Presented at Short Course VI on Exploration for Geothermal Resources,
organized by GRÓ GTP, GDC and KenGen, at Lake Bogoria and Lake Naivasha, Kenya, Nov. 13- Dec. 4, 2022

DIRECT-USE OF GEOTHERMAL ENERGY IN KENYA

Martha Mburu
Geothermal Development Company
Kenya
COUNTRY
mmburu@gdc.co.ke

ABSTRACT

Kenya is endowed with vast geothermal potential along the East Africa Rift Valley System (EARS) with several prospects at different stages of development. Kenyan geothermal resources are mainly harnessed for electricity generation, but it is significantly evident that utilizing the energy for Direct-Uses would have a significant impact in many sectors such as in agriculture, industrialization, and tourism. With the formation of Geothermal Development Company (GDC) in 2008, a fully government-owned Special Purpose Vehicle (SPV) to accelerate the development of geothermal resources in Kenya, Direct-Use was given a central role since one of GDC's mandates is to market and promote the Direct-Use technology. From records, Direct-Uses in Kenya started about a decade ago with a local settler who used geothermal heat at the Eburru geothermal resource to dry pyrethrum. It is also recorded that local people in Eburru, Suswa and Narok all condensed steam from naturally occurring fumaroles for domestic uses. Since 2000 significant research on geothermal Direct-Uses has been undertaken, culminating in both commercial and small-scale demonstration projects. These projects have been used to showcase and market the technology and the country is now focused on implementation of commercially viable Direct-Uses projects.

1. INTRODUCTION

From records, Direct-Uses in Kenya started about a decade ago with a local settler who used geothermal heat at the Eburru geothermal resource to dry pyrethrum. It is also recorded that local people in Eburru, Suswa and Narok all condensed steam from naturally occurring fumaroles for domestic uses. Implementation of commercial geothermal Direct-Uses started in early 2000 when Oserian Development Company started using geothermally heated water to heat rose flower greenhouses, enrich carbon dioxide (CO_2) levels in the greenhouses, as well as applyting heat sterilization of soils which kills plant pathogens thus enhancing plant growth. In recent years, Kenya has done a lot of research, collected lots of data and information as well as marketed the technology to private investors and has now commenced the commercialization of the technology.

2. GEOTHERMAL ENERGY UTILIZATION

Geothermal resources can be utilized for two main applications: Electricity generation and Direct-Uses. The temperature of the resource is the main determinant factor for the choice of application. Direct-Uses use low to medium temperature resources for a wide range of applications (Figure 1). Due to a low cost of investment and efficiency, Direct-Uses are widely used and a quickly growing application worldwide (Lund and Boyd, 2015).

