Proceedings World Geothermal Congress 2020+1
Reykjavik, Iceland, April - October 2021

Geothermal economic development and opportunities in Zambia: Five forces model approach.

Agnelli K. Author

Ministry of Energy, Department of Energy, 51254 Ridgeway, Lusaka Zambia

Agnelli317@gmail.com; agnelli.kafuwe@moe.gov.zm

Keywords: Zambia, economic development, geothermal value chain, private investment, five forces.

ABSTRACT

Zambia is situated in the southern part of the African rift valley system. The geothermal fields in Zambia belong to the Western branch of the East African rift system which are predominantly deep-flow low-enthalpy systems. With a strong focus on inclusive economic development, the Government has recognized the importance of supporting clean and sustainable energy as a key driver for economic growth. Geothermal energy has not only been identified as one of the major clean sources of sustainable energy but it has also the potential to further unlock the economic potential of interrelated industries such as agriculture, horticulture and tourism. This paper demonstrates the Five Forces model application to the economic development of geothermal resources in Zambia. The model highlights the geothermal strategies, competition with other technologies and geothermal economic development. This aims to identify opportunities in the geothermal value chain for Government support in leveraging private sector investments and open further the geothermal sector to foreign direct investments. The paper also demonstrates the social and economic benefits which accrue as a result of geothermal economic development and help in achieving some of the targets such as Sustainable Development Goals (SDGs). Lessons from other countries such as Iceland and New Zealand are adapted to suite the Zambian context.

1. INTRODUCTION

The power sector in Zambia has been predominantly hydroelectricity based and this has made the country susceptible to climate change. This prompted the Government to start aggressively promoting alternative sources of energy including renewable energy to diversify the energy mix away from a hydro dependent power system. As at 2018 Zambia's total installed capacity by technology was 2,892.94 MW broken down as follows: Hydro 2,398.25 MW, Coal 300MW, Heavy Fuel Oil 110MW , Diesel 83.60, Solar 1.09MW (ERB, 2018).Figure.1 shows installed energy generation by technology.

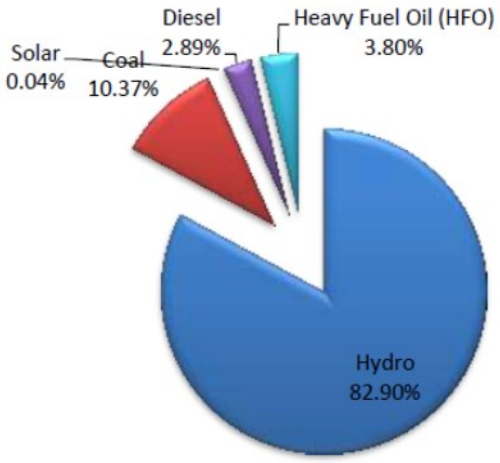


Figure1: National installed generation capacity by technology as 31st December, 2018

With the energy diversification drive Geothermal energy was identified as one of the energy sources to be exploited as it is renewable and is also baseload energy which is not affected by climate change.With the energy diversification drive Geothermal energy was identified as one of the energy sources to be exploited as it is renewable and is also baseload energy which is not affected by climate change.

2. GEOTHERMAL SYSTEMS OF ZAMBIA

Zambia has over 80 hot springs and geothermal manifestations. There was extensive exploration work that was conducted by the Geological Survey Department and C.A. Legg in the early 1970s. During this time there was a shortage of salt in the country the Zambian Government commissioned this study with the view to assess possibilities of producing salt from geothermal brines. From

this commissioned study .about 50 hot springs had their geology surveyed and geochemical analyses conducted (Legg, 1974). According Legg, Zambia's hot springs can be classified into seven main geographical groups listed below:

- Northern group;
- Mansa-copper belt group;
- Western group;
- Eastern group;
- Southeastern group:
- Choma group; and
- Lochnivar group.

