POTENTIAL ENVIRONMENTAL AND SOCIO-ECONOMIC EFFECTS OF GEOTHERMAL EXPLOITATION ON THE LOCAL COMMUNITY
A CASE OF SUSWA GEOTHERMAL PLANT

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DECLARATION

This research project is my original work and has not been submitted in any other institution of higher learning.

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This research project has been submitted with our approval as University supervisors.

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DEDICATION

This study is devoted to my dearest family, my children and Oltetia for being thus accessory, particularly whenever it looked like I was on the verge of yield. They never ceased to remind me of the fact that what I sought was information which information is power.

"Scientia potentia est".

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ABSTRACT

This study sought to assess the potential environmental and socio-economic effects of geothermal exploitation on the local community in Suswa that primarily encompasses pastoralists who practice a nomadic lifestyle and open range grazing. The analysis targets the local community living around the energy project in the Suswa area. The objectives were to assess potential environmental and socio-economic effects of exploitation of energy, on the area people in Suswa and to debate on viable ways for addressing the issues which may arise so as to boost the standard of living of the local community living around the Suswa geothermal energy plant. This study took a look at the hypotheses that there exists no significant difference between geothermal power exploration and environmental effects on the local community in Suswa and that there exists no significant difference between geothermal power exploration and the economic and social welfare of the local community in Suswa by conducting a chi square test for various environmental and socio-economic effects.

This study was conducted using descriptive survey design. Samples for the questionnaire survey were chosen using simple random sampling whereas purposive sampling was applied in obtaining key informant interviews and participants for the focus group discussions. The information used was provided by the Kenya Population and Housing census, 2019. This study was conducted using both primary and secondary data that produced both qualitative and quantitative data. Data collected was analyzed by using descriptive statistics and inferential analysis, using the applied math's package for scientific discipline (SPSS) to get frequencies, percentages, means and variance, and then presented in form of tables and graphs.

In the findings, the families interviewed expressed fears that the exploration might create a health risk, to employees in the industry and to the communities and their animals living around the projected Suswa geothermal plant such as respiratory diseases and possible miscarriages of both humans and animals.

On the other hand, the potential advantages are likely to fall within the areas of education; infrastructure, health, economic empowerment; environmental management and support of art & culture. The pertinent conclusion of the study supported the findings that the potential socio-economic and environmental effects of the energy project still needs further efforts to ensure a win-win state of affairs for each; the government and also the local community living in the vicinity of the Suswa geothermal energy plant.

This study recommended that albeit socio-economic impacts being inevitable in any energy development project, this ought to be minimized by holding informatory and consultative forums with the community and by taking their interests, fears and issues into consideration, and ensuring the implementation of sound environmental management and operation systems by the government.

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ACRONYMS AND ABBREVIATIONS

ADB	African Development Bank
AFD	African Development Fund
CDCF	Community Development Carbon Fund
CO_2	Carbon Dioxide
CSR	Corporate Social Responsibility
EAPL	East African Power & Lighting Company Ltd
EARS	East Africa Rift System
EGS	Enhanced Geothermal System
EIA	Environmental Impact Assessment
FGD	Focus Group Discussion
GDC	Geothermal Development Company
GEF	Global Environment Facility
GHG	Green House Gases
GIS	Geographic Information System
GW	Gigawatt
H_2S	Hydrogen Sulfide
ICE	Immigration and Customs Enforcement
K-12	Kindergarten - 12th grade American Education System
KII	Key Informant Interview
KENGEN	Kenya Generation Company
KM	Kilometer
KPLC	Kenya Power & Lighting Company
LBNR	Lake Bogoria National Reserve
MW	Megawatt

MWe	Megawatts Electric
NGOs	Non-Governmental Organizations
NIMBY	Not in My Back Yard
OHM	The standard unit of electrical resistance
PTA	Parent Teachers Association
TDS	Total Dissolved Solids
TSC	Teachers Service Commission
UNDP	United Nations Development Programme
UoN	University of Nairobi
US	United States of America
US$	United States Dollars

