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Market Opportunities for the Direct Use of Low Temperature Geothermal Heat in Uganda

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ABSTRACT

As a country, Uganda has a growing interest to diversify its energy mix from dependency on hydro power and traditional biomass. Prospects for the exploitation of the existing geothermal potential are therefore not only in power generation, but also direct use applications, although geothermal development is still in the preliminary stages. This study places emphasis on the range of opportunities for direct use of low temperature geothermal heat in Uganda. Because the transportation of heat over long distances is uneconomical; it is advisable to utilize the heat within a given radius of its source. In this study, the areas within such radii where geothermal activity is witnessed were assessed based on; fluid temperature, climate, population as well as main economic activities to better understand the market opportunities for the heat that will be extracted. Some of the more outstanding geothermal fields were studied; from which it was observed that out of the diversity of sectors for investment, agriculture-based industries; agricultural drying and milk pasteurization, pose higher opportunities for success given the available sources of raw materials. It would however be important to carry out a detailed industry specific market analysis at the feasibility phase for a better understanding of the development of the selected industries for implementation.

1. Introduction

The geothermal potential of Uganda was initially estimated to be 450 MW, McNitt (1982), however, current estimate is put at 1, 500 MW, Bahati (2016). Although the actual use of this potential has not yet been realized, plans are underway to use this energy for electricity generation and direct use applications in some locations. Presently, electricity generation is an important motivation for geothermal exploitation owing to the low rate of electrification in the country as well as the need to minimize the country's dependency on hydro power. The country however has a broad range of areas that require not only electricity, but process heat as well. The economy of Uganda is dependent on agriculture and has many industries for processing agricultural products. This means that there is a broad range of industries that

require process heat for value addition to products. This therefore creates a broad range of possibilities on the future use of geothermal energy, not only for economic growth but also for social development.

Uganda experienced an increase in GDP from about 5% in 2014 to about 5.6% in 2015, mostly driven by infrastructure development, Deloitte (2016). The economy of Uganda however greatly depends on the agricultural sector. In 2015, the sector contributed 26% to the GDP, while employing approximately 60% of the population. The main agricultural crops include coffee, grains, sugarcane, cotton and tea. Coffee accounts for 20% of total export earnings and one third of foreign exchange earnings, Deloitte (2016). The tourism industry has been highlighted as the fastest growing of the service sectors in the country, and the single largest export earner.

2. Literature Review

Direct use of geothermal heat in Uganda is currently limited to the use of hot springs in their various locations. The local inhabitants utilize the hot spring waters for bathing for therapeutic values, watering animals and as tourist attractions. The Kisiizi spring which has clear warm waters at about 30 ^{o}C is being used at an institutional scale. Kisiizi hospital in Rukungiri makes use of the warm waters from the spring to supply water for bathing and other domestic uses. This is one of the major direct applications of geothermal heat in Uganda, Armannsson and Kato (no date). Geothermal waters have also found application in Katwe and Kibiro, where they are used for salt production especially in the warmer seasons, East African Business Week (2011), although presently, sun drying has taken precedence. However, with all the potential available for direct use applications, not much evidence is there to show for it.

The role of this paper is to assess and show the potential for marketability of geothermal energy in eight of the most promising geothermal sites in Uganda; Buranga, Kibiro, Katwe, Panyimur, Rubaare, Kitagata, Ihimbo and Kanangorok. Figure 1 shows the location of these geothermal sites.

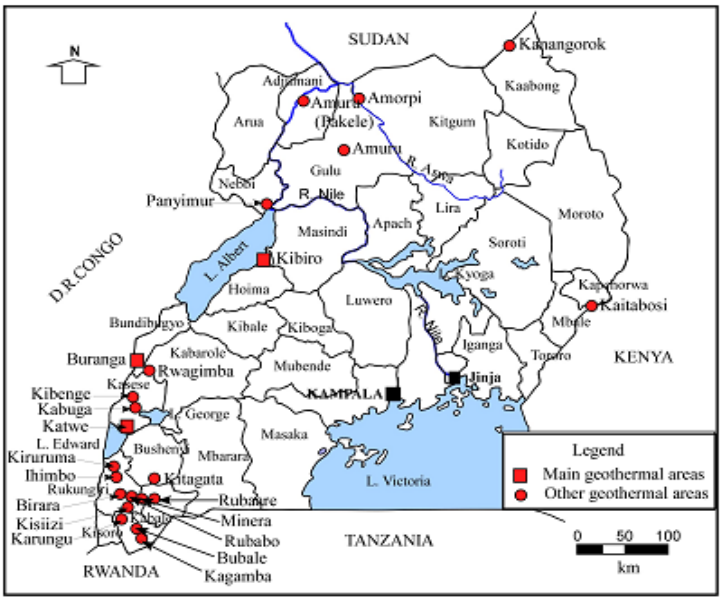

Figure 1: Geothermal areas in Uganda.