Table 1 and 2 in the annex lists a few of the hot springs which have complete geochemical data. This was used to estimate the reservoir temperatures of these fields, which helps in guiding which hot springs are suitable for further geothermal exploration and development

The Northern group hosts the Kapisya and Kaleya hot springs which are situated in northern Zambia, close to the shores of Lake Tanganyika. These springs are fairly dilute in their chemical compositions. The other springs in this group are the Kaputa and Chiengi hot springs and are situated near Lake Mweru. The chloride concentrations in these hot springs are quite high. A traditional salt industry thrived around these hot springs where the brine from these hot springs was used to produce salt.

In the Mansa-copper belt group, there are the Mansa and Kabinda hot springs both situated in Mansa town. The other hot springs in this group are the Luano, Kafue and Chondwe hot springs, all of which are located in the Copper-Belt region. The Chondwe hot springs have large deposits of calcium carbonate around their periphery.

In the Western group there are the Kaimbwe Moshi and Chibemba hot springs in the Northwestern province. The Bilili, Kassip, Kapiamema, Longola, Lubungu and Bilili hot springs are situated around the Kafue national park in central Zambia. It is worth noting that the Kaimbwe hot springs are connected to a salt pan which is probably the largest in Zambia where a traditional salt industry was established and salt is still collected to this day, panned by traditional means.

In the Eastern group there are several hot springs namely Sitwe, Shiwa Ng'andu, Kanunshya, Kalamulilo, Chongo, Nabwalya, Kazakaza, and Nsefu, which are situated in the Luangawa trough. The others are Msoro, Mwape amd Kanzi.

The Southeastern group has the Mililo, Masaka, Bwingi, Kaligala, Chinyunyu, Mikwa and Kampika. These hot springs have Karoo basement faults and are situated in the Luano valley.

The Choma Group of hot springs includes the Mackleneuk, Chibimbi and Mosali springs. These springs are mostly situated on farms and have high levels of fluorine. They are within the Karoo basement rocks.

The Lochnivar group includes the Lochnivar, Bwanda, Gwisho and Namulala hot springs. These hot springs are hosted in the Kafue trough. They are some of the hottest hot springs in Zambia with surface temperatures as high as 95°C. They are located along a well-defined fault. Extensive exploration has been done in this area in the recent past, by Kalahari Geothermal Exploration, including the drilling of slim wells with positive results for exploration and production drilling (Maxwell et al., 2018).

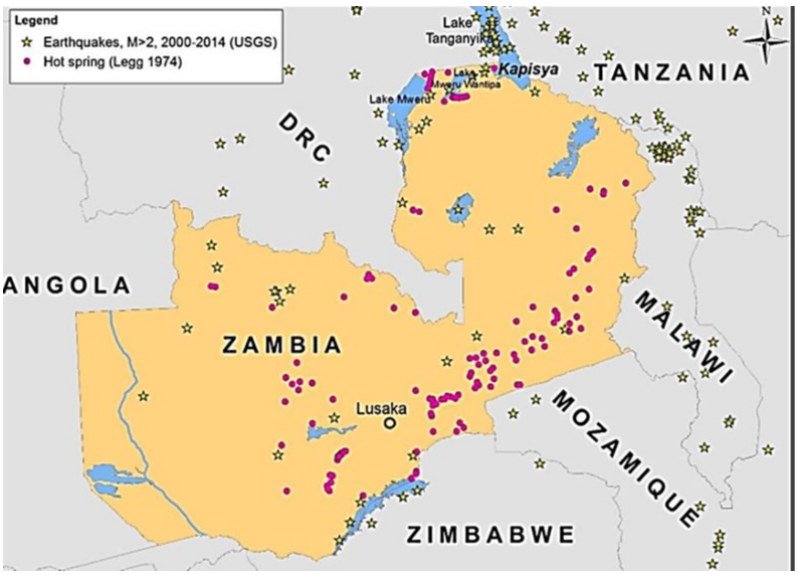


Figure 2: shows the location of hot springs and geothermal fields in Zambia.