CHAPTER ONE

INTRODUCTION

1.1 The Background of the Study

Geothermal energy was recorded to have first been used for industrial generation in Lorderello, Italia in 1904 (World Energy Resources, 2016) despite being employed by early civilizations. The geothermic method encompasses the tapping of the earth's heat which is taken into account to be in abundance of 95% (Simiyu, 2013). Geothermal energy is considered a kind of unpolluted and renewable energy (green energy) as a result, countries globally have embraced exploration and utilization of geothermal as alternative source of energy. Worldwide leading geothermic energy power producers are found in the United States of America, Philippines, Iceland, costa Rica, Indonesia, New Zealand, Mexico, Japan, El Salvador, Turkey, and Kenya (Mangi, 2018). Since WWII warfare, developed countries like USA have used geothermal as alternative source of energy because of its affordability economic competitiveness as compared to various sources of energies provided regionally on the market. The ecological implications of geothermic developments are receiving alarming interest leading to a shift in perception on the world's natural and limited environmentally harmful resources.

In the year 2004, five nations namely; Iceland, Philippines, El Salvador and Costa Rica including Kenya generated beyond 16% of their respective electric power that was injected to their national grid from geothermal as approximated (WEA, 2018). African countries principally situated in Eastern Africa, specifically Kenya, Uganda, Tanzania, Ethiopia, Malawi, Zambia, Rwanda, Eritrea and Burundi, all lie geographically within the extremely volcanic region of the East African Rift System (EARS), which is a geological feature endowed with heat energy. Today in Africa, it is only Ethiopia and Kenya that have ongoing geothermal exploration projects, comprising the infrastructure of electricity with complete energy capability presently standing at over 260MWe for Kenya and 8MWe for Ethiopia (Teklemariam, 2013).

Exploration of geothermal development in the Republic of Kenya commenced in 1952 before independence (KPLC, 1992). This activity was dispensed by a syndicate of corporations together with Power Securities Companies Ltd, the regional Power & Lighting Company for East Africa (EAPL)and Associated Electrical Industries Export Ltd.

Prospects within the Suswa area, in Kenya were believed to have a high potential production of 10,000 MWe. Scientific studies commenced in 1993, showed the Suswa Caldera volcano to be one amongst the extremely prospective energy areas in Kenya (Chebet, 2013). Drilling of the calculable 300 MW Suswa Phase I geothermal project was, to start with all the elaborated surface studies completed by early 2013. However, technical incapacity and also the inabilities to find exploration wells, prevented immediate exploration. GDC jointly with a US-based renewable energy technology firm CYRQ Energy were expected to invest Ksh30 billion (US$ 300 million) to put up a 330MW geothermal power station in Suswa area, Narok County (GoK, 2018) to develop the steam through drilling, exploration, appraisal and production wells. The power plant construction was projected to be completed between 2016 and 2018.

The costs of geothermal plants are weighty, for instance direct costs especially on "Greenfield" sites, where no previous development has ever taken place can be astronomical. As per Johnson and Ogeya (2018) an enquiry well costs over US$ 1 million to drill and needs an additional 3No. wells merely to prove the supply and use of the resource. Exploration of geothermal heat energy is assumed to be sustainable and reliable, with the impact of geothermal development projects usually presumed to be positive, however negative impacts on the ecological system have been noticed in developed countries (Johnson & Ogeya, 2018). The local inhabitants of the area around the Suswa geothermal plant are principally the Maasai community whose projected population was 12,000 folks as per the 2019 census (Kenya Population & Housing Census, 2019).

Livestock keeping is the main economic activity of the local community with a tokenized range of active cultivation (Chebet, 2013). The locals also rely upon revenue from activities of tourists that include hiking, camping, cave exploration, habitation and wildlife tours that are undertaken within the natural and unspoiled breathtaking attraction sites of Mt. Suswa. This mountain has a unique shield-shaped magnificent duo-crater volcano cone covering a vicinity of 270 km^2. The inner crater is roofed by a forest that is home to a variety of wildlife e.g. spotted hyenas, baboons, wild dogs, lions, rock hyraxes, leopards and bats and civet cats. The outer crater, calculable at about 10km in diameter, is dotted with Maasai homesteads and the famous volcanic rock caves (Nation Newspaper, 2019).

1.2 Statement of the Research Problem

The inhabitants of this region are principally peregrine pastoralists who move every now and then in keeping with their tradition. Problems and challenges associated with Geothermal exploration include land use changes, that cause human displacement because of the very fact that energy exploration is location-specific (Mariita, 2002).