3. Buranga Geothermal Prospect

The Buranga geothermal prospect stretches between the districts of Bundibugyo and Ntoroko at the north-western base of the Rwenzori Mountains in the Western Rift Valley. The two districts lie at the border with the Democratic Republic of Congo. While Bundibugyo district is predominantly an agricultural area, Ntoroko district is dominated by pastoralism. The two districts are also engaged in fishing on Lake Albert and River Semuliki, Bahati and Natukunda (2015). Buranga field falls within the Semiliki National park which is an area of national importance for nature, landscape conservation and natural heritage preservation. The source fluid temperatures at this geothermal prospect are estimated to be between 120 – 150 °C, Bahati and Natukunda (2015).

3.1 Economic Activities

The main economic activity in Ntoroko district is livestock rearing; cattle, goats, sheep and chickens are the major animals kept. Crop farming and fishing are also practiced in the region. Crops cultivated are mainly cassava, maize and cocoa. Fishing along the Semiliki River and from Lake Albert is a common practice. Livestock and crop farming is still under traditional practice in the district and marketing is still substandard due to several factors including poor roads, which hinder mobility, Nyakecho (2008). The area however experiences floods in the rainy season and droughts in the dry season, which affect the main economic activities.

Bundibugyo district has a population of over 200, 000 people. Crop farming is the main economic activity with emphasis on food crops such as: cassava, beans, bananas (for eating, beer and sweet) sweet potatoes, soya beans, maize, and finger millet. Cash crops include: cocoa, rice, vanilla and palm oil, whereas tomatoes, cabbages and onions make the biggest portion of the vegetables. Bundibugyo district is Uganda's largest producer of cocoa. Figure 2 gives the actual and estimated yields of different crops commonly grown in Bundibugyo district for the years 2009 and 2012 respectively. This shows the potential for food processing and value addition, as per annual production. Most of the farming is done on a subsistence scale. Fishing is also practiced on Lake Albert and tourism at the Semliki national park, the hot springs, the Semliki wild reserve and the pygmies near Ntandi.

Crop	Acreage 2008/9 (Ha)	Yield 2008/9 (MT)	Yield estimate (2012)
Cocoa	4, 741	15, 000	18, 000
Cassava	7, 784	23, 144	21, 040
Beans	2, 502	3, 650	3, 318
Banana (eating)	4, 752	22, 092	11, 000
Banana (beer)	386	1, 090	654
Banana (sweet)	37	752	75
Sweet potatoes	1, 168	3, 380	3, 314
Soya beans	568	440	440
Rice	110	71	28

Figure 2: Status of crop production in Bundibugyo district.

3.1.1 Cocoa growing in Bundibugyo

Bundibugyo district is a major cocoa producing area with 85% of the farmers engaged in cocoa growing, Kajubu (2015). Cocoa can be harvested throughout the year, and only the amount will rise or fall depending on the season, Muzzale (2014). Harvesting usually begins when there is a sufficient number of ripe pods to start fermentation. The frequency of harvesting depends on the crop and increases during the peak periods of pod production, Amoa-Awua (2015). The bimodal rainfall pattern in Uganda allows for two major harvesting periods each year. The rainy seasons are the months of March to May and August to November, while the dry spells occur in the months of June to July and November to January. Harvesting commences 2 weeks after the on-set of rains and peaks one and a half months after. It is done over a period that overlaps part of the dry season, and goes on for approximately 3 months, Development and Management Consultants International (1998). The cocoa harvesting seasons are March, April, July and October to December, Kajubu (2016).

