Review Article

Prospects and challenges of Geothermal Energy in Uganda

Abstract

This paper explores geothermal energy use as a renewable energy option in Uganda is discussed in pursuit of sustainable development. Uganda has been undergoing fast economic growth particularly as demonstrated by its resilience against the effects of COVID-19, it must develop its renewable energy resources to match this growth. In this paper, we present the findings of an exploratory research to ascertain potential of geothermal energy for Uganda of 1500MW (3.6% of overall energy potential). The prospects and challenges of geothermal energy development are discussed. In concluding remarks good policies with strong political will , manpower training , financial support for research , and financial and subsidy incentive programs .

Key words: Geothermal Energy, Electricity, Barriers, Uganda.

1.0. Background

1.1 Preamble

Energy plays a crucial role in economic development. It is the engine for driving nearly all other sectors of the economy [1, 2]. Energy drives engines and processing in industry, irrigation and drying in the agricultural sector and in the water sector, it is used for pumping water for irrigation, water treatment [3]. Uganda predominantly relies on traditional biomass for her energy needs, this has led to deforestation of the country's forest resource. Over 87% of Uganda's energy mix is from biomass mainly used for cooking (NDP, 2020). Uganda needs to diversify her energy mix to meet her development needs. This is the rationale upon which geothermal energy resource potential is re-examined.

1.2 Energy resources and global development

Global geothermal potential is about 75 GW and actual production is 15.4GW about 24.9% of this is produced in U.S.A for 2019 (WEC 2020). With Global geothermal leading producers include U.S producing about 3.8GW_e, Philippines 1.87, Indonesia 1.16 and Turkey 0.62GW_e (Young et al. 2019). Geothermal is favourable due to a small carbon footprint. It is among the largely untapped geothermal resources with which does not emit a lot of carbon emission (Pan et al. 2018).This geothermal technology has grown for more than a century and contributes less than 5% of global energy mix. The great East African rift valley system has a potential of about 15,000 MW_e of which less than 1000MW_e has been developed (Kombe, 2019). The earliest of geothermal power plant was founded in 1904 at Larderello, Italy powered by steam from fairly shallow wells and vapour and produced dry steam; it was a simple power plant design (Taleb 2009). The design of geothermal power plants today varies in several types and designs to take care of the type of steam produced by the wells, such as single-flash geothermal power plant, double-flash geothermal power plant, flash binary geothermal power plant, simple organic Rankine cycle, organic Rankine cycle with Internal Heat Exchanger (IHE) Nasruddin et al. (2016), and regenerative organic Rankine cycle with IHE, At the moment, the capacity being operated is amounted about 10.7 GW, in countriesthat have utilized geothermal energy. Geothermal power generation capacity of 15000MW exists (Zakkour 2016). Geothermal direct utilisation of 70,885MWt exists worldwide in more than 82 countries, it's a clean energy source that has an immense potential for development (Lund and Boyd 2015)..

1.3 Energy resources and power sector in Uganda

Uganda is richly endowed with energy potential of 41,800MW, of this however, 1268.9MW (3%) only is developed as shown in Figure 1. Geothermal power development in Uganda, has been constrained by a number of challenges, despite its numerous benefits; to mitigate this efforts have been put on the use of clean energy sources. Sustainable development goal (SDG7) is to ensure access to affordable, reliable, sustainable, and modern energy for all. Attaining SDG 7 depends on the quantity and quality of energy resources. Global energy policies are shifting towards greater consumption of renewable energy, exploiting renewable has been a priority for Uganda since 90% of all energy consumed is from renewable energy namely hydro, biomass and solar (Fashina, et al., 2018). Uganda should, therefore, focus at the scenario of 100% renewable energy mix.