3. PORTER´S FIVE FORCES MODEL

The Porter's five forces model will be used to analyse the attractiveness and opportunities of geothermal development in Zambia. This will also involve According to Michael Porter 'the essence of formulating competitive strategy is relating a company to its environment and the industry structure has a strong influence in determining the competitive rules of the game as well as the strategies potentially available to the firm. The intensity of competition in an industry is rooted in its underlying economic structure and goes well beyond the behavior of current competitors.

Figure 4 shows the five basic competitive forces competition an industry depends on.

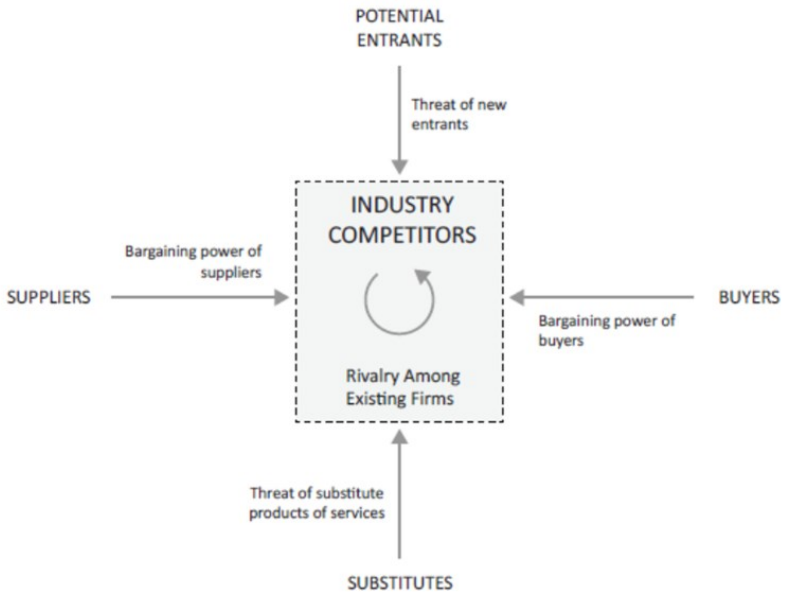


Figure 4: Forces Driving Industry Competition

Source: Porter (1980)

The five competitive forces are; threat of substitution, threat of entrants, bargaining power of buyers, bargaining power of suppliers and rivalry among existing firms. Customers, suppliers, substitutes and potential entrants all are "competitors" to firms in the industry and depending on the particular situation may be more or less prominent. From this context competition in a wider perspective may be extended rivalry. (Porter, 1980)

3.1 Threat of new entrants

The threat of new entrant to an industry such as power sector can present a challenge as they can bring more capacity, gain market share and substantial resources. New entrants usually enter a marketplace when the profit margins are high and with low entry barriers. However, when the barriers are high the newcomer can expect retaliatory measures from entrenched competitors (Porter 1980 & Lynch 2006). The main factors that restrain new entrants in the geothermal industry are economies of scale, product differentiation, capital requirements, access to distribution channels and government policy.(Bjornsson et al;2012)

3.1.1 Economies of scale

According to Bjornsson et al, most geothermal plants are sparsely located and have small capacities. However, as their experience improves and their capacities expand, the production price of geothermal energy tends to fall further if the plants attain economies. This then implies that if plant capacity increases, the average cost of drilling and plant construction decreases and the electricity produced become less expensive (Pew Center on Global Climate Change 2011). This means that it becomes harder for new companies entering the market and compete with existing large corporations which would have already achieved economies of scale.

3.1.2 Product differentiation

The nature of electricity is that it is a homogeneous product and this lack of differentiation in product and brand loyalty in the electricity market might theoretically strengthen the buyer power. In a perfectly competitive market, price is set according to supply and demand, and the lack of product differentiation means lower barrier to entry because entrants do not have to spend heavily to overcome existing customer loyalties (Porter 1980).