Cocoa is an internationally traded commodity and nearly all cocoa beans produced in Uganda are exported. According to Lutheran World Relief (U) (2015), the world price of cocoa has fluctuated between USD 2, 500 to USD 3, 000 per metric ton in the recent years. And although the price may have dropped to about USD 2,700 per metric ton because of exceptionally good weather in the major cocoa growing countries, it is still considered profitable for cocoa growers. Local farm-gate prices in Uganda currently range from UGX 4,200 /kg – 7,000/ kg for dry cocoa with 7.5 -7.8 moisture content, Lutheran World Relief (U) (2015). The Figure 3 is a representation of the annual production and income from the sale of cocoa over a period of 10 years. Ugandan cocoa is reputed to have special aromatic properties that are favored by chocolates manufacturers. This increases the demand of Ugandan cocoa by the large chocolate companies that manufacture special flavor chocolates and makes it a favorable economic venture.

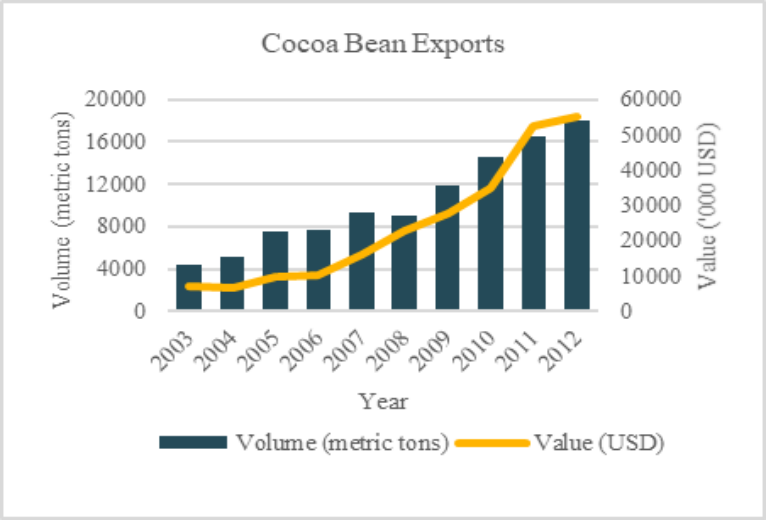

Figure 3: National cocoa bean exports from 2003 – 2011. Estimated values for 2012.

3.2 Market Opportunities

The Buranga geothermal prospect has a wealth of opportunities to provide the market for utilization of geothermal heat. Agroprocessing stands out as the main area of direct use applications in the fields of agricultural drying, especially cocoa to yield a uniform quality product. Milk pasteurization, leather tanning and fish processing especially drying are also

good investment opportunities. Development of a geothermal spa would serve as a boost to the tourism industry.

4. Kibiro Geothermal Prospect

The Kibiro geothermal prospect is located on a small peninsula in Lake Albert under the Rift Valley escarpment in Hoima district, Bahati and Nyakecho (2010). This geothermal prospect has subsurface temperatures of above 200 °C, Bahati (2003). This expands the range of geothermal direct use applications it can serve.

4.1 Economic Activities

Hoima district has a population of over 500, 000 inhabitants. Agriculture is the main economic activity with emphasis on food crops such as: sorghum, maize, finger millet, pigeon peas, groundnuts, sunflower, sweet potatoes and beans, and vegetables including; tomatoes, cabbages and onions. Cash crops include: cocoa, vanilla and palm oil. The estimated area under cultivation is 1, 610 square kilometers, and over 63% of the working population is engaged in agriculture, Ministry of Trade, Industry and Cooperatives (2017). Figure 4 shows the productivity of the region per unit land area. Fishing is also practiced on Lake Albert which has one of the most diverse fish fauna in Uganda. The district has 22 fish landing sites that also act as main outlets to the markets. Gold mining is done at the River Kafu basin, and salt mining at the Kibiro hot spring, Ministry of Trade, Industry and Cooperatives (2017). The recent discovery of oil and gas in the Albertine Graben region has influenced the economy and development of Hoima district.

Enterprise	Present productivity (kg/acre)	Ideal production (kg/acre)	Target 5 years (kg/acre)
Rice	1, 646	2, 550	2, 000
Maize	681	1, 600	1, 500
Cassava	2, 000	10, 000	2, 700
Pineapples	3, 145	6, 000	4, 423
Bananas	500	6, 000	862
Beans	350	900	550
Ground nuts	450	1, 000	700
Sweet potatoes	2, 100	5, 000	3, 000
Millet	600	1, 800	1, 000
Coffee	1, 500	2, 000	2, 000
Cocoa	400	900	550
Cotton	1, 200	1, 500	1, 500

Figure 4: Productivity and acreage of some crop enterprises in Hoima district.