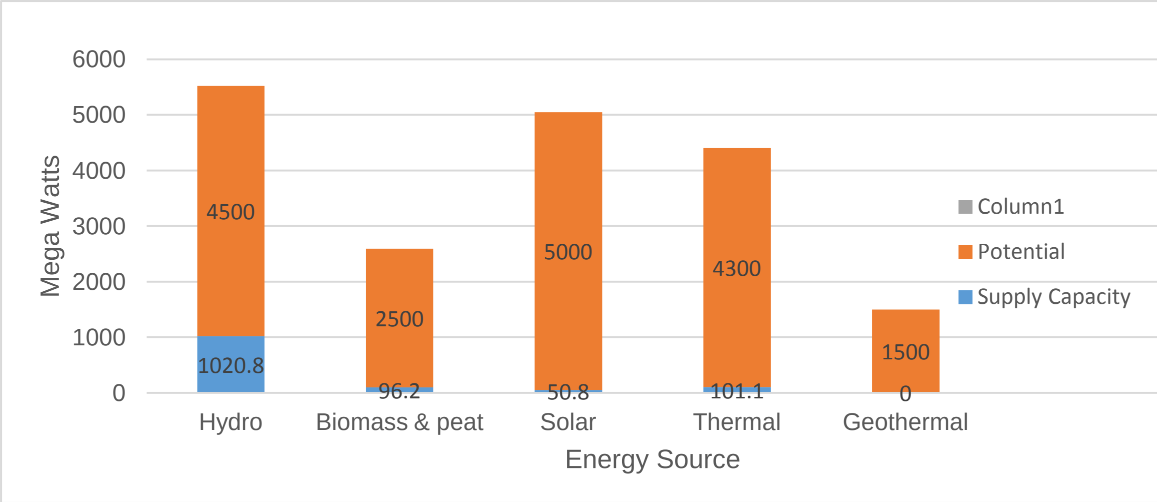


Figure 1: Present and future cumulative power generation potential in Uganda
(No concuerda la cantidad de 41800 MW, la suma es solo 17,800!!, por tanto el porcentaje es erroneo)

Source: Adapted from ERA(2020)

As shown in the graph above, hydroelectricity dominates Uganda's energy mix with 80%, followed by thermal co-generational 8%, biomass co-generational at 8% and solar energy at 4%. *(revisar porcentajes* Most hydroelectricity potential is along the R. Nile, Geothermal energy and most nuclear power is in Western Uganda while Fossil fuels are also predominantly in Western Uganda. Wind energy potential is in the mountainous, isolated, hilly and remote areas of Karamoja, Kalangala Islands (Wabukala et al. 2021). Biomass and Solar are more evenly distributed all over the country.

1.4 Why this paper?

This paper seeks to provide the current geothermal energy potential prospects and challenges with the aim of prioritizing technologies that promote clean affordable reliable energy consumption. The growing emission of greenhouse gases is a global concern. This can be mitigated by using cleaner modern renewable energy sources. It is in this light that prospects and challenges of geothermal energy development in Uganda. .(falta concluir enunciado).

The rest of the paper is structured as follows: the second section gives an overview of Uganda's geological structure, the third section reviews literature, the fourth section treats methodology while section five focused on results and discussion. The sixth section is on conclusions and recommendations.

