 11: Geothermal steam from a discharging well

Most geothermal prospects in Africa where drilling has been done have confirmed significant steam production when the wells were tested. Geothermal steam is a good resource for direct use applications such as Industrial heating, Space heating and cooling, Drying of farm produce, green house heating, Production of hot water for domestic uses and Agri-processing applications among others.

The geothermal steam can also be used to produce pure steam for processes that require high quality steam such as food and medical applications.

3.2.3 Geothermal brine

Most geothermal prospects in Africa have proven significant brine production when the wells were tested. Geothermal brine is a good resource for direct use applications such as heating, recreation, balneology, mineral extraction among others.

3.2.4 Carbon dioxide (CO_2) gas

Geothermal steam in some of the geothermal prospects in Africa contain high levels of CO_2 gases which can be extracted for commercial uses. CO_2 gases have high demand for industrial applications and extracting the gases from geothermal steam presents profitable investment opportunities. The prospects in Aluto in Ethiopia and part of Olkaria in Kenya have shown some high levels of CO_2 in the steam. This is likely to be replicated in most geothermal prospects especially those lying along the African rift systems. Table 1 below shows sample chemical composition for geothermal fluids in Kenya, Uganda, Tanzania and Ethiopia. The CO_2 from the sample of Kenya shows high values that can be extracted at commercial scale.

Table 1. Typical chemical composition of fluids from different geothermal resources

Country	B (ppm)	SO_4 (ppm)	Cl (ppm)	CO_2 (ppm)	F (ppm)	H_2S (ppm)	SiO_2 (ppm)	Fe (ppm)	Ca (ppm)	Li (ppm)	Na (ppm)	K (ppm)	Mg (ppm)	HCO_3 (ppm)
Sample of 2-phase well fluids in Kenya	0.258	225.6	385	560.34	142.08	0.408	592	1.738	0.454	2.366	585	188.4	0.49	319.4
	0.349	236.7	420	547.58	159.39	0.34	581	1.36	1.027	2.476	603.8	186.1	0.712	
	0.544	238.8	420	371.8	166.67	0.34	538	1.507	0.803	2.375	611.4	192.9	0.706	
Sample of 3 hot springs - Uganda	14.8	3222	3133				70	0.02	6.24	1.2	4716	166	1.94	2850
	18.1	4186	4019				77	0.02	6.55	1.51	5991	218	1.97	3630
	17.2	3842	3735				76	0.91	7.01	1.41	5561	199	1.97	3360
Sample of 3 hot springs - Tanzania		160	185		7		85		49		790	102	19	1990
		255	400		3		151		54		1240	60	34	2600
		260	220		2		150		63		1330	74	19	3010
Sample of 2-phase well fluids - Ethiopia		26	514		74		899		0.1		1070	235	0.1	1642
		177	787		75		907		0.1		1170	303	0.1	1423
		23	514		73		936		0.1		1000	228	0.1	1464

3.2.5 Valuable minerals

Geothermal brine in most prospects in Africa contain high levels of minerals which can be extracted for commercial purposes. Some of the minerals in brine like Lithium and Silica have high commercial values in the market and this presents opportunities for commercial extraction. The concentrations of these minerals vary from one field to another, and analysis will need to be done to guide decisions for extraction. Samples of fluid chemistry of some wells in Olkaria - Kenya and Aluto - Ethiopia (Meseret and Kibret, 2001) and from some hot springs in Uganda and Tanzania (Hochstein et al, 2000) shows presence of varying quantities of valuable minerals such as Silica, Lithium, Sodium and potassium in the fluids (Table 1).

3.3 Investment Opportunities in Geothermal Direct Uses in Africa

The geothermal resources available for direct uses in Africa offer wide opportunities for investment in various commercial applications. The potential investment opportunities are discussed below;

3.3.1 Recreational Facilities

Geothermal steam and brine can be used for commercial recreational activities such as Geothermal Spas, Balneology, Saunas and Steam baths. Most of the geothermal prospects in Africa produce or have potential to produce geothermal fluids that are suitable for recreational applications such as silica and sulfur rich brine. Investors can be incentivized to set up commercial recreation facilities in areas that have geothermal resources.

Examples of recreation facilities that have been setup in Africa include Lake Bogoria and Lake Magadi in Kenya, Songwe and Ngozi in Tanzania where investors have set up recreation facilities using geothermal hot water. In Olkaria, Kenya, and in Songwe, Tanzania, geothermal spas have been set up (Figure 12 and 13) and attract many visitors annually which generate income for the investors and provides returns on investment and profits. Such investments can be set up in most geothermal rich areas in Africa which will spur development of the geothermal resources.