Masindi district, which borders Hoima district, has several economic activities owing to its natural features, and rainfall reception zones. The major economic activities carried out in high rainfall zones of the district include: pit-sawing especially in the Budongo Forest, as well as the growing of crops such as maize, cassava, sugar cane, tobacco and bananas. This has contributed to increased household incomes enabling the population to sustain their livelihoods. Similar activities are carried out in areas receiving medium rainfall, however,

pastoralism, fishing and cotton growing are the major activities carried out in low rainfall zones, Masindi District Local Government (2009).

4.2 Market Opportunities

Owing to the geothermal source temperatures, the region has the capacity to apply numerous direct use geothermal applications in the agroprocessing industry such as: coffee, cotton, cassava and pineapple drying, drying of timber, heating of greenhouses and establishment of a geothermal spa for recreation and balneological purposes.

5. Katwe Geothermal Prospect

The Katwe geothermal prospect is situated in the Katwe-Kikorongo Volcanic Field (KKVF), south of the Rwenzori massif in Kasese district. It is bordered by the Lake Edward and Kazinga Channel to the south and to the east by Lake George. The prospect stretches from Lake Katwe to Lake Kikorongo and is bordered to the south by Lake Edward and the Katwe – Katunguru road, to the west by River Nyamugasani, to the north by the Kikorongo – Bwera road and to the east by the Katunguru – Kasese road, Bahati and Nyakecho (2010). The prospect occupies an area of approximately 150 km^2, Bahati (2012). The fluid temperature estimates from reliable geothermometry for this prospect are between 160 – 220 °C, Bahati and Nyakecho (2010).

5.1 Economic Activities

Kasese district in western Uganda has a population of over 700, 000 people whose main economic activities are crop production, animal grazing, brick making, timber harvesting and charcoal making. The main cash crops grown include: coffee both Robusta and Arabica, passion fruit, cotton, pineapple and mangoes while the major food crop grown is maize grown in the Kitwsamba-Hima area. Other food crops include beans, Irish potatoes, cassava, millet, groundnuts, sweet potatoes and soya beans.

Mining, tourism, fish farming and industry are the other areas of economic activity. Some of the mineral resources mined in the region include: copper, cobalt, cement and lime, and salt. Tourism is made possible by the presence of numerous wildlife species, national parks and bird sanctuaries, while industry includes cement production and agroprocessing. According to Kasese District Local Council (2009), there is one agroprocessing plant found in Kasese Town Council called Reco Industries Ltd and it deals in the production of fruit juice, chili sauce, pepper, and other products.

Salt production is one of the major economic activities in Kasese district. Aasen (n.d) infers that Lake Katwe has the capacity to sustain a plant for over 30 years at 40,000 tons/annum NaCl production from its reserves of 22.5 million tons of crystalline salts. The lake contains the best salt reserves in Uganda which are believed to come from a salty volcanic rock and brought into the closed crater by saline springs around the edge of the lake which discharge water adding about 2,000 tons of salts to the lake each year. Although no comprehensive record keeping exists at the site, annual production at the lake is put at close to 15,000 tons/year.

5.2 Market Opportunities

Geothermal direct use application would play a vital role in boosting the salt extraction industry in the area. Timber drying, brick hardening, waste water treatment, a geothermal spa

and drying of agricultural produce such as coffee, cotton, pineapples and mangoes, as well as food and fruit processing create lucrative areas of investment.

6. Panyimur Geothermal Prospect

Panyimur Geothermal Resource Area (PGRA) is one of the low temperature geothermal fields that are found in the Western arm of the East African Rift system. The Panyimur hot springs are divided into three hot springs which include Amoropii, Okumu and Avuka. All three lie on the Rift Valley escarpment. They extend in a northwesterly direction and are likely to be controlled by a major boundary fault (Muhwezi, 2009). The hot springs are located on escarpment front just near the shores of Lake Albert, in Panyimur sub-county, Nebbi District. Subsurface temperature estimates of 80 - 120˚C have been inferred within the region, although the presence of hydrogen sulphide suggests that higher temperatures are possible, Armannsson and Kato (no date).