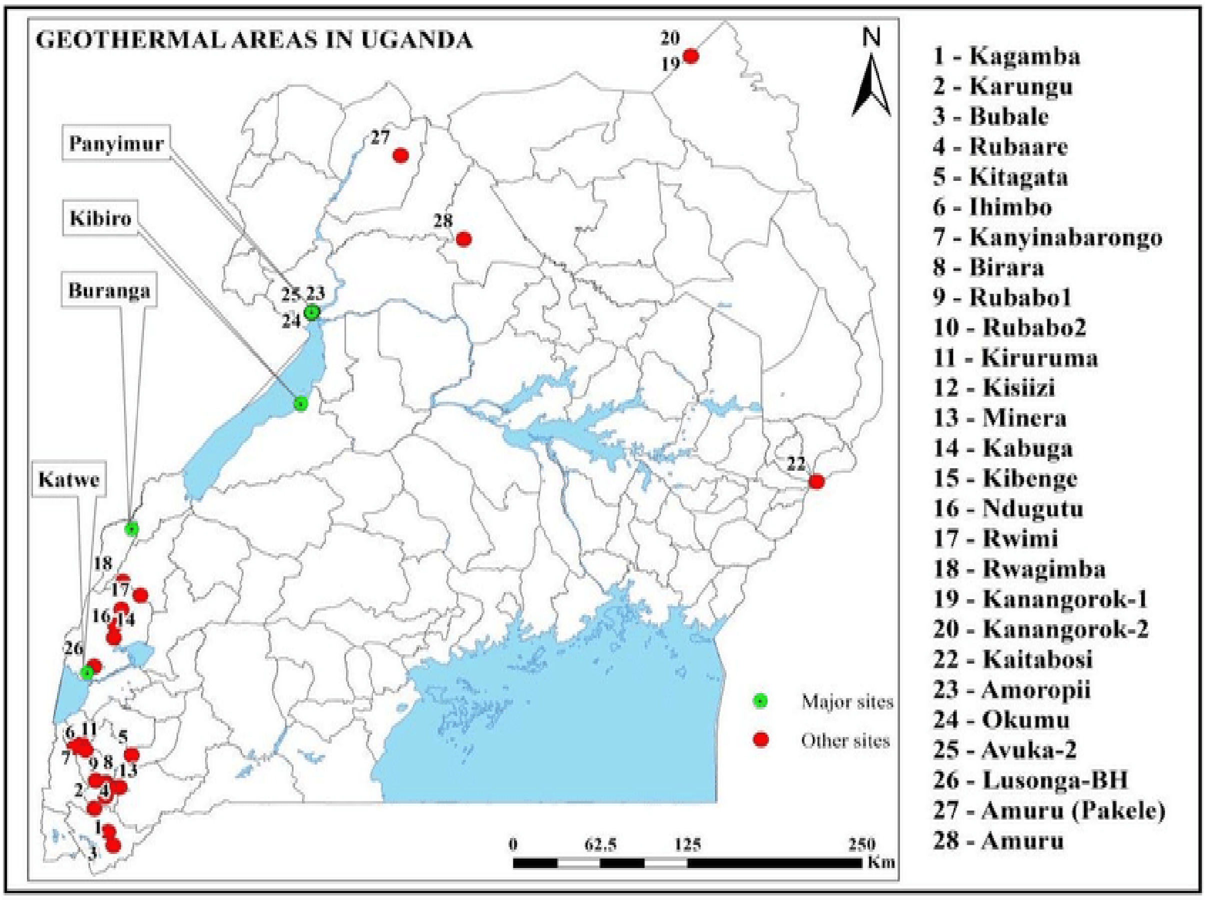
2.0 Overview of Uganda's Geological structure