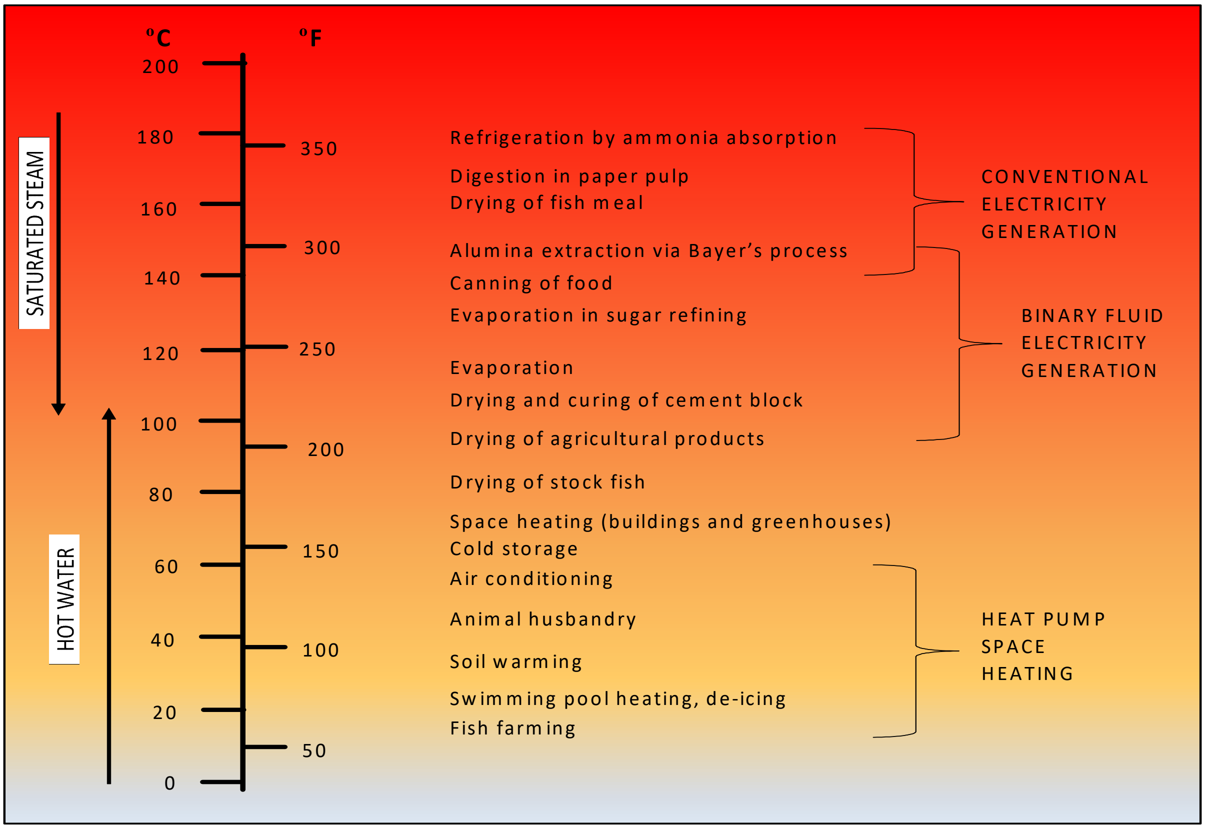

FIGURE 1: Modified Lindal diagram (Líndal, 1973; GDC, 2020)

3. HISTORY OF DIRECT-USE IN KENYA

Though growth in geothermal Direct-Uses has been very slow, there are records of semi-commercial Direct-Use projects in Kenya, since the 1930s, but research has resulted in significant growth over the last 10 years. Kenya's geothermal Direct-Use is mainly in agriculture and tourism.

3.1 Greenhouse heating

Geothermal resources can be used to enhance agricultural practices. The common forms of applications include greenhouse heating, soil warming, use of carbon dioxide (CO_2) in greenhouses etc. Heating of greenhouses controls the temperature and humidity of the growing environment, thereby reducing fungal infections. This translates to minimal or no use of fungicides in the heated greenhouse thus reducing on production cost and the produce will have less or no chemical traces. Commercial heating of greenhouses of Oserian Development Company, set up in 2002 uses a low enthalpy well to heat the rose cut flower greenhouse and CO_2 from the well is put into the greenhouse to enhances photosynthesis. The horticulture greenhouse at Menengai also uses heat from a low enthalpy well to enhance growth, Figure 2.

3.2 Heating of aquaculture ponds

Tilapia and catfish, the main fish grown in Kenya require 29°C water for optimal growth. This is because at that temperature, the metabolism of the fish is at its peak. Experiments have shown that for every one-degree rise in temperature above 20°C, the metabolism of fish rises by about 3%. By heating

Oserian Rose-flower greenhouse GDC's Horticulture greenhouse

FIGURE 2: Greenhouse heating at Oserian Company and Demo project in Menengai in Kenya

the water to an average water temperature of 22°C, the growth of fish is projected to improve by approximately 30%. Heating fish ponds also protects the fish against cold weather; hence creating a good environment for growth and development. In Menengai geothermal field, GDC has set up a demonstration unit for heated aquaculture ponds. Figure 3 shows the heated aquaculture project in Menengai.