6.1 Economic Activities

The main economic activities in Nebbi district are crop agriculture, animal husbandry and fishing. Some of the crops grown include; coffee, maize, tea, cotton, cassava, millet, sorghum, simsim (sesame), pineapples, tomatoes, cashew nuts, okra, to mention but a few. Fishing is done on Lake Albert and in the Albert Nile and is practiced widely for both subsistence and commercial purposes. The common fish caught are the Nile perch (Lates Niloticus) and Tilapia (Oreochromis Niloticus). The district produces over 7, 595 tons of fish annually, Ministry of Trade, Industry and Cooperatives (2017), some of which are smoked, sun dried or salted to improve their shelf life. The region also prides in production of honey and hosts a modern honey processing factory. The area has several touristic sites and features; a national part, cultural and historical sites, and magnificent water falls.

6.2 Market Opportunities

Although the prospect has lower source temperatures compared to the other prospects considered in this paper, there still exist opportunities to apply geothermal energy of the drying of agricultural produce, especially coffee and maize, thereby enhancing food security, as well as fish drying. Honey processing can also be developed to add value to the locally produced honey.

7. Rubaare Geothermal Prospect

The geothermal area is situated in Rugarama sub-county, Rushenyi county in Ntungamo District. The subsurface temperatures at Rubaare are estimated to be 134 - 140˚C based on reliable Na/K and silica geothermometers, Armannsson and Kato (no date).

7.1 Economic Activities

Agriculture is practiced on a large scale in Ntungamo district. The major crops grown include banana, coffee, pulses (beans and peas), cereals (millet, maize and sorghum), potatoes and vegetables. Banana growing is a major economic activity in this area and takes up a considerable area of cultivated land. Livestock rearing, especially of cattle is carried out, providing milk, meat, skins and hides, although goats, pigs and rabbits are also kept for meat, and poultry for eggs, Ministry of Trade, Industry and Cooperatives (2017).

Tourism in Ntungamo District is not well developed although there exist several touristic sites, including: The Karegyeya Rock, Lake Nyabihoko, the Uganda-Rwanda Border and a diversity of bird species to gaze upon in the wetlands.

7.2 Market Opportunities

The source temperatures on the region allow for geothermal application in the areas of: plantain commonly known as matooke and millet drying, milk pasteurization, leather processing and a geothermal spa.

8. Kitagata Geothermal Prospect

Kitagata geothermal area is found in Kitagata subcounty, Igara county, Bushenyi district. It is situated on Ishaka - Kabale road at approximately 16 km from Ishaka town and 0.8 km from Kitagata trading center. The Kitagata geothermal prospect has its subsurface temperatures estimated to be between 120 - 140˚C, Armannsson and Kato (no date).

8.1 Economic Activities

Bushenyi district has a land area of 3, 949 square kilometers, lying between 910 and 2,500 meters above sea level. The main physical features include natural tropical forests of Karinzu and Imaramagambo covering an area of 784 km which serve as tourist attractions. The district's main economic activity is agriculture, which covers an estimated land area of 2, 215 square kilometers. Bushenyi is well known for the growing of bananas and dairy farming, however, coffee and tea are also grown on a considerably large scale, Aruho (2013). The people are also involved in semi-intensive agriculture, trade and commerce, transport, stone quarrying, sand mining, mineral mining, construction, tourism, and lumbering.

8.2 Market Opportunities

The use of geothermal heat in agroprocessing; drying of millet, matooke, coffee and tea is marketable, and would reduce the strain on forests to provide wood for such activities. Milk processing, leather tanning, timber drying, and a geothermal spa are also good ventures.

9. Ihimbo Geothermal Prospect

Ihimbo geothermal area is in Bwambara sub county, Rujumbura county, Rukungiri district. The geothermal area is situated in Ihimbo forest at a distance of about 1.5 km from the Rukungiri - Kihihi road via Bugangari, Bwambara and Nyamirama and about 2 km from River Ntungwa, River Birara being its main tributary. The source temperatures at Ihimbo are estimated to be 80 – 100˚C, however, the presence of hydrogen sulphide suggests that the source might be hotter than predicted by geothermometry, Armannsson and Kato (no date).