Geothermal potential exists in the Uganda Rift valley system with over 24 sites. Major geothermal areas namely Katwe- Kikorongo (Katwe), Sempaya- Buranga and Kibiro, Panyimur in West Nile. The other potential sites are Kanangorok, Karungu, Bubale, Rubaale, Kitagata, Kibenge and Kabuga as shown in map below in Fig.2. Geological surveys were first done by a British geologist, Wayland in 1921 and geysers in Western Uganda were studied and by 1935 he had produced a full geological survey report on Uganda, where 46 hot and mineralised springs were listed (Kamese,2004). Geothermal energy potential was first estimated in the 1982 to be 450 MW (McNitt,1982), the exploration stage was initiated in 1993 with over 40 sites were studied and exhibited impressive geophysical properties including temperature gradient, micro-seismic and earthquake done. For instance, Kibiro had a subsurface temperature of over 150-250 ^{0}C, the manifestation of hot springs is at 86 ^{0}C, 10-15 ppm of hydrogen Sulphide (H_2S), Katwe-Kikorongo had a subsurface temperature of 140-200 ^{0}C, and a surface temperature of 32 ^{0}C, the manifestation of hot springs is at 30-70 ^{0}C, 30-40 ppm of hydrogen Sulphide (H_2S),. The temperature gradient for is 13-36 ^{o}C /Km making the geothermal reservoir deep-seated. Large geophysical anomalies were identified in Katwe and Kibiro. Sempaya - Buranga had a subsurface temperature of 120-150 ^{o}C, the manifestation of hot springs is at 98 ^{o}C is a spectacular geothermal resource as illustrated in Fig.12. Panyimur had a subsurface temperature of 200 ^{o}C, the manifestation of hot springs is at Amoropii (60^{o}C), Avuka (45 ^{o}C) and Okumu (47 ^{o}C), 10-12 ppm of hydrogen Sulphide (H_2S),. Geochemical exploration studies were also carried out, Isotope hydrology studies to delineate flow characteristics of geothermal waters and identify their recharge areas. The geothermal fluids for Katwe- Kikorongo are rich in carbonates and sulphates, and salinity of 19,000 -28,000 mg/kg total dissolved solids. The source of high concentration of hydrogen sulphide is both volcanic and hydrothermal. Kibiro is depleted in sulphates with 35 ppm and its interaction with hydrocarbons produces H_2S; salinity levels of 4000-5000 ppm. Geological surveys revealed Magmatic source of heat for Katwe, Buranga and Kibiro. It has explosion craters, ejected pyroclastics, lava flows tuffs with a lot of granites and gneissic rocks. (Bahati, et. al., 2008, 2004).


Fig.2; Illustration of a geothermal hot spring at Sempaya

In 2014, the geothermal resources department was created in Ministry of energy and mineral development (MEMD) with a budget of Uganda Shillings 100Million (U.S $30000) for core staff and Geothermal energy Development project had a budget of Uganda Shillings 5.1 billion (U.S $1.2 Million) Ministry of Finance Planning and economic Development (MOFPED).The sub surface temperature levels range between 150 ^{o}C to 200 ^{o}C. A model by Government and federal Institute of Geosciences and natural resources Germany has been developed for possible geothermal power development with 30MW for the start and 150 MW in the medium term. Preliminary viability and feasibility studies involving drilling of deep exploration wells that will help provide information on the reservoir temperature, fluid chemistry and other petro physical parameters are being done. Geothermal power is costed at U.S$ 0.077 per kWh which is cheaper than most renewable energy resources like hydro and solar (ERA 2020). Installing 150 MW of geothermal power would allocate electricity to 3,000,000 people in rural areas of western Uganda.

Fig 3. Map of Uganda locating geothermal energy resources.



Therefore a good understanding of the geological structure and tectonic setting of Uganda as part of the great East African Rift valley system is of immense value to Geothermal energy development. it is also useful actualising the potential mineral resource bases existent like copper and cobalt at Kasese, gold and silver at Buhwezu, Limestone at Hima, mixed salt brines at Katwe, gypsum at Kibuku, Rare earths elements (REE), zeolites and bentonite clays. All these have reinforcing values that geothermal reservoirs developed into geothermal power would power mineral development (Mugadu 2001).

3.0 Literature Review

Kombe (2019) considered barriers and strategies in East Africa including financial, institutional, technical social and environmental barriers. Jianchao et al. (2018) used PESTEL to analyse prospects and challenges in which he highlighted political economic, social technological environmental and legal challenges to analyse geothermal energy development in China (Colmenar- Santos et al. 2018), studied measures to remove barriers to geothermal energy in European Union (EU) and classified geothermic resources as low, high enthalpy and renewable energy mix his finding were that in low enthalpy geothermal power the barriers were mainly social, economic and financial barriers while in Agricultural sector barriers were lack of technical knowledge, social, technical, financial and normative or institutional barriers, in the high enthalpy geothermal power financial and economic barriers the overriding. Kubota et al. (2013) investigated barriers of developing geothermal power generation in Japan societal acceptance by stakeholders in hot springs and identified financial and economic barriers, development risk societal barriers and local acceptance as the most prominent barrier. Taleb (2009) examined barriers hindering the utilisation of geothermal resources in Saudi Arabia he identified non-technical barriers as political economic, social and educational barriers as summarised in table 1.