Figure 12: Photo of Songwe Geothermal Spa, Tanzania



Figure 13: Photo of Olkaria Geothermal Spa, Kenya

Table 2 below is a high-level estimation of potential return on investment from a typical geothermal Spa like that of Olkaria.

Table 2: High level estimation of potential return on investment from a geothermal Spa

Recreation facility	Estimated investment USD	Annual O&M costs USD	Amortized annual cost (Investment and O&M	Estimate annual no of customers	Charges per customer USD	Annual revenues USD	Simple annual return on investment (25 yrs economic life) USD
Olkaria Geothermal Spa	600,000	150,000		20,000	15	300,000	46,000

3.1.1 Heating and production of hot water

Geothermal resources in Africa have potential for direct heating purposes and can also be used to heat fresh water to produce hot water for domestic uses, in industries, hospitality facilities and heated swimming pools among other uses. Some parts of Africa are fairly cold in some periods of the year and demand for hot water is viable for hospitality and domestic uses. In water deficit parts of the continent, geothermal resources can be used as a source of water for domestic and agricultural uses. In Tunisia for example, geothermal hot springs and boreholes are used to provide water for domestic uses and for irrigation purposes considering that the country is water deficit. In some parts of Kenya, locals use basic methods of condensing geothermal steam vents to collect water for their domestic uses. Most homes and hotels in geothermal rich areas in Africa still use the electric heated showers for providing hot water for bathing which is not only costly but also risky. Majority of swimming pools in Africa are rarely utilized because of the cold water.



Figure 14: Photo showing hotels and resorts around Olkaria Geothermal area

Considering the existing demand for hot water in vicinities of most geothermal resources, there is a commercial opportunity for investing in production of hot water using geothermal heat. Many geothermal resources in Africa are located in areas rich in hospitality facilities, domestic and industries that would need hot water. In Olkaria geothermal field in Kenya, there are many hotels and greenhouses in the neighborhood that provide a ready market for hot water (Figure 14). In such a case, investors can partner with the geothermal power operators to utilize the geothermal brine and steam to generate fresh hot water for distribution to the nearby homes, businesses, industries, greenhouses and hotels where needed. This will require creating appropriate regulations to govern production and sale of hot water. There is a high potential of attaining good returns from such an investment.

3.1.2 Green-house applications

Geothermal fluids have been widely used in green-house applications in some parts of Africa for long. In Kenya, geothermal brine and steam is currently used to heat and fumigate greenhouses near Olkaria geothermal field and the CO_2 from geothermal steam is also used to enrich the plants in the greenhouses. In Tunisia, reports show that the geothermal heat is utilized for heating greenhouses during cold seasons and cooling them in hot seasons (Figure 15) and is also used as source of water for irrigating the greenhouses (Ben Mohamed, 2010). In Tanzania, information show that some pilot applications of geothermal heat for green house heating have been done in the Songwe geothermal prospect.



Figure 15: Photo showing geothermal heated greenhouse in Tunisia (Mouldi, 2010)

The use of geothermal resources for green house heating and cooling are good investment opportunities in Africa. Available information shows that heating of greenhouses serves not only at providing an optimal temperature for crop growth but also helps to fumigate them and thus significantly reduce the need for use of chemicals to control pests and fungicides. Similarly, the use of geothermal CO_2 helps to accelerate plant growth and reduces dependence on artificial fertilizers.

When looked at from an economic perspective, there are great investment opportunities in geothermal greenhouse applications in Africa. According to a publication by IRENA (Geothermal Agri-food Value Chain 2022), Geothermal heating is applied in greenhouses mainly to produce flowers, fruits and vegetables on a large scale, making food available throughout the year. The publication further explains that using geothermal energy in greenhouse heating improves productivity of the greenhouses, reduces operational costs and increases profitability. In these applications, investors in geothermal heating applications can partner with greenhouses farmers and geothermal power developers so that they can tap the waste heat from the geothermal fields and supply the greenhouse farmers thus generating their own revenues.