The Suswa area is endowed with natural surroundings that make it a most suitable tourism hub. Today's tourists, increasingly seek out comparatively undisturbed natural areas and perpetually seek out new experiences, such as, can be provided by the Mt. Suswa caves. Therefore, the interference and dilapidation of natural surroundings, as well as destruction of wildlife migratory routes within and outside protected areas (Kubo, 2003), that are likely to be the result of geothermal exploration, would be a tragedy for the local community's livelihood. Community tourism has become a big part of the commercial projects undertaken by the Suswa community; thus, if meddled with, could have a major impact on the local community. To this end, the local community formed the Mt. Suswa Conservancy whose role is to promote sustainable use of its resources, in a bid to control their revenues derived from tourism and to prevent massive environmental degradation of the Mt. Suswa ecosystem.

The level of education of the local community is low, excluding them from skilled employment within the energy plant (Kollikho & Kubo, 2001), which is required for development and exploitation of geothermal resources such as professionals in reservoir management and earth sciences, drilling technology, as well as environmental management.

Geothermal plants have been linked to emissions of Hydrogen Sulphide (H_2S) gas. This gas once unleashed to the atmosphere may be a hazard. It is a colorless chalcogen gas with the characteristic foul odor of rotten eggs. It is poisonous, corrosive, and flammable. Its properties can cause wheezing, eye irritations, metabolic process diseases like seen in California (US) and could destroy the environment (Bates, Gawell & Kagel, 2007). Albeit all this in most geothermal explorations, unfortunately environmental and health problems get the least amount of condemnation. In the context of this research, the local community find this exploration unfavorable because it would mean offering their ancestral land to the geothermal energy project for exploitation, which would possibly result in the permanent displacement of the human and animal population.

In addition, there are the health problems, with some fatal, that may arise. The environmental degradation that would mean destruction of flora and fauna. The locals find exploitation of geothermal energy to be a threat, as it would reduce the grazing land for their livestock, and come with unfamiliar amendments of land use, land rights and lifestyle (Obuya, 2002). The local community also stand to lose revenue gained from the tourism activities, as well as the loss and disruption of the Mt. Suswa inner crater, believed by the Maasai people to be God's domicile place (Kaitano, 2016).

Cases have been reported to the World Bank Review Panel, where locals are discontent with transfer plans and disruption of economic activities due to geothermal exploitation (Sena, 2015), where the norm of forceful evictions, lack of consultation, and inconsiderate resettlement serve among such cases. Given the above problems, this research was dispensed to assess the potential effects such exploitation would have on the environment and the socio-economic well-being of the local community living around the Suswa geothermal plant. The above necessitate a study that may be ready to define the gaps that are created by a blanket assumption of unpolluted energy whereas not underscoring the requirements of the populace.

1.3 The Research Questions

i. What are the potential environmental consequences of geothermal exploitation on the local community in Suswa?

ii. What are the potential economic and social effects of geothermal exploitation on the local community in Suswa?

iii. What viable strategies can be employed to mitigate potential environmental and socio-economic matters arising from the exploitation of geothermal energy, so as to safeguard and boost the quality of life of the local community?

1.4 The General objective of the survey

The survey concentrated on assessing potential environmental, social and economic effects of geothermal exploitation to the local people in Suswa.

1.4.1 The Specific Goals of the research

i. To evaluate potential Environmental consequences of exploitation of geothermal on the local people in Suswa.
ii. To assess potential Social and Economic impacts of the exploitation of geothermal on the local community in Suswa.
iii. To discuss strategies for mitigating Environmental and Socio-economic issues that may arise from the exploitation of geothermal energy, so as to safeguard and boost the living standards of the locals living around the Suswa geothermal plant.

1.5 Hypotheses

H_0: There exists no significant difference between geothermal power exploration and environmental effects on the local community in Suswa.

H_1: There is a significant difference between geothermal power exploration and environmental effects on the local community in Suswa.

H_0: There exists no significant difference between geothermal power exploration and the economic and social welfare of the local community in Suswa.

H_1: There is a significant difference between geothermal power exploration and the economic and social welfare of the local community in Suswa.

1.6 Justification of the Study

The justification of the study on the advantages accruing to the local people through geothermal power exploration revolves around policy making, managerial, practice and more so future researchers' knowledge. This study will, therefore, be strategic in informing policies and laws that may be developed in response to or anticipation by energy-related activities. Establishments that are concerned in these activities are as an example, The World Bank, The Government of Kenya, Civil Society Organizations, Geothermal mining entities, and a host of other stakeholders. They can identify this paper as a resource in the formulation, implementation, observation, and analysis of such endeavors thanks to the Suswa Geothermal Plant.