3.1.3 Capital requirements

Entering the electricity market requires a huge capital outlay and the geothermal sector is not an exception from that. The geothermal industry is faced with high upfront capital requirements, higher early stage exploration risk on the resource location and development uncertainty. Long project lead times also induce risk-related mark-ups over other renewable and traditional energy alternatives. This creates a barriers to entry for new entrants. Economic conditions combined with these factors, mean that private

firms seeking to develop geothermal projects may face greater difficulties in obtaining the requisite capital for exploration and development (Bjornsson et al, 2012). Although industry analysts suggest that geothermal development is currently less attractive to investors, equity investors see real opportunity in the sector (U.S. Department of Energy 2009).

3.3.3 Access to distribution channels

The geothermal market is somewhat geographically constrained, there is a question if it is economically feasible to carry the product from the resource to the market. Governments have been developing investment frameworks in renewables, and ways of overcoming administrative and grid access barriers.; this is the case for the European Union, and a Directive in 2001 led the 27 Member States to develop frameworks to support these factors (European Wind Energy Association 2011).Although renewable energy can access the electrical grid, they face some problems and in addition to cost, intermittency and reliability are two of the most important issues facing renewables growth. That being said, when renewables provide too much or not enough power, the reliability of the grid is affected and because renewables cannot economically store energy, they are not able to dispatch power on demand. On the other hand, only geothermal has capacities on the same order as conventional energy systems. Although geothermal power has the capacities, it can only achieve its best cost competitiveness in areas characterized by high enthalpy and low exploration and installation costs (International Energy Agency 2003).

3.3.4 Government policy

The growth in the geothermal industry has been led by the United States where the green energy bill and the stimulation package have accelerated geothermal development and deployment. This has led to the conclusion that many geothermal plants have recently realized very high operating margins. This can be related to two factors; the government's mandates and subsidies, as well as the growing market for carbon credits on the secondary market (Bjornsson et al, 2012).

In summary: There is low product differentiation in the electricity market, hence an assumption can be made that that high barriers to entry are created in the geothermal industry with distribution channels, high capital requirements and economies to scale. However, government policies significantly help in reducing these barriers.

3.2 Intensity of competitive rivalry

According to Porter (1980), rivalry occurs when one or more competitors either feel the pressure or see the opportunity to improve its position. Due to the fact that price cuts are quickly and easily matched by rivals and could have an impact on reducing revenues for all the firms involved; demand might be expanded by advertising battles that ensue or there can result enhanced levels of product differentiation in the industry where all the firms benefit. In finding out the intensity of competitive rivalry few important factors have to be examined. These are switching costs or lack of differentiation, diverse competitors and exit barriers.

3.2.1 Switching costs or lack of differentiation

When products or services are difficult to differentiate, the buyer's choice is predominantly focused on price and service which consequently results in pressure for intense price and service competition. However, if differentiation is possible, this would create layers of insulation against competitive warfare because buyers would have preferences and loyalties to particular sellers (Porter 1980; Lynch 2006). Governments have been supporting renewable energy and this has started making renewable energy competitive to non-renewable energy. In the long run this would lead to the conclusion that where e.g. geothermal energy is easily accessible it would be a cheaper and more favorable alternative to generate geothermal electricity. However, if the market segment already contains numerous strong competitors, rather than battling for market share with already established strong competitors the opportunity for geothermal companies would be to get a share of the increasing market instead.

3.2.2 Diverse competitors

Michael Porter (1980) said that competitors have different strategies, origins, personalities and, differing goals and strategies for how to compete. They may also have a challenges anticipating each other´s intentions accurately and agreeing on a set of "rules of the game" for the industry. The energy sector composition is such that there are many different competitors that have different approaches and goals and, combined with the factors aforementioned the likelihood for them to intensify competitive rivalry is very high

3.2.3 High exit barriers

According to Michael Porter when exit barriers are high, excess capacity does not leave the industry, and companies that lose their competitive battle do not give up. On the contrary, they struggle to hang on but due to their weakness, they tend to resort to extreme tactics. Consequently, the entire industry's profitability becomes persistently low. Michael Porter mentions that one of the major sources of exit barriers is specialized assets. Assets that are highly specialized to a particular business or locations are highly illiquid.