Table 1: Summary of relevant empirical studies

Author (year)	Title	Approach and key finding
Taghizadeh-Hesary et al. (2020)	Role of energy finance in geothermal power development in Japan.	It analyses social, legal economic, social and technical barriers of geothermal power development in Japan
Young, et al. (2019)	An Analysis of Non-Technical Barriers to Geothermal Deployment and Potential Improvement Scenarios	Makes an in-depth analysis of all barriers except technical barriers and measures for overcoming them.
Ambumozhi (2018).	Overcoming Barriers to Geothermal Energy Development in Indonesia.	Analyses technical and non-technical barriers to geothermal development in Indonesia
Pan, et al. (2018).	Establishment of Enhanced Geothermal Energy Utilization Plans: Barriers and Strategies	It reviews barriers and strategies to adopting geothermal resources in respect of Institutional, regulatory, technological and financial aspects.
Colmenar-Santos et al. (2018).	Measures to Remove Geothermal Energy Barriers in the European Union	It examines the market barriers that make it, difficult to use low enthalpy, high enthalpy and electrical use of geothermal resources in EU.
Levine and Young (2017)	Crossing the Barriers: An Analysis of Land Access Barriers to Geothermal Development and Potential Improvement Scenarios	Analyse Land access challenges to including tribal and cultural resources, environmentally sensitive areas, biological resources, land ownership, federal and state lease queues, and proximity to military installations.
Thorsteinsson& Tester (2010)	Barriers and enablers to geothermal district heating system development in the United States	It analyses barriers and enablers to utilising Geothermal district heating systems for space and water heating.
Taleb (2009)	Barriers hindering the	It identifies obstacles and enablers to geothermal development in Saudi Arabia

	utilization of geothermal resources in Saudi Arabia	

4.0 Methodology

The study used qualitative research approach, inductive (Edmonds & Kennedy, 2020), exploratory and investigative (Merriam, 2002) in nature. It included a holistic view, with the structure impacting on context settings such as policies, sociocultural, context and situation analysis (Kzillen & Jarrett, 2007). We explored and interpreted complex data from sources such as documents, literature and archival information (O'Leary, 2017). Documentary review was done by reading different sets of documents and triangulating facts therein. The important aspects to be considered in this study to maintain a high level of: validity and reliability, was addressed through using strategies like triangulation; the researcher's position or reflexivity, variation in sampling like location, groups of people, time; and providing a detailed description about the research process (Merriam, 2002). In-depth exploration under a qualitative framework helped best answer the research questions (WNeuman, 2006).

5.0 Results and Discussion

5.1 Prospects of Geothermal Energy in Uganda

5.1.1 Power generation

The sites whose exploratory work has been done and commendable results are Katwe-Kikorongo, Sempaya- Buranga, Kibiro and Panyimur. Their high temperature gradient indicate a potential for geothermal reservoirs, hence fit for deep exploratory drilling and carrying out an environmental impact assessment. This leaves a great opportunity for geothermal power development from 24 major sites that can generate up to 1500 MW.

5.1.2 Direct uses

These are non-electric uses, geothermal energy in Uganda has limited direct uses including heating (Low and high enthalpy), tourism, swimming and bathing, curative (medicinal value) and drying crops (Jianchao et al. 2018).

Geothermal is used for combined low and high enthalpy geothermic opportunity for domestic and commercial purposes, where hot water and quick dishes are prepared using hot water got from hot springs like those in Kibiro and Kitagata. Therefore geothermal can provide a reliable and sustainable heat source causing savings of up to 80% in emissions.

Tourism both local and foreign Visitors frequent who come to enjoy the beautiful and spectacular sites hence earning revenue to the country. Swimming and bathing mainly in the warm waters folks in the area often spend time swimming and bathing so it gives immense recreation value. And enhances recreational value of the revelers visiting the site.