On managerial and practice of geothermal power exploration managers are able to identify areas of concern as far as environmental and socio economic issues are concerned so that major steps and interventions are taken to reduce the effects and encourage accruing benefits. The dissemination of a number of the findings from this paper can greatly enlighten the general public on the dynamics of development and their entitlements within the geothermal power exploration processes. Being an interdisciplinary research, academics can be able to utilize the data on this study to further the building of knowledge across several fields. It will additionally fill a number of the literature gaps within the realm of mining and development in relevance to indigenous people.

1.7 The Scope of the Study

The survey was piloted across the areas around the Suswa Geothermal plant, a project situated in both Narok and Kajiado Counties and covering an area of about 750 kms^2 with a sample size of 290 by insightfully looking at embedding environmental, social and economic effects of the Suswa geothermic exploitation. The environmental, social and economic problems that were investigated embrace land dilapidation, soil erosion, air pollution, sound pollution, thermal effluents, solid wastes, chemical discharges, deforestation, health, education, cultural practices, and infrastructure among others.

1.8 The Limitations of the Study

The anticipated confines were; enclosed resource constrictions, accessibility of the target population particularly thanks to their peregrine modus vivendi. The respondents were expected to be aloof and suspicious towards the explanations for the study, this was mitigated by the use of approval letters from the relevant authorities and additional assurance that information given would be used for research only and would be treated as confidential. Accessibility and mobility were hindered due to the remoteness of the area and the under-developed road networks in the area, where huge cracks and formation of gulleys of up to 50m deep x 20m wide within the roads were encountered.

1.9 Definition of Significant Terms Used in the Study

Geothermal Energy: Refers to the underground heat confined within the rock and fluid that fills the fissures and pores within the rock in the earth's crust (Dipippo, 1991).

Exploration: The process of tapping into the geothermal resource from the earth for industrial or other uses (Kollikho & Kubo, 2001).

Indigenous/Peregenic/Local Community: This is a term that is used synonymously with the Maasai community and it is outlined in the United Nations definition which is based on their robust linkage to the territories and encompassing natural resources (Kubota, Hondo, Hienuki & Kaieda, 2013).

Environmental Degradation: This is used to note the depreciation of the ecosystem through exhaustion of resources like air, water, and soil; the destruction of ecosystems; habitat destruction; the extinction of wildlife; and pollution (Mariita, 2017).

Socio-economic livelihood: This research can limit its factors under socio-economic to education, employment, and health that are closely tied to development (Payera, 2018).

Land use: The community under research have traditional ways of using their land like communal ownership and pastoral activities (Lesser, 2016).

1.10 Organization of the study

The study is organized into five (5) chapters.

Chapter one (1) covers the background of the study, casing the problem statement, research questions, and objectives; it outlines the justification, scope, limitations, and the assumptions of the study. The chapter includes the definition of significant terms used in the study.

Chapter two (2) contains the literature review research of the global, regional and local perspectives. The study additionally contains theories that guide the study and formulation of the conceptual and theoretical framework.

Chapter three (3) depicts the research methodology that captures the research design, target population, sampling, methods of collecting data, and finally ethical considerations.

Chapter four (4) encompasses analysis, presentation and interpretation of findings arising from data analysis using techniques represented within the previous Chapter Three (3). These findings are presented in form of tables, pie charts and bar graphs.

Chapter five (5) outlines the findings, the conclusion, the recommendations and finally the projected areas for further study.

CHAPTER TWO
LITERATURE REVIEW

2.1 Introduction

The chapter covers literature which is relevant to and consistent with research objectives. It is specifically concerned with previous empirical studies relevant to the study in order to develop a link between environmental and socio-economic implications of geothermal exploitation. The sources of literature comprise scholarly studies, publications, environmental impact assessments, reports, journals, and government publications among others. The review took a three-pronged approach with global, continental/regional and local contexts that helped in the identification of a literature gap at the tip of the chapter. This chapter highlights the conceptual and theoretical framework of the study and to finish, the outline of the study is given.