The geothermal power industry requires highly specialized assets, as the geothermal heat is only accessible in limited areas. This would lead to liquidity constraints and lower value therefore, companies would be compelled to continue producing despite lower margins. From the foregoing, an assumption can be made that the geothermal power industry has high exit barriers (Bjornsson et al, 2012)

In summary: The above mentioned factors indicate that there is a high intensity of rivalry among existing competitors. For geothermal companies and diverse competitors, there exists high exit barriers even though they have different approaches and

intentions. Being an undifferentiated product electricity relies mainly on price battling on the market which contributes further to competitive rivalry.

3.3 Substitute Products

Porter (1980) said that all firms in an industry are competing, generally, with industries producing substitute products. Substitutes limit the potential returns of an industry by placing a ceiling on the prices firms in the industry can profitably charge. According to Porter (1980) the more attractive the price-performance alternative offered by substitutes, the firmer the lid on industry profits. When identifying substitute products, it is a matter of searching for other products that can perform the same function as the product of the industry.

As geothermal industry is competing with other power industries, the electricity generated from other sources also has the same function. With already established power companies which might have already reached economies of scale there will be a tendency for the large companies to set a ceiling price for their generated power. As the geothermal industry is an industry with a homogeneous product, producers will have to charge within the price ceiling for their product or risk losing customers due to scale economies reached by larger, established electricity companies.

In summary: Electricity can be considered a homogeneous product, and it is hard to substitute electricity. On the other hand, rivalry on the electricity market is strong where different methods used in producing electricity compete. Natural resources can therefore play a large part in which method is chosen to produce electricity.

3.4 Bargaining power of customers

Michael Porter uses the term, buyers, to describe what can also be called the customers of the organization. A buyer group is powerful if the following conditions hold; if buyers are concentrated and there are few of them, if the product from the organization is undifferentiated, if backwards integration is possible and if the selling price from the organization is unimportant to the total cost of the buyer (Porter 1980; Lynch 2006). Among the main factors that illustrate bargaining power of customers in the geothermal industry is, if a customer is a large volume buyer and if the product is standardized.

3.4.1 Large volume buyers & standard products

Electricity can be considered as a standard product, which means that the buyer can find an alternative electricity producer to buy from if the price is not attractive enough. Also, if the buyer group is concentrated or purchases large volumes relative to sellers' sales, they could exert price pressure, which can cause a problem for electricity producers. If we assume that geothermal plants have high fixed costs, the buyer can put pressure on the price and raise the stakes to keep capacity filled (Porter 1980). If the industry is made up of numerous producers and large volume buyers, it could lead to high bargaining power of customers. On the other hand, if the producers were fewer, their power would be less. In the power industry, there are number of producers and the customer will always be looking for a cheaper alternative so we can assume that there is a constant threat of substitutes.

3.5 Bargaining power of suppliers

Michael Porter (1980) said that in many industries, government is a buyer or supplier and can influence industry competition by the policies it adopts, and many times the government´s role, as a supplier or buyer, is determined more by political factors than by economic circumstances. Governments and major landowners are often the supplier of costly land on geographical locations that fit geothermal energy. This means that in addition to government policy and subsidies they can influence the fixed costs for geothermal plants. In the power industry, governments, and sometimes major landowners, have high bargaining power as they can use policies and subsidies to help some sectors and hurt other ones at the same time. Moreover, where demand for electricity is growing rapidly, the price of electricity could go up as well. This could lead landowners to want their share of increasing price and take some of the electricity producers´ profit

4. OPPORTUNITIES IN THE GEOTHERMAL SECTOR IN ZAMBIA

4.1 Fish drying

Kapisya geothermal field is situated on the shores of Lake Tanganyika where there is also a fishing industry. The fish caught locally is sometimes smoked with wood gathered from the area. Gathering wood for fish drying is one of the contributors to deforestation. Refrigeration for the local fish industry is not available due to the lack of electricity to the area. Fish drying using geothermal resources can significantly contribute to the growth of the fish industry near Kapisya geothermal field.