FIGURE 3: Heated fish ponds at Menengai geothermal project, Kenya

3.3 Drying of agricultural products

In Kenya, drying of agricultural products is commonly done using open-air sun drying. Commercial dryers use electricity, fossil fuels or wood. Drying of agricultural products is energy dependent; lack of which leads to post-harvest losses. Low enthalpy geothermal energy with moderate temperature of 40°C to 100°C is feasible for drying of agricultural products and thus offers a solution to this problem. The pyrethrum dryer at the Eburru was built in the late 1930s. It utilizes hot water from a shallow borehole, about 200 m deep. The well gives hot water at about 90°C, which was utilized to dry pyrethrum flowers for a white settler farm (Figure 4). To date, the dryer is still used by the local community. GDC's semi-commercial, geothermal-powered grain dryer in Menengai, which was commissioned in 2019, under ICEIDA funding, uses fluids from a low enthalpy well and can dry 6 tonnes of grains in 5 hours.

3.4 Food value addition and preservation

The 150 L batch milk pasteurizer (Figure 5) uses geothermally heated water to pasteurize milk. The studies and the demo project show substantial energy saving in milk processing using geothermal energy compared with other energy sources.

Pyrethrum Dryer, Eburru, 1939

Grain Dryer in Menengai, 2019

FIGURE 4: Pyrethrum dryer in Eburru and a semi-commercial grain dryer in Menengai

FIGURE 5: Geothermal-powered milk pasteurizer in Menengai

3.5 Heated spas and pools

In Kenya leisure activities such as heated swimming are gaining popularity and play a key role in the tourism sector. Geothermal spas and natural springs have been set up in Olkaria by KenGen, and Lake Bogoria. The Olkaria geothermal spa uses separated brine for the spa before it is reinjected. Lake Bogoria spa uses a natural spring which has been directed to the pool. Figure 6 shows the Olkaria and Lake Bogoria spas.

Olkaria Geothermal Spa

Lake Bogoria Hotel Geothermal heated pool

Figure 6: Olkaria geothermal spa and Lake Bogoria spa, Kenya

3.6 Water harvesting from fumaroles

In water-deficit areas where there is presence of fumaroles and hot springs, some communities in Kenya harvest water from geothermal steam (Figure 7). In Eburru and Suswa, communities harvest water from fumaroles for domestic purposes such as watering livestock and sometimes for drinking.

FIGURE 7: Domestic water harvesting from naturally occuring fumaroles at Eburru and Suswa

4. POTENTIAL FOR DIRECT-USE APPLICATIONS IN KENYA

The manufacturing sector is a key driver of economic development throughout the world. This is largely driven by the agriculture sector which provides most of the raw materials for industries. Agriculture is the mainstay of Kenya's economy, directly contributing 24% of the Gross Domestic Product (GDP) and 27% indirectly through linkages with manufacturing, distribution and other related sectors. One of the main challenges facing the manufacturing and agriculture sectors is high electricity costs and power outages. To mitigate this, formation of Special Economic Zones such as Geothermal Resource Parks will promote development and enhancement of agriculture and industries. The sectors are projected to benefit from low thermal energy tariffs as well as concessionary electricity rates to catalyze industrial and agricultural production and to make Kenya's manufacturing and agricultural sectors competitive in the regional market.

4.1 Growth enhancement in horticulture and aquaculture

4.1.1 Horticulture

The main reason for heating greenhouses in Kenya is to even out temperature throughout the day and to control the humidity of air below 85%, especially during the early morning hours when the air temperature approaches the dew point. This prevents condensation of water on the leaves of the crop; hence, reducing incidences of fungal diseases. Furthermore, greenhouse heating maintains the temperature at an optimal level for the growth of the crop resulting in improved productivity of 15-25% and early maturity of the crop. Greenhouse heating is done for a period of between 6 to 8 hours per day. The amount of energy required to regulate relative humidity is about 300 kWh/ha (VEGA, 2014a). Greenhouses used for intensive floriculture propagation should be heated to at least 20°C at all times and their energy requirement is approximately 1000 kW_{th}/ha (VEGA, 2014a).