2.2 Global Perspectives on Geothermal Exploitation

An acknowledgement of the advantages of geothermal energy took place in the 1970's during the United Nations Conference on New Sources of Energy in 1961. The meeting aimed at publicizing the advantages and potentialities of geothermal energy as a reliable and alternative source of energy. There after interest in geothermal energy development increased steadily particularly from 1964 once as several states commenced preliminary investigation projects (Goff, 2000). Numerous studies are undertaken globally on energy exploitation and its effects on the environment, social and economic. For instance, Poland, Sowizdzal (2018) indicated that hydro-geothermal resources utilized and that the underground hot water is the energy carrier created with the wells. Petro-geothermal energy resources, such as sources of warmth accrued in earth debris. The medium temperature geothermal sources occur, connected in the main rock's debris; such as limestone and dolomites seldom with igneous volcanic and crystalline rocks. Subject to the hydro-geothermal strictures these sources can be used for various functions i.e. initial of all is for heating, however additionally for restorative functions.

Lohse (2018) conducted a study on the environmental impact of hydro-geothermal energy production in regions of medium enthalpy in Europe. The findings indicated that geothermal energy production is a low concentration carbon technology which is efficient for sustainable energy distributions. Hydro-geothermal stations justified a considerably low surface depletion and environmental influences are domestically significant and hence governable.

Taking advantage of the event of optimized overall ideas for geothermal centered heat and power production to positively impact the environmental in entire perspective, the combined extraction of underground heat and power production from energy sources put together is the most considered climatic and environmentally friendly energy provided in comparison to alternative source like fossil systems of decaying energy.

Manzella et al. (2018) conducted research on the environmental and cultural attributes of geothermal energy in Italy. In their findings, they indicated that in Italy geothermal power production has accrued unendingly because of the resources being overseen effectively. As soon as initial excavation of the superficial carbonate reservoir, the increase of fluid production is then restriction to 1 km depth owing to the positive results of deep drilling that exposed a reservoir hosted within the interior metamorphic and granitic rocks and as a result of pumping of water and condensed steam separately into the reservoirs. Geothermal energy's supplement approximately 2% of electricity supplied in Italy (TERNA, 2016b), numerous legislations have given birth to measures regulating research carried out to investigate the usage of geothermal heat energy in Italy. In the year 2010 for instance, an LD eased up analysis on exploitation of energy resources and offered incentives to caution the sources of renewable. The initiative leads to entry of new geothermal exploration players into the market, it was substantiated by the facts showing close to 120 new permit applications from different research organizations seeking permission to carry out analysis on geothermal resources and district heating appropriate for electric power production.

According to the World Bank (1994), in Imperial County, California, MidAmerican, renewable energy coupled with taxpayers is the main remunerator in the regional economy. About 25% of the county's tax base is contributed by the overall energy activities translating to over12 million dollars income tax levied on resident individuals. Taking the case of Nevada for instance, geothermal power supply to the locals, attracts lump sum revenue used part to mitting, generating cost and tax levies, capital tax, changed business, payment of lease bonus net proceeds of mine tax and royalties to the state and county and salaries and benefits to workers and a spread of native tradesmen for product of quality services delivery. After the enactment of the Amendments 2005 Geothermal Steam Act deliberating that 25% of earnings proceedings of leasing geothermal energy source are assigned to state authority in the local leadership. In the year 2008 Nevada gained 7.5 million dollars from geothermal proceedings and in turn invested the entire capital money to the state fund making a tremendous support to K-12 public schools across the designated state. On the other hand, California had bagged along 9.9 million dollars where 40% of her of it was allocated to the native counties; 30% appropriated to the reusable energy sources Investment thrives; remaining 30% allocated to CEC for loans and as incentives to cultural hegemonies or non-public institutions (World Bank, 1994).

The power production plants are also source of tourism adventure and attraction; perhaps students, researchers, and other people of interested pay regularly visit the site and therefore rejuvenating economic activities to the area people and thriving businesses and as at August of the year 2012 California had hosted over 75,000 tourists at the Calpine Geysers visitor Center from all the fifty (50) states and seventy-nine (79) other countries since it opened its doors in 2001 (World Bank, 1994).