3.1.3 Mineral extraction



Figure 16: Photo showing salt production from Katwe geothermal prospect, Uganda (Bahati, ArGeo 2008)

Geothermal brine contain significant quantities of valuable minerals that can be extracted for commercial uses. These minerals include Silica, Manganese, Lithium, Sodium, Carbonates and Chlorides among others (Table 1). Extraction of these minerals from brine has promised to be viable investment and have attracted investors in some parts of the world. In the USA, studies of brine from the Salton Sea geothermal have confirmed commercial quantities of lithium (U.S. Department of Energy online publication, Nov 2023). In Kenya, feasibility studies for extraction of Silica and Lithium from brine at Olkaria has been conducted with a view of piloting the processes. In Uganda, extraction of Sodium Chloride (salt) from the hot springs is being done at the Kibiro and Katwe prospects (Figure 16).

Given that the geothermal prospects in Africa have been proven to contain reasonable quantities of valuable minerals, commercial mineral extraction from the resources is a proven viable investment opportunity. In this arrangement, investors can be incentivized to set up mineral extraction processes alongside the power generation and other uses of the geothermal resources, to utilize the waste fluids in extracting the valuable minerals.

3.1.4 Agri-processing applications

The heat contained in geothermal fluids can be used in Agri-processing applications such as drying of agricultural products such as fruits, vegetables and cereals. The heat can also be used in milk pasteurization and poultry hatching among others. Many geothermal resources in Africa are found in agriculturally rich areas and as a result demand for heat applications is high. There is a big market for dried fruits and vegetables globally and the African countries that are rich in geothermal resources are also great producers of farm produces like cereals, fruits and vegetables. Most of these farm products go to waste annually due to peak production leading to food deficits during low seasons. With the cheap geothermal heat, such losses can be significantly reduced by cheaply drying the products as a way of preservation. Drying of agricultural produce using geothermal has been tried in several resource rich areas in some countries in Africa. Examples include Pyrethrum drying in Eburru, Kenya and grain drying in Uganda among others.

Table 3: Economic evaluation of agricultural drying using geothermal energy in Kenya (Albert Simiyu, MSc Research 2016)

ITEM	SPECIFICATIONS	PRICE($)
Heat exchanger		44,800
Batch dryer		65,000
Piping System	Steel (150m)	30,000
Construction cost		60,000
TOTAL INVESTMENT COST		199,800
Depreciation 1% of investment cost		1,998
Operation & maintenance cost. 15% of initial cost		29,970
TOTAL PROJECT COST		231,768
BENEFITS		
Income from Drying one Batch	$195 per Batch	$66,300 Per year

African countries such as Kenya, Tanzania, Uganda and Ethiopia produce large quantities of cereals, fruits and vegetables that can be dried for domestic and export markets. Similarly, the countries are good producers of milk which can be economically pasteurized using geothermal energy. Coincidentally, most of the geothermal rich areas are equally agriculturally endowed thus presenting a commercial opportunity for setting of drying facilities.

In this approach, investors in crop drying and pasteurization facilities can partner with geothermal power developers to utilize most of the heat that would otherwise go to waste.

This means that the heat would be cost effective making the drying processes using geothermal heat to be commercially viable. MSc research by Albert Simiyu (2016) for the Pan African University Institute of Water and Energy Sciences on a grain drying facility using geothermal heat demonstrated that such an investment would give a positive revenue (Table 3).

3.1.5 Industrial heating applications

The high heat contained in geothermal fluids can be used for industrial heating applications. Such applications include leather production, textile production, beet sugar production and bitumen production among others. These industrial processes require heat sources of above 120 °C and this is available from most geothermal fluids found in Africa. Utilizing the cheap heat in geothermal energy will significantly reduce the industrial heating costs besides reduction of greenhouse gas emissions in the industrial processes.

Examples of existing industrial applications using geothermal heat in the continent are not documented. However, in other parts of the world, information of such applications are available and well documented. Even though industrial heating has not been well applied in Africa, availability of abundant geothermal resources of high temperature present opportunities for investment in geothermal industrial heating applications. Interestingly, the areas rich in geothermal resources are also rich in raw materials for the industrial applications. Cotton is widely grown in many African countries that are rich in geothermal such as Ethiopia, Uganda, Kenya and Tanzania and the abundant geothermal heat can be use in textile making processes. In similar ways, the geothermal rich countries in Africa are also rich in livestock production making application in leather production a viable venture. Investors in industries requiring geothermal heat need to partner with geothermal developers to utilize the geothermal heat that is often not utilized in power generation. Using geothermal heat can significantly lower production costs besides reducing emission of greenhouse gases.