Iceland is renowned for utilisation of geothermal resources which also include fish drying. There are over twenty companies that use geothermal resources for commercial fish drying (Arason, 2003). Geothermal fish drying as in Iceland can be used by the local fish industry at the Kapisya geothermal field. Sun drying of fish is predominantly used for fish preservation by the local fish industry in Kapisya. There are some challenges with sun drying of fish that are experienced during the rainy season as the fish is dried out in the open. However, with geothermal drying indoors, the wind or rain do not affect the drying process and there are no interruptions to the it. This is not the case when the fish is dried in the open in the sun, and in the case where the rainfall activity is high during the rainy season the drying process is frequently interrupted. According to Arason (2003), the following disadvantages are experienced in sun drying of fish:

- Sun drying makes the fish prone to contamination by dust;
- It is very dependent on the prevailing weather conditions;

Kafuwe

- There are slow drying rates in sun drying and this increases the chances of mould; and
- Drying of fish in the sun may not reduce the moisture content of the fish, thereby increasing the risk of mould as well as making it difficult to prevent mould growth.

The local fish industry in Kapisya and others localities along the shores of Lake Tanganyika encounter the challenges mentioned above regularly. According to Arason, 2018, fish drying using geothermal resources has many advantages, such as:

- It has a shorter drying time compared to sun drying;
- The drying can be done all year round and is not dependent on prevailing weather conditions;
- Contamination of the fish from flies and insects is controlled and prevented;
- The water content is consistent and the product quality is high; and
- This is a utilisation of local clean renewable resource compared to smoking fish as means of preservation using fire wood.

With the foregoing benefits the fish industry near Kapisya geothermal field can expand and exploit the potential of the geothermal resources in their region. This is very advantageous especially as there is no commercial refrigeration currently available, due to the non-electrification of the region.

4.2 Dairy processing

Geothermal has been successfully used to process dairy products in New Zealand. The Maori Tuaropaki Trust run the successful Miraka Milk Plant. Milk production is in significant deficit to demand and significant volumes are imported; actual production is well below estimated capacity. The location of geothermal fields is ideal as most are in rural areas where the population of cows is high. An example is the Bwengwa geothermal field. There are over 90,000 head of traditionally managed cattle in the near the Bwengwa geothermal field close to Lochnivar National Park. Little milk from these herds reaches the market as collection points are scarce. Making an assumption that 20% of herd are milking and assuming only half the milk could be collected, it is possible to have this as a basis for a viable processing industry. This needs considerably more research and liaison with the local farmers by consultants familiar with the industry. It is of note that there are various ongoing initiatives to improve the local dairy industry, including the Dairy Transformation Programme, which is funded by the New Zealand Government.(P.Vivian-Neal, 2018)

4.3 Power production

Identified geothermal systems identified in Zambia are mostly associated with Karoo (Permian) era sedimentary basins (figure 14) with crustal faults in which meteoric fluids circulate, being heated by the regional geothermal gradient and rising, to be held beneath low porosity sedimentary rocks (the Cap Rock), which can form low/medium temperature geothermal reservoirs of 130-200OC. Such setting hosts binary power plants in USA (largely Nevada) and Turkey. This is a different geologic setting to that associated with magmatic, active volcanism as developed in Iceland East African Rift (Kenya) and around the Pacific Ring of Fire.