Zhang and Hu (2018) reviewed the establishment of Geothermal sources of energy in China where they found out that it was evenly scattered across the country in units, in that case the hydrothermal systems characterized with extremely higher temperatures were mainly found in the free Region Tibet, Taiwan Island and Yunnan Province of the Asian economic giant. Hydrothermal systems of medium heat were located different basins. The expansion of exploration activities of the green energy in China is not meeting the expectations and speculation as anticipated. The piloted findings further indicated that hydrothermal systems created through faulting process comprise a substantial quantity of energy essential in generating geothermal power generation. However, the underground heated water within the Tatum geothermic fields has higher total dissolved solids (TDS); a matter requiring a lot of analysis to resolve this issue, in so far as power generation is concerned. Investigations have been done in the Meso-Cenozoic sedimentary basins which have massive storage of energy which is primarily purposed on domestic use or in greenhouse crops, in addition steam energy source of medium temperature can also be used in dualistic power stations.

Yousefi et al. (2018) dispensed a reconnaissance study on economic assessment of underground heat in Iran. RETScreen (clean energy management software) was used to project the profitability of the establishment. And the outcome indicated that the influences of a humidity deviation is insignificant compared to the change in temperature within the field of geothermal energy. In Iran by the end of 2010, only two (2) power generation establishments had been implemented and as a latest pilot study proposed an estimate 9% of Iran has the potential of geothermal energy (Noorollahi &Yousefi, 2010).

2.3 Regional Perspectives on Geothermal Exploration

According to Mburu (2014), the African Rift carries an energy-producing potential of over 10,000 MWe of geothermal and much more of thermal energy. If properly utilized this energy could be the replacement of the use of fossil or decaying fuels and the solution to address global warming. Ethiopia which is dowered with the largest geothermal resource has gone ahead to explore it and instituted government policies that can be used to guide the exploration of geothermal resources.

Omenda and Teklemariam, (2010) carried out an overview on utilization of geothermal resources in the East Africa Rift System (EARS). Supported by their findings, it was noted that the East Africa Great Rift is the epicenter of steam energy accumulated in the Earth's interior mantle and escapes to the surface of the earth crust through the fissure and fault line during volcanic eruptions, high intensity adjustment of bedrocks causing earth quakes, and the upward percolation of hot springs and fumaroles. EARS is one of the most vital zones on the globe and Ethiopia and Kenya rifts, possess the foremost intensive geothermal resource base in Africa and within the world. Other countries like Djibouti, Uganda, and Eritrea have less but still have important resource bases. The Eastern Africa countries have the potential to generate over 14,000 MW of energy from geothermal power if the current technologies are put to maximum utilization. However, only 268 MW is currently generated by both Kenya (260 MW) and Ethiopia (8 MW).

EARS have been indicated as largest geothermal reservoir among others on earth (Ogola, 2004) making energy demand in Africa a subject of international interest. Hydropower plants have become unreliable due to Biomass production which is a crystal rectifier to wanton deforestation and drought cycles and the costly of imported diesel and petroleum products has increased in recent years. A local generation system with a predictable supply and at affordable prices even for remote locations could be provided by the EARS geothermal resources. The East African region has the potential to generate approximately a third of the world's energy production between 2500 MW and 6500 MW from geothermal power (Omenda, 2005). The potential for the above has been minimally explored, however, apart from Kenya and Ethiopia, the other African countries e.g. Tanzania, Djibouti, Eritrea, Zambia, and Malawi have solely initiated studies into geothermal exploration.

Kabaka indicated that in Tanzania, the areas with likely geothermal energy resources are largely situated within the great rift and therefore common surface manifestations are in hot spring sites found in areas where faulting activities were experienced. They include Kilimanjaro northern volcanic province, Meru and the Rungwe Volcanic Province in southwest Tanganyika. There are also some coastal areas that show geothermal energy manifestations are within the basins of Rufiji to the south of Dar es salaam and northern Tanga region, are hot springs, that are located in the coastal sedimentary basin and are attributed to rifting and intrusions.

Bahati and Natukunda (2008) conducted a research study on development of geothermal exploration in Uganda. It was discovered that geothermal sources which projected at 450 MW within the Rift System of Ugandan were situated in the Western great Rift Valley that runs along the border of Democratic Republic of Congo (DRC) and its part of the western branch of the ERS. The main energy locations are Katwe, Kibiro, and Panyimur set in Kasese, as well as Bundibugyo, Buranga, Hoima and Nebbi districts respectively. Located in the Southwest, North, and Northeast Uganda are other geothermal resources exploration areas. Uganda unfortunately remains at the pre-feasibility stage. There are however three (3) promising prospects, at Buranga, Katwe, and Kibiro all at advanced stages of surface exploration and can shortly be subjected to the drilling of the first primary deep exploration wells and feasibility studies. The reported subsurface temperature predicted by Geothermometry and admixture models predict120°C -150°C for Buranga, 150°C -200°C for Katwe and 200°C -230°C for Kibiro.