9.1 Economic Activities

The main economic activity in Rukungiri district is agriculture, which employs over 90% of the population. About 1, 150 square kilometers of the 1, 352 square kilometers of arable land is under cultivation, Ministry of Agriculture, Animal Industry and Fisheries (2016). Production is mainly subsistence, although the potential for intensive commercial farming exists. The two chief cash crops are coffee and matooke. Due to its altitude, Rukungiri District is ideal for cultivation of all crops including temperate fruits. Thus, in many sub counties there are successful farmers engaged in the production of grapes, apples, pears and

peaches. The district also has some of the best dairy farms in the country especially in the sub counties of Kebisoni and Buyanja. About 3.52 million liters of milk are produced in the district annually, Ministry of Agriculture, Animal Industry and (2016).

Several the inhabitants also derive their livelihood from fishing, particularly from Lake Edward. However, fish farming is also practiced by some families and fish processing takes the forms of; smoking (598,272 kg), salting (435,107 kg) and frying (54,388.4kg). The district also has very scenic views and several tourist attractions including; Bwindi impenetrable forest national park, Queen Elizabeth national park, Kisizi falls, Ilimbo and Minera hot springs.

9.2 Market Opportunities

The nature of agricultural and fishery activities in Rukungiri district presents a range of value addition sectors that can be boosted by geothermal heat. These can be; agro-processing of crops such as matooke, coffee, as well as fruit drying for export, juice processing, milk pasteurization and leather tanning. Fish drying, and processing can take advantage of the growth in commercial farming in the area, and geothermal spa for balneological and leisure purposes.

10. Kanagorok Geothermal Prospect

Kanangorok geothermal area is in the Kidepo Valley National Park, Kaabong district near the border of Uganda, South Sudan and Kenya. This area is located 9 km south of Mt. Lotuke that marks the border of Uganda and South Sudan. Kanangorok is a promising area owing to permeability and subsurface temperatures of 140 – 160 ˚C, Armannsson and Kato (no date).

10.1 Economic Activities

Animal husbandry is the main economic activity in the district. A great majority of the district population are nomadic pastoralists who roam the landscape looking for grass and water for their animals. Due to severe climatic conditions, agriculture is not widely practiced. However, the district has small holder farmers who grow both perennial and annual crops. The perennial crops include banana, coffee, and tea, while the annuals include maize, sweet potatoes, beans, cassava and groundnuts, Uganda Bureau of Statistics (2012).

10.2 Market Opportunities

Some of the possible uses of geothermal heat in this region include direct applications such as; maize drying, milk pasteurization and leather tanning. However, development of such projects may be difficult because of the nomadic nature of the inhabitants, thereby creating a threat to feasible project implementation.

11. Discussion

The market opportunities have been proposed on the basis of two key areas; the resource characteristics and economic considerations. The characteristics of the resource include; temperature, flow, chemistry and other parameters related to its sustainable utilization. The temperature of the source is very critic in the choice of direct use application. Applications such as heat for sterilization, distillation and sugar evaporation would require temperatures above 100ºC, whereas agricultural drying, milk pasteurization, balneology, to mention a few can be feasible with temperatures below 100ºC, Pasta, Zarrouk & Zyl (2015). Economic

considerations encompass the population and an its behavior. The behavior considers the current economic activities that dominate in a given prospective geothermal site and the nature of these economic activities. This also takes into consideration the amounts of produce from the activity in question.

12. Conclusion

The geothermal potential in Uganda has the capacity for application in direct use; drying of agricultural produce, dairy processing, balneology, apiculture, salt extraction and processing, and various industrial applications. Some ongoing direct use applications are in existence; however, the mode and scale leave room for enhancement. The agricultural based economy of Uganda makes it a suitable sector for the application of geothermal heat to enhance agricultural processes, hence boosting the economy.

All the geothermal prospects considered attest to the broad range on market opportunities for geothermal heat in the agroprocessing sector, notably agricultural drying of food, grains, fruits and vegetables, milk processing and leather tanning. Fish drying also has high prospects, as well as the development of geothermal spas for recreation and balneology to boost the tourism industry.

There exists a market for many of the products whose value can be boosted and enhanced using geothermal energy. However, there are several challenges limiting the advancement of these market prospects. These include: poor roads for transportation of produce to the targeted consumers, low awareness on best farming practices, and unpredictable long dry spells. Dealing with these challenges will go a long way in allowing areas to realize their full geothermal potential.

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