4 PROMOTION OF GEOTHERMAL DIRECT USES AS A CATALYST TO INVESTMENT IN GEOTHERMAL DEVELOPMENT IN AFRICA

For many years, the focus of geothermal development in Africa and globally has been towards electricity power generation. The geothermal resources that are suitable for electricity power generation are the medium to high temperature geothermal resources and as a result, the low and some medium temperature resources have basically been ignored in the geothermal development schemes. As a result, wells that produce low temperature resources are counted as lost investment opportunities. Notably, the low temperature geothermal resources are the most prevalent type of geothermal resources in Africa and in the rest of the world and ignoring them in the geothermal development schemes means that a lot of opportunities are lost.

Geothermal direct use applications can make use of all kinds of geothermal resources ranging from very low to very high temperature. This provides incentives to developers to invest in development of geothermal resources without the fear of failure to acquire resources suitable for power generation. If a developer drills a geothermal well that yields low temperature resources, direct use applications will come in handy to utilize the resource and generate revenues for the investor. Governments in geothermal rich countries will need to develop policies that will assist in incentivizing direct use investments in the continent. Below are some of the ways in which promoting direct use applications will help in promoting investment in the geothermal sector in Africa.

4.1 Reduction of drilling risks

Promoting investment in direct uses will reduce the risks associated with drilling for geothermal resources. This is because, unlike the traditional model of geothermal development where focus is on electricity generation, direct use applications can utilize many kinds of geothermal resources acquired through drilling including hot wells with no permeabilities through enhanced heat mining. Because of these, it means that any geothermal well drilled will be useful and the risk of sunk costs in drilling will be significantly reduced.

Under the geothermal development model that focuses electricity generation, the probability of a getting high enthalpy wells ranges between 33% to 70% with a median of 68% according to research by Stanford university. In African countries where drilling has been done, the probability of winning high enthalpy resources are in the same range as shown by the Stanford study. Normally, the low enthalpy and low-pressure wells are considered as '*not successful'* with respect to power generation focused investment. However, with the promotion of direct use investments, these low enthalpy, low pressure wells and even the outlier wells such as very high pressure and cyclic wells have potential to generate revenues through direct use applications. This scenario motivates investors to venture in geothermal development since the drilling costs will be ultimately recovered either through conventional power generation or direct use applications.

4.2 Ease of access to capital for investors in geothermal development

Investment in geothermal direct uses will reduce the capital risks in geothermal development because even where the resources turn out to be low temperature or unique characteristic wells, they can still be utilized for commercial purposes via direct use ventures and hence earn returns on the investment. As a result, financiers

will have higher confidence that their capital investments will not go to waste since even low temperature resources will still have commercial values.

In the current focus on electricity generation, financiers will always demand for bankable feasibility study reports that demonstrates that the geothermal development under consideration have a proven resources for power generation and failure to demonstrate this makes financing to be difficult. Equally, investments in geothermal power generation are normally high capital-intensive processes whereas direct uses do not require high capital investments which will encourage more financiers to venture in geothermal development financing. Studies in direct use applications such as mineral extraction and crop drying have shown that these applications are commercially viable. Direct use initiatives that are coupled with high enthalpy applications stand a great chance of being economically viable hence can easily attract financing.

4.3 Opening up of areas currently considered as low temperature prospects.

The traditional model of geothermal development that focuses on power generation and as a result many geothermal prospects have been disregarded because of their low temperature projection. With the promotion of geothermal direct uses, areas that are presently ignored because of low prospects for high temperature resources will become attractive to direct use investors. Even investors in power generation will not shy away from investing in low temperature prospect areas because even if they fail to strike high temperature wells, they can still partner will direct use investors to still recover their invested costs. In the long run, all areas that have signatures of existence of geothermal resources will stand a chance to be opened up for development because of potential to generate returns through opportunities for direct use applications. Whereas returns from investment in geothermal development can be earned quicker from electricity generation, direct use applications present the next route for earning returns from geothermal investment. Coupling power generation and direct uses provides the highest route to generating returns from investment in geothermal development.