Geothermal water at 55°C can be used to provide thermal energy to heat the greenhouses. Hot water at 100°C can provide energy for cold storage using Lithium Bromide vapour absorption refrigeration systems (VEGA, 2014a).

4.1.2 Aquaculture

Tilapia and catfish, the main fish grown in Kenya, require 29°C water for optimal growth. This is because at that temperature, the metabolism of the fish is at its peak. Experiments have shown that for every one-degree rise in temperature above 20°C, the metabolism of fish rises by about 3%. By heating the water for aquaculture production with an average water temperature of 22°C, the growth of fish is projected to improve by approximately 20%. This requires about 1260 kW_{th} of energy per hectare of aquatic ponds (VEGA, 2014b).

Fish is a highly perishable product which requires immediate cold storage after harvesting to prolong its shelf life. It is common to park fish in ice to keep it cold during storage and transportation (Odoli, 2009). The production of ice to store fish requires the use of water/ammonia vapour absorption equipment which should be supplied with hot water at a temperature above 140°C. Maintaining an aquaculture unit at a constant temperature requires supply of heated water on a flow through basis throughout the day. Approximately 0.95 kg/s of heated water will be required to maintain a hectare of aquatic pond at 29°C (VEGA, 2014b).

4.2 Milk processing

Milk processing by pasteurization in Kenya is a regulatory requirement by the Kenya Dairy Board. The main products marketed by the milk processors are pasteurized skimmed milk (short and long life), cultured milk (yoghurt and sour milk) and to a lesser extent powder milk. Besides powder milk, which requires very high temperature, the other products can be readily processed using thermal energy from geothermal brine. Milk processors consume large amounts of water for cleaning to meet the high standards of hygiene required in milk factories. At least 0.6 litre of water are required for every litre of milk processed (Kiruja, 2011). The waste water from milk processors, mostly from cleaning operations, is rich in nutrients. Disposal of this water poses challenges, but it is possible to recycle the nutrients by using the water for irrigation (VEGA, 2013).

4.3 Preservation of agricultural products drying

Drying of crops after harvesting is done to reduce the moisture content in order to improve the shelf life. This is because drying considerably slows down the microbial and chemical reactions that take place after harvesting, leading to spoilage. Cereals are the most important crop for drying in Kenya, especially maize. Small scale farmers form the majority of maize producers in Kenya, producing about 75% of the crop. All the maize is consumed locally, and supplemented with imports, which account for about 10% of the local demand (VEGA, 2014c).

The main sources of energy used to dry crops in Kenya are solar, wood fuel and heavy fuel oils depending on the scale of drying involved. Industrial drying is achieved using hot air at a temperature of 50°C-100°C. The crops with potential to benefit from geothermal drying around Menengai are maize and onions. Onion dehydration requires 55 MJ/kg of dried produce to reduce the moisture from 80% to 4%. Maize requires 350 kJ/kg to dry from 27% to 13% moisture content while sliced fruits require 900 kJ/kg to dry from 80% to 20% moisture content (Kinyanjui, 2013). Drying can be done using batch or continuous dryers. In batch drying the produce is exposed to elevated temperature for 2-24 hours to achieve the desired moisture content; therefore, the maximum drying temperature should not exceed 75°C, to avoid compromising the quality after drying (Basak et al., 2014). However, for continuous drying, elevated temperature does not have adverse effects on the produce because the exposure is for a short period.

4.4 Meat processing

Abattoirs are categorized depending on their throughput. Category A abattoirs are those with a minimum throughput of 200 heads of cattle and a similar number of goats and sheep per day. Export level abattoir require chilling capability to achieve at least -10°C for 24 hours in addition to having all category A requirements (Chabari, 2014).

Hygienic conditions in an abattoir must be maintained at very high standards to avoid accumulation of microbes which could cause diseases in humans. This requires hot water to melt away the animal fats which stick on surfaces and create breeding ground for the germs. Other operations requiring thermal energy include freezing of the meat, precooking of meat for canning and sterilizing the canning containers. Precooking operation is performed before canning by boiling or steaming the meat. The containers used for canning should be sterilized using heat before the meat is canned. Within the first 24 hours after slaughtering, meat should be chilled to prevent it from developing a sour taste (Kiruja, 2017).