Concerning the balneological (medicinal) Value, people strongly believe in the curative value of these hot springs. They immerse aching muscles in hot springs only to get a healing. It is useful in healing skin diseases and rush. Possibly the presence of this highly mineralized water with Sulphur compounds may actually help in deterring bacterial and fungal infections hence improving their health situation. Although, the curative value of these resources has not been scientifically studied. It remains an alternative to curing certain complications and disorders that people around this area suffer from.

Drying crops especially annual crops like maize and beans are often dried using geothermal energy. This helps reduce post-harvest losses as quicker drying of cereals preserves its value and increases its price.

5.2 Challenges of Geothermal Energy Development in Uganda

Government has expressed commitment to meeting the needs of its people by promoting an energy mix that is rich in renewable energy, however, to achieve this, a number of challenges have to be addressed. The following are the challenges that may reduce the steady growth of Geothermal Energy development and its utilisation in Uganda.

5.2.1. Land access barriers and competition

Land issues are very complicated especially in Uganda where the land law and property rights are not properly assigned, worse still the intending project to be sited on such land, is not only private land but a tribal and cultural aspect (Young et al. 2019). Most land is for traditional subsistence agriculture being the major occupation of the inhabitants; ownership of such piece of land may also belong to families or communally owned. Geothermal energy projects adversely affect land for agricultural development through construction of power plants and transmission lines. Geothermal energy projects on a large scale will involve distortion of biodiversity and ecosystems, construction activities is associated with destruction of certain plant and animal species, interference with breeding and migratory patterns. The habitat quality will be adversely affected this is a great threat especially to the endangered species (Iwayemi 2008). Most geothermal sites are located in environmentally sensitive areas that are part of Queen Elizabeth national park that is conserved and would require de-gazetting to fully exploit the geothermal resources. The biodiversity and ecological value of the land, has in it species of biological value that must be preserved including Guerrillas, white rhinocerous and other bird species. Altough compensation schemes to displaced people have been suggested, this still makes geothermal power development difficult (Levine and Young 2017).

5.2.2 Large investment costs

One overriding challenge to geothermal energy development is the high installation and investment costs of geothermal energy equipment. For instance it cost about U.S $ 5million to drill one oil test (Kombe 2019). The high initial costs of investment erodes investor confidence, it also contributes to overall inadequacy of financial instruments as well as uneven financial sectors. Therefore the high upfront costs of geothermal energy projects remain a challenge to its development. While operational and Maintenance costs Geothermal Energy Development is considered as alternatives for all urban, rural and even remote areas including island communities, however, the high operational and maintenance costs prohibit the widespread use of RE devices. There are a few public and private player engaged in the provision of RE devices. Worse still is the lack of expertise and limited institutional capacity all that have reduced the participation and the 'fruits' that accrue to use of RE devices.

5.2.3 Lack of awareness and information

Limited information available to the public regarding geothermal development and its socioeconomic and environmental benefits. The public sector is largely ignorant about geothermal energy technologies, no training has been offered to them so they will remain nostalgic about their old technologies which are obsolete and ineffective. The deficiency of technical knowledge limits individuals from making rational choices as far as accepting geothermal technology for sustainable development is concerned.

5.2.4. Government policy, incentives and institutional challenges

Precisely, there is no policy on geothermal energy development, an alternative renewable energy policy of 2007 has a weak implementation machinery. Government policy activates an enabling framework for geothermal resource development (Kombe,2019).The insufficient funding of geothermal energy entities leaves room for institutional weakness. In 2014, the geothermal resources department was created in MEMD with a mandate not properly defined and a small budget of Uganda Shillings 100Million (U.S $30000) for core staff and Geothermal energy Development project had a budget of Uganda Shillings 5.1 billion (U.S $1.2 Million MOFPED). Limited public finances create competition of financial resources among different sector, this further restricts the availability of funds for geothermal energy resource assessment, carrying out feasibility studies. With such financial challenges it becomes difficult to efficiently and quickly achieve geothermal energy development. At the institutional level the geothermal energy unit has been too underfunded to implement its mandate. The weak institutional machinery is a great blow to proper coordination and consultations with relevant stakeholders coupled with low budgetary allocations, prevents the development of synergies and linkages needed for geothermal energy development.