4.4 Attracting more investors to geothermal development

Promotion of direct use applications will motivate more investors to venture into geothermal development beyond the traditional investors in power generation. Considering there are many opportunities for geothermal direct uses, investors will find it easy to invest in existing developed fields since some upfront costs have been paid for in development of the power generation investment. Some direct use applications can be retrofitted on a brown field which will reduce the capital requirements thus making it attractive investment. In developing of green fields, the fact that there are higher probabilities of acquiring low enthalpy resources is a motivator to developers not to fear investing in drilling of green fields (if one misses out on high enthalpy, will likely strike a low enthalpy). Similarly, the time to develop a direct use venture is much shorter than that for a power plant and the capital required for direct use investments are moderate. To put up a geothermal power plant require above 4000 USD per KW but to put up a direct use investment such as geothermal drying systems could cost much less which gives small investors an opportunity to venture into geothermal sector that increasing the number of investors in the sector.

4.5 Improving returns from existing geothermal investments

The current model of power generation means that only the high temperature resources are utilized leaving large portions of geothermal resources that are low temperatures to go to waste. The waste fluids from power generation plants and even the natural hot springs and low enthalpy wells present opportunities for direct use applications. Promoting investment in direct uses will improve utilization of geothermal resources given that any acquired resource will find commercial applications.

5 CONCLUSIONS AND RECOMMENDATIONS

From the discussions above, the following conclusions have been drawn.

a) There is abundance of geothermal resources in many African countries that lie along the Africa rift system and even outside the rift system
b) A large portion of geothermal resources in the continent are low temperature and are thus suitable for direct use applications.
c) There are many investment opportunities for geothermal direct uses that can be exploited in Africa.
d) Promoting investment in direct use applications presents an opportunity to catalyze development of geothermal resources in the continent.

The following recommendations are made;

a) It is necessary to address the factors that inhibit investment in geothermal direct uses in the continent.

b) Governments will need to develop appropriate policies that will incentivize investment in geothermal direct uses as a way of opening up geothermal development in the continent.
c) There is need to carry out more research focused on direct use application potential across the continent and to map out the kinds and scales of direct use applications opportunities for each geothermal prospect.
d) There is need to create awareness and provide incentives that will promote investments in direct use applications

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REFERENCES

Árni Ragnarsson; Overview of direct geothermal applications and uses worldwide, III GGDP Roundtable Harpa Conference Centre –Reykjavik, Iceland (2016)

Jack Kiruja; Direct Uses of Geothermal Energy, *Short Course VI on Exploration for Geothermal Re*sources, Lake Bogoria and Lake Naivasha, Kenya (2011)

A. Khaireh and F. Aye; Geothermal Development in Djibouti Republic – A Country Report, *Proceedings of the 4th African Rift Geothermal Conference (2012).*

P. Omenda; Geothermal exploration in Kenya, *UNU Short Course V on Exploration for Geothermal Resources*, Lake Bogoria and Lake Naivasha, Kenya (2010)

T. Jóhannesson and C. Chatenay; Direct use of geothermal resources, *Short Course VI on Utilization of Low- and Medium-Enthalpy Geothermal Resources and Financial Aspects of Utilization*, UNU-GTP and LaGeo, in Santa Tecla, El Salvador (2014).

Gianelli and Teklemariam; Hydrothermal alteration in the Aluto-Langano geothermal field, Ethiopia (1993)

Mouldi Ben Mohamed, 2010: Geothermal Direct Application and its Development in Tunisia, Proceedings World Geothermal Congress 2010

Solomon K, Fikru W and Tesfaye K, 2021: Status of Geothermal Exploration and Development in Ethiopia, Proceedings World Geothermal Congress 2020+1

Shakiru Idrissa Kajugus, 2021: Geothermal Development In Tanzania – An Update, SDG short course V, Kenya https://www.carbon-counts.com/uganda-geothermal-resources

Subir K. Sanyal and James W. Morrow, 2012: Success and the learning curve effect in geothermal well drilling – a worldwide survey – Stanford geothermal workshop 2012 (https://pangea.stanford.edu/ERE/pdf/IGAstandard/SGW/2012/Sanyal.pdf)

Vincent Kato and Dr. Michael Krami Geochemistry of Ruwenzori hot springs, 2005: Department of Geological Survey and Mines and Federal Institute for Geosciences and natural resources, Uganda,

Eriya Kahwa, 2021; geothermal development in uganda: country update SDG Short Course V on Exploration and Development of Geothermal Resources, Naivasha, Kenya

IRENA, 2022: Powering Agri-food value chains with geothermal heat, a guidebook for policy makers

Albert Simiyu Khamala, 2016: Drying of Agriculture produce using geothermal heat in Kenya, MSc research for the Pan African University Institute of Water and Energy Sciences (PAUWES)