4.5 Processing of hides and skins

A tannery requires thermal energy for drying of the processed leather and to heat water to the temperatures needed for chemical processes. Water at a temperature of 35°C-65°C is required mainly during the tanning process. In addition, hot air of up to 80°C will be required to dry the treated leather. On average, 25 MWh/1,000 m^2 of leather is required in a tannery, of which 50% is consumed by thermal processes (Cotance and industriAll, 2012).

4.6 Edible oils and soaps processing

Kenya imports crude palm oil from Malaysia to process into refined edible oils in addition to using pressed oils from locally grown oilseeds such as sunflower, canola, rapeseed, soy and maize germ. Most of the processed oil is consumed within the country, though a small amount is exported regionally. The refining process is energy intensive and involves the application of thermal energy to catalyze some processes or to evaporate impurities. Most of these processes can be achieved by using hot geothermal water except deodorizing, which requires the crude palm oil to be heated to over 200°C using steam to evaporate the volatile impurities.

4.7 Textile processes

The textile industry was included in Kenya's vision 2030 as a target sector to drive the country's industrialization plan. There is renewed focus on the upstream of the textile value chain with the revival of ginneries and garment manufacturers such as Rivatex in addition to providing incentives to the cotton farmer through competitive pricing for their produce.

The processes involved in textile manufacture require electrical energy, thermal energy and fresh water. In total, seven processes require water usage at a temperature of 60°C-100°C. Drying of the fabric in tumble dryers requires hot air at a temperature of 80°C.

4.8 Cement processing

The government of Kenya in its "Vision 2030" aims to become a middle-income economy by the year 2030. Plans are underway to construct new roads to open up connectivity and ease transportation and movement in the country. Furthermore, housing projects are to be constructed in cities and major towns in the country. With such projects, the demand for cement is projected to grow over the coming years. It is worth noting that high production costs in a cement manufacturing plant is largely from electricity and thermal energy costs.

A cement manufacturing plant requires significant amounts of energy to produce clinker, the main ingredient in cement. Energy in form of electricity is required to prepare the raw meal (limestone, clay, sand, and iron ore), run the kiln and in integrated cement plants to grind the clinker, gypsum and other materials to produce cement in grinding mills. For integrated cement plants, energy in the form of heat is required to raise the kiln temperature to over 1,450°C required to produce clinker. In Kenya, this heat is predominantly generated by coal and to a lesser extent by diesel oil. Such sources of energy are expensive and contribute to high greenhouse gas emissions. It is for this reason that geothermal energy comes into play. It is possible to entirely power a cement manufacturing plant by use of geothermal energy. This is projected to contribute to huge energy cost savings in the plant as well as reduce on the carbon foot prints posed by other energy sources such as coal and fossil fuel.

4.9 Paper processing

Pulp and paper industry is highly energy intensive and requires both electrical and thermal energy for its processes. Most of the energy used in the paper processing is sourced either from fossil fuel, electricity or biomass. With the draw-backs associated with these sources of energy, geothermal is the best alternative owing to its low greenhouse gas emissions and lower cost as compared to electricity and fossil fuel.

4.10 Tourism - Swimming and spa

The tourism sector is one of the key economic drivers in Kenya, generating 8.8% of the country's GDP, worth USD 7.9 billion in 2018. The sector accounts for over 10% of total employment, contributes 9% to GDP, 18% to foreign exchange earnings and is a major source of government revenue at 11% in form of taxes, duties, licence fees, park entry fees among others (State Department for Tourism, 2020). Leisure activities such as spa swimming are gaining popularity in the country. A spa offers unique characteristics due to its nature and plays a key role in the tourism sector. Low enthalpy geothermal wells and those with high geothermal waters (brine) are candidates for establishment of a spa. A spa requires brine at about 38°C, though environmental factors such as evaporation losses and wind speed play a critical role in temperature management.