5.2.5 Inadequate research and development

There is little focus on research and development (R&D), there is not a visible plan or budget given to research institutions or universities, although Makerere University has a program of renewable energy at post graduate and Makerere University Business School with Energy economics and governance more still has to be done in stepping up budgets and doing coordinated research in RE development especially solar, wind and biomass. Working systems must be promoted to tap into international R&D collaborations. Native technical knowledge on Solar and wind technologies are still low and without a convincing technical direction, this leaves related technologies to be imported at a very high cost, expatriates also cost the country yet a sustainable indigenous pool of workers need to be developed.

5.2.6 Inadequate human capacity and training

Specialised training in Geothermal has been through sponsorships into the Auckerlandd University in New Zealand and United Nations University collaborating with University of Iceland (Hochstein 2005). There is a need to forge a critical mass of workforce to operate geothermal energy projects. However, geothermal energy projects call for a wide variety of skills in fields of Geoscience, Engineering (renewable energy, electrical, mechanical, mechatronics, chemical), material science, geophysics, geochemistry, energy management, social sciences all that cannot be easily acquired in large pools. This remains a barrier for geothermal energy development.

5.2.7 Inadequate infrastructure to support geothermal energy development

Poorly built transport and communication network to support geothermal energy projects. Most roads are murram roads that become impassable in the wet season, the few tarmacked roads are poorly maintained. All these become a challenge to geothermal energy development.

5.2.8 Shortage of financial resources

According to Ji and Zang (2019) one of the greatest challenges to geothermal is shortage of green energy finance. The shortages arise from both from public and private investors needed to carry out geothermal energy resource assessment. The exploration, drilling, Environmental impact assessment, appraisal and operation will require heavy funding which is still a challenge for Uganda's geothermal energy development. The green energy financing schemes have ushered the Feed in Tariffs (FiTs) and power purchase agreements and Renewable portfolio schemes with no packages to assist Uganda (Noh, 2019).

5.2.9 Socio-cultural and environmental challenges

Geothermal power development impact on the natural environment and the pre-existing ecosystem, surface distortions as well as displacement occurs. Households may need resettlement. The production of brine may also leave societies devastated (Marita 2003, Colmenas- Santos et al. 2018). This may also not be easily accepted by the locals who may resist this development.

6.0 Conclusions and recommendations

6.1 Conclusion

This study has taken a keen interest in exploring the geothermal resources located in Uganda. The potential for geothermal energy has been known for a long time. The policy shift from the traditional biomass to clean energy highlights the need to actualise the use of geothermal energy development as renewable energy to meet her energy demands. Therefore prospects as well as challenges that constrain geothermal development thus far are briefly explained.

6.2. Policy recommendation

Diversification of Uganda's energy mix. There is need to fast track the development of a geothermal energy policy to guide the exploration and development of geothermal power in Uganda's energy mix. This would increase the renewable energy mix as advocated by the renewable energy policy of 2007.

Specialised manpower training with skills and knowledge on geothermal energy technology, financial support for research in geothermal data collection and analysis. Geothermal speciality training institutions should be established in preparation of the vast potential resources in addition to the existing energy training. This would equip workers with competences to develop this subsector.

Financial and subsidy incentive to individual, communities as well as private organizations for the development of the geothermal energy project and community participation/ownership of geothermal Energy projects for security and infrastructure. Loan facilities can be sought from African Development Bank (AfDB) as well as global environmental facility (Scwerhoff 2019).

Regular environmental audits and environmental systems strengthening and streaming to ensure proper use and restoration of existing ecosystem services. A budget for environmental restoration and clean energy planning should be established (Mariita 2003).

A regional geothermal institution needs to be established to establish standards and promote geothermal power uptake. It would also coordinate training development and restoration of disused sites.

Concessions and reserve evaluation plans for potential investors upon expression of interest to develop geothermal resources. Land would be availed with numerous friendly terms to create a conducive investment climate.

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