With the promotion of diversification of power generation the Zambian Governments encourages private sector to undertake geothermal exploration with develop geothermal resources for power generation. For example, in 2011, the Department of Energy granted a geothermal exploration permit to Kalahari Geo Energy Ltd, ("Kalahari") a private Zambian company was granted feasibility study rights to carry out geothermal exploration in Bweengwa River geothermal resource area. Following an extensive and systematic exploration programme that included hydrochemistry, geophysics and the drilling of six temperature gradient holes, Kalahari is currently undertaking resource delineation work. The results from the pre-feasibility studies, which included slim hole drilling, have been yielded positive results with geo-thermometers ranging from 130°C to 180°C with very good permeability. Arising from the pre-feasibility study, an initial field power capacity was determined to be as 15MWe and as high as 90MWe.

KenGen of Kenya was also contracted to conduct feasibility studies on two sites in the country namely Kapisya and Chinyunyu geothermal fields. The initial results indicated a power density of about 2MWe each site respectively.

As outlined in the SREP investment plan geothermal energy is one of the priority energy sources for exploration and development.

Below are sites in Zambia that have studies conducted on their power potential.

Table 3:

Location	Model	Reservoir Temp	Reservoir Area	P90 (MWe)	P50 (MWe)	P10 (MWe)	Source
Bwengwa River	Fault Hosted	150-160 ℃	12-14Km^2	2	15	92	Kalahari /Geologica USA
Kapisya	Fault Hosted	120-130℃	0.5-1Km^2	-	2	-	KenGen
Chinyunyu	Fault Hosted	120-130℃	0.5-1Km^2	-	2	-	KenGen

Source: SREP Investment Plan, 2019

5 . DISCUSSION AND CONCLUSION

Zambia has aggressively started promoting renewable energy including geothermal energy for both direct use and power production. In analysing the attractiveness of the economic geothermal development in Zambia Micheal Porter's Five Forces model was used. As regards to the barriers to entry for developers there are lower barriers to entry as there are very few players in the geothermal in Zambia as much of the geothermal resources remain untapped.

When it comes to rivals in the power sector hydro power generation is still dominant and it could be argued that there is very high rivalry from diverse power developers other than geothermal such as wind, solar, hydro and also coal. Geothermal power is renewable energy, not affected by climate change and is also baseload power which is ideal for industrialisation. The Zambian has begun the push to industrilaise and and geothermal energy has is an exceptional source of baseload renewable energy.

The cascading uses of geothermal energy give it another competitive advantage over other energy sources as it can also be used for direct use such as fish drying, milk processing, horticulture and hot spas in the tourism sector.

REFERENCES

Arason. S:The Drying of Fish and Utilization of Geothermal Energy-The Icelandic Experience. GHC Bulletin, 2003

Bjornsson, E.J., and Valtysson, K.T.: Performance Analysis of Publicly Listed Companies-A Principal Componenet Regression, Arhuss School of Business , (2012)

European Wind Energy Association EU Energy Policy to 2050-Achieving 80-95% Emissions Reductions (2011).. Available from:http://www.ewea.org/fileadmin/ewea_documents/documents/publications/reports/EWEA_EU_Energy_Policy_to_2050.pdf

Legg, C.A.,: A reconnaissance survey of the hot and mineralised springs of Zambia. Ministry of Mines and Industry Economic report of the Geological Survey (1974)

International Energy Agency Renewables for Power Generation: Status & Prospects. (2003). Available from:iea.org.

Maxwell, W., Haizlip, J., Prina, N., and Vivian-Neal, P., 2018**:** *Bwengwa River, Zambia – Exploration of a Non-Volcanic African Geothermal System*, Proceedings, 43rd Workshop on Geothermal Reservoir Engineering Stanford University, Stanford, California, 2018, SGP-TR-213, 15 pp.

Porter, Michael: Competitive Strategy; Techniques for Analyzing Industries and Competitors. New York: The Free Press. (1980).