5. GDC'S DIRECT-USE JOURNEY

GDC was incorporated in 2008 under the Companies Act as a special-purpose vehicle (SPV) to accelerate the development of geothermal energy in Kenya. One of GDC's mandates is to promote and market Direct-Use technology. With such a mandate, research on Direct-Use commenced immediately and by 2020, significant strides were realized in pre-feasibility studies, data collection, projects implementation, knowledge sharing and marketing of the technology.

5.1 Pre-feasibility studies

Since 2010, various studies have been done:

- Geothermal Direct-Use guidebook;
- Geothermal powered milk processing;
- Processing of meat and other abattoir products using geothermal energy;
- Geothermal greenhouse heating;
- Heating of aquaculture ponds;
- Geothermal powered grain drying;
- Direct-Use concept of viability, market sounding;
- Direct-Use powered industrial parks; and
- Geothermal powered honey processing.

The studies show that geothermal Direct-Use can be used commercially to spur food security through growth enhancement, food preservation and value addition. It can also create jobs to local communities and improve livelihoods. Industrial applications such as cement and paper processing can also use geothermal energy directly, reducing energy cost and hence higher profitability.

5.2 Menengai demonstration studies

After the GDC-USAID collaboration of 2012-2015, and the GDC-ICEIDA collaboration of 2015-2019, the Menengai Direct-Use demonstration projects were set up as a proof of concept and as a marketing tool for the technology.

The following demo projects were set up:

- Containerized dairy demonstration unit – 2015;
- Aquaculture ponds – 2015;
- Greenhouse – 2015;
- Laundry and dryer units – 2015; and
- Geothermal-powered grain dryer – 2019.

The demo projects have been used to market the technology to various groups comprised of potential investors, education and government institutions, and local communities. It is estimated that more than 3,000 persons have visited the projects.

5.2.1 Energy source

The initial design for the demonstration units assumed the use of a low pressure geothermal well in Menengai, MW-03, to provide the heating fluid. The well has a wellhead pressure of 1.6 bar-a and temperature of 95°C. About 10 t/hr of brine at 95°C flows into a water bath where a stainless steel heat exchanger coil is used to heat cold water from 21°C to 85°C (Figure 8). The heated clean water is then used as a source of heat to all the pilots.

FIGURE 8: Low enthalpy well as the heat source and a simple helical coil heat exchanger

5.2.2 Heated greenhouse

The aim of greenhouse heating is to even out temperatures while controlling humidity. This reduces or eliminates fungal infection in the plants thus reduces the use of fungicides in the greenhouse. In Menengai Direct-Use demonstration projects, heating of greenhouse environment is achieved by use of hot water at about 55°C contained in steel pipes. The project has witnessed reduction of use of fungicides by more than 80% compared to unheated greenhouses. This has resulted in healthy produce from the greenhouse, enhanced maturity period and reduced cost of production.

5.2.3 Heated aquaculture ponds

The aquaculture ponds are heated by mixing hot and cold water to achieve a temperature of 29°C. This is the optimal environment for growing fish and the project has shown that the growth of fish is enhanced; where the maturity period is achieved in 6 months compared to the unheated ponds, which take 9 months to mature. It has also been realized that warm water prevents diseases brought about by cold environment. Furthermore, heating of the fishponds promotes high density of fish stocking.

5.2.4 Geothermal-powered milk pasteurizer

The milk pasteurizer in Menengai has a capacity of 150 L and has a jacket where hot water is indirectly used to heat milk. Pasteurization occurs by indirectly heating milk by use of hot water to about 70°C and maintaining this temperature for 30 minutes. Thereafter, the cooling process begins by using the mains water to lower the milk temperature to 40°C. Further cooling is achieved by use of chilled water to 4°C where pasteurized milk can be stored or consumed. The findings from the project show that thermal energy cost savings of about 60% can be realized by using heat from geothermal as opposed to fossil-based fuels, which are commonly used to generate heat for commercial milk processing in Kenya.

5.2.5 Laundry and dryer units

This unit utilizes hot water for washing and drying clothes. The temperature for washing clothes is determined by the type of garment and thus a mixture of hot and cold water is used to achieve the temperature specified by the clothes' manufacturer. Instead of using electrical appliances, the unit uses hot water from the heat exchanger unit for washing and drying clothes. The unit shows thermal energy cost savings of more than 50% compared to using electricity for heating water to wash clothes and electric coils for drying clothes.

5.2.6 Grain dryer

The geothermal grain dryer in Menengai geothermal field is a batch type and has three main units: The wet bin, the drying chamber and the storage bin with capacities of 12 tonnes, 6 tonnes and 8 tonnes respectively. It is designed to dry grains such as maize, wheat, sorghum and millet by using warm or hot air to take away moisture from the grains. The dryer uses geothermal fluids as a source of heat instead of conventional sources of heat such as biomass, fossil fuel and the sun. The air required for drying is heated to temperature of about 45°C to 60°C for quality standards of the dried product to be attained while the drying duration is between 4-6 hours depending on the initial and target moisture content of the product. The advantages of using geothermal as the source of thermal energy for drying is that it is clean, reliable and less expensive compared to fossil-based fuels and electricity. The project saves more than 60% of thermal energy compared to using fossil-based fuels.

The Direct-Use demonstration centre has shown the viability of Direct-Use technology as well as the advantages of using geothermal energy, such as reliability, cleanliness and affordability. With these observed benefits, GDC has begun a Direct-Use commercialization process where medium to large-scale Direct-Use ventures are to be established in or near Menengai geothermal field.

5.3 GDC's Direct-Use commercialization journey

GDC, after successfully demonstrating and marketing Direct-Use technology, is currently focusing on commercializing the technology in partnership with potential investors. The aim is to promote industrialization, food security, community empowerment and revenue generation. In 2020, GDC carried out a detailed pre-feasibility study of a geothermal powered industrial park (resource park) adjacent to the Menengai geothermal field. The park is to be powered by thermal energy from geothermal brine, either from the brine separated from power plants or from unutilized low enthalpy wells to be used for Direct-Uses. The first sets of investors are being contracted after GDC advertised for such investments in 2021 and it is envisaged that in by 2024, the investments will be in-pace.

6. LESSONS LEARNED IN KENYA'S DIRECT-USE JOURNEY

Kenya has achieved a great milestone in the Direct-Use journey in the last decade. Studies undertaken, data collected and experience in projects implementation and operations show that geothermal Direct-Use would play a very important role in spurring development and ensuring food security in regions that are endowed with geothermal energy.

6.1 Kenya's Direct-Use success story

Though Kenyan Direct-Uses of geothermal energy are still in infancy, they are going in the right direction. The Direct-Use strategy that Kenya has adopted will have a great impact in food security, employment and economic growth.

6.1.1 Commercial project

Kenya has implemented three commercial Direct-Use projects: Oserian greenhouses heating, the Olkaria Geothermal Spa and Lake Bogoria Spa Hotel. These projects have reported increased services and products' marketability as a result of utilization of geothermal energy.

6.1.2 GDC Direct-Use demo projects

GDC has demonstrated Direct-Use technology since 2015. More than 3,000 persons have visited the Menengai demonstration site and have learned the science and benefits of geothermal Direct-Uses. Through its demonstration projects, GDC has demonstrated that Direct-Use technology is viable, reliable and offers a cheaper, reliable energy source. Data collected from the five demo-projects shows that commercial scale Direct-Use projects are profitable and can offer competitive advantage to similar projects operated using other energy sources.

6.1.3 Direct-Use commercialization journey projects

After demonstrating Direct-Uses for over five years, GDC commenced a journey to commercialize Direct-Use. The journey started with "A detailed pre-feasibility study for setting up a geothermal powered Industrial Park" (GDC, 2020). Through an Expression of Interest and a Request for Proposal, GDC is currently in the process of contracting three commercial investors. It is envisaged that by 2024, the investors will have set up their industries/applications in Menengai.