Pew Center on Global Climate Change). *Geothermal Energy*. (2011 Available from: http://www.pewclimate.org/technology/factsheet/geothermal

U.S. Department of Energy Energy Efficiency & Renewable Energy:(2009).Geothermal Technologies Market Report. Available from:http://www.nrel.gov/analysis/pdfs/46022.pdf

Zambia Investment Plan (2019)

ANNEXES

Hot Springs and Geothermal fields	Surface Temperature	Estimated Reservoir Temperature		Discharge (l/s)	Comments
		Lower range	Higher		
EASTERN GROUP					
Malanga	58	72	119	2	Lower estimate Truesdell\Higher estimate Fournier
Chikoa	64	104	148	6	Lower estimate Truesdell\Higher estimate Fournier
Msoro	58	165	199	5	Lower estimate Truesdell\Higher estimate Fournier
Mwape	46	135	155	4	Lower estimate Fournier\Higher estimate Gigennbach
Kanzi	35	93	138	2	Lower estimate Truesdell\Higher estimate Fournier
SOUTH-EASTERN GROUP					
Mililo	65	169	202	-	Lower estimate Truesdell\Higher estimate Fournier
Kalingala River	50	123	164	6	Lower estimate Truesdell\Higher estimate Fournier
Chinyunyu	63	109	115	6	Lower estimate Truesdell\Higher estimate Fournier
CHOMA GROUP					
Muckleneuk North	44	-	-	0.3	Low confidence with geothemometry
Muckleneuk Main	74	-	-	6.3	Low confidence with geothemometry
Chibimbi	58	-	-	0.6	Low confidence with geothemometry
Mosali	52	-	-	0.4	Low confidence with geothemometry
LOCHNIVAR GROUP					
Lochnivar Park	-			-	
Gwisho	71	151	205		Low estimate Truesdell\Higher estimate Giggenbach
Bwanda	94	162	211	17	Low estimate Truesdell\Higher estimate Gigennbach
Namulala	52	-	-	9	Low confidence with geothemometry

Figure 1. Geothermal fields in Zambia.(Adapted from C.A.Legg,1975)

Hot Springs and Geothermal fields	Surface Temperature	Estimated Reservoir Temperature		Discharge (l/s)	Comments
		Lower range	Higher range		
NORTHERN GROUP					
Kalaye	51	118	164	7	Lower estimate by Truesdell\Higher estimate by Fournier
Kapisya	85	115	123	25	Lower estimate Silica \Higher estimate by Truesdell
Kaputa	51	71	86	2	Lower estimate Quartz\Higher estimate Gigennbach
MANSA GROUP					
Mansa	49	151	188	4	Lower estimate Truesdell\Higher estimate Fournier
Kabunda	42	176	217	3	Lower estimate Truesdell\Higher estimate Fournier
Luano	50	147	184	10	Lower estimate Truesdell\Higher estimate Fournier
WESTERN GROUP					
Kaimbwe	53	120	140	2.5	Lower estimate Fournier\Higher estimate Giggenbach
Lupiamanzi	79	106	149	15	Lower estimate Truesdell \Higher estimate Fournier
Longola	70	106	149	10	Lower estimate Truesdell \Higher estimate Fournier
Lubungu	76	119	167	15	Lower estimate Truesdell \Higher estimate Fournier
EASTERN GROUP					
Kanunshya	28	114	175	1	Lower estimate Truesdell\Higher estimate Gigennbach
Kalamulilo	40	125	184	3	Lower estimate Truesdell\Higher estimate Gigennbach
Chongo	12	165	215	11	Lower estimate Truesdell\Higher estimate Gigennbach
Nabwalya South	67	138	195	10	Lower estimate Truesdell\Higher estimate Gigennbach
Kazakaze	55	94	158	2.5	Lower estimate Truesdell\Higher estimate Gigennbach
Nsefu	56	148	185	5	Lower estimate Truesdell\Higher estimate Fournier
Nsefu Spring	30	141	197	5	Lower estimate Truesdell\Higher estimate Fournier
Manze	29	92	113	5	Lower estimate Fournier\Higher estimate Giggenbach
Musaope	74	176	208	7	Lower estimate Truesdell\Higher estimate Fournier

Figure 2. Geothermal fields in Zambia.(Adapted from C.A.Legg,1975)