6.2 Challenges

Even with focused and aggressive marketing of Direct-Use technology, there still seems to be a glaring gap in understanding how Direct-Use projects need to be implemented and operated. The link between the government, potential investors, financiers and local communities is lacking. This gap would be the hindrance for Direct-Use update. This link can be mended by the government establishing a clear Direct-Use policy.

The following are the identified key challenges in the implementation of Direct-Use projects in Kenya:

- Lack of a clear government Direct-Use policy;
- Infrastructure development;
- Projects funding;
- Training and knowledge transfer; and

- Structured ways of community involvement.

7. CONCLUSION

Though growth in geothermal Direct-Uses in Kenya has been slow, there have been significant developments over the last 10 years. These have been achieved through research and aggressive marketing of the technology. Kenya's geothermal Direct-Use projects are currently in agriculture and tourism, but the future focus will in in industries especially value addition in agriculture.

The studies show that geothermal Direct-Use can be used commercially to spur food security through growth enhancement, food preservation and value addition. It can also create jobs to local communities and improve livelihoods. Industrial applications such as cement and paper processing can also use geothermal energy directly, reducing energy cost and hence increasing profitability.

The Direct-Use demonstration centre in Menengai has demonstrated commercial viability of Direct-Use technology. With these observed benefits, Kenya has begun the Direct-Use commercialization journey.

Even with focused and aggressive marketing of the Direct-Use technology, there still seems to be a glaring gap in understanding how Direct-Use projects need to be implemented and operated. The link between the government, potential investors, financiers, and local communities is lacking. This gap would be the hinderance for Direct-Use update. This link can be mended by the government establishing a clear Direct-Use policy.

REFERENCES

Cotance and industriAll, 2012: Social and environmental report: The European leather industry. Cotance and industriAll, Brussels, Belgium, 48 pp.

GDC, 2020: *Pre-feasibility report for establishment of industrial park at Menengai geothermal field*. GDC internal report.

Kinyanjui, S., 2013: Direct use of geothermal energy in Menengai, Kenya: Proposed geothermal spa and crop drying. Report 9 in: *Geothermal training in Iceland 2011*. United Nations University Geothermal Training Programme, Reykjavík, Iceland, 109-142.

Kiruja, P.J.M., 2011: Use of geothermal energy in dairy processing. Report 16 in: *Geothermal training in Iceland 2011*. United Nations University Geothermal Training Programme, Reykjavík, Iceland, 303-326.

Kiruja, P.J.M., 2017: *The viability of supplying an industrial park with thermal energy from Menengai geothermal field, Kenya*. University of Iceland, MSc thesis, United Nations University Geothermal Training Programme, report 1, 55 pp.

Líndal, B., 1973: Industrial and other applications of geothermal energy, except poser production and district heating. *Geothermal Energy,* Paris, UNESCO, LC 7297*,* 135-148.

Lund, J.W. and Boyd, T.L, 2015: Direct utilization of geothermal energy 2015 worldwide review. *Proceedings World Geothermal Congress 2015, Melbourne, Australia*, 31 pp.

State Department for Tourism, 2020: *Revised national tourism policy, 2020 on enhancing resilience and sustainable tourism in Kenya*. Republic of Kenya, Ministry of Tourism and Wildlife, State Department for Tourism, 40 pp.

VEGA, 2013: *The Powering African Agriculture (PAA) project: Geo-mega dairy prefeasibility study*. USAID Kenya, Nairobi, 72 pp.

VEGA, 2014a: *The Powering African Agriculture (PAA) project: Priority geothermal direct-use applications for Kenya and pre-feasibility studies – greenhouses*. USAID-Kenya, Nairobi, 24 pp.

VEGA, 2014b: *Powering African Agriculture (PAA) project: GDC Menengai MW03 mini aquaculture and greenhouse project*. USAID-Kenya, Nairobi, 6 pp.

VEGA, 2014c: *The Powering African Agriculture (PAA) project: Priority geothermal direct-use applications for Kenya and pre-feasibility studies – drying*. USAID-Kenya, Nairobi, 17 pp.