Moussa &Suleiman (2015) averred in their country report about geothermal development in the Djibouti Republic which has promoted and speeded up the development of renewable green energy in an attempt to be ready for the energy challenge tomorrow. Djibouti being geographically located between two oceanic ridges; the Gulf of Aden and the Red Sea that meet with the East Africa Rift, geothermal energy has brought about a first and primary priority. Due to its location, huge quantities of energy emanate from the shallow earth mantle to the earth crust; Djibouti with Iceland is an only region worldwide where an oceanic ridge extends offshore making it suitable to carry out exploitation activity. With a potential calculable production of over 1,000MW, the development of the geothermal energy trade becomes evident.

The Lake Assal project is a program funded by the World Bank with the ADB, GEF, OPEP fund, and AFD. This project is undergoing one of the most active investigations is to establish a production unit of 50 MW in the preliminary stage. The objectives of developing this project are to finance the tendering process of the development of a 50 MW geothermal power plant in the Lake Assal region and exploration phase of 80 km away from the city of Djibouti, situated at the top of the Great Rift Valley. The cost of making the project a success was conservatively estimated at about 31 million dollars and will cover the design and execution test protocol and drilling program.

The Environmental Impact Assessment requirements to embody information on the technology to be used, the potential trans-regional impacts, and contingency plans within the event of an accident (Teklemariam, M., & Beyene, K, 2005). There's but little literature on the impacts the exploration has had on the native individuals in the Federal Democratic Republic of Ethiopia, since most of the analysis done focuses on hydro-power that is the main supply of energy for Ethiopia (Teklemariam &Beyene, 2005).

In Tanzania there's no formal geothermic utilization; native uses of dregs for feeding animals, washing and skin bathing are the sole informal geothermic utilization. The present generation connected to the grid is at 1,522.3MWe and is predicted to achieve 5,000MWe by the year 2020 (Table 1). Geothermal was hierarchically low thanks to the upstream uncertain direct prices and the absence of confirmed geothermal resources.

2.4 Local Perspectives on Geothermal Exploration

The first nation, south of the Sahara to exploit geothermal power and carry this out to a significant scale was Kenya (Kiplagat et al., 2011). The Exploration of geothermal resources in the Republic of Kenya started and accelerated around 1956 to the 60s. As from the year 1967 the UN together with the East African Power and Lighting Company Ltd of those days, carried out geological research within the areas of Lake Bogoria and Olkaria. The results of the findings in that survey showed Olkaria as the most prospected area, due to the results wherever wildcat wells were trained, resulting in the development of the three (3No.) primary geothermic stations and other scholars rated power generation at 15 MWe that were launched in the year 1981 and 1985. The process of exploration and drilling has been continuing through the involvement of the public and private sector. The work force associated with generation of geothermal power in Kenya is on the market within the literature (Marita, 2017).

Omenda and Simiyu (2015) indicated that exploration for energy started in the 1950s with surface exploration to establish geothermic wells being drilled at Menengai, Olkaria and Eburru geothermal grounds in Kenya. The bigger Olkaria geothermal grounds has approximately 200 wells drilled manufacturing 570 MWe whereas six wells have been drilled in Eburru and twenty-five at Menengai. Geothermal development is presently being sped up in Kenya with drilling continuing in Menengai and Olkaria geothermal fields.

Wetang'ula (2014) conducted an environmentally friendly baseline study for geothermic developments on Bogoria, and Arus-Bogoria geothermic prospected areas in Kenya. The study was carried out between 14th of February and 8th July in the year 2005 and was financed jointly by the Government of Kenya and KenGen Ltd. A pilot study to confirm that any potential environmental issues that could arise may be foreseen was prioritized and the results of the study showed that the anticipated impacts on the ecological system could be important in LBNR. On the other hand, the magnitudes of social impacts are insignificant. However, the social impacts may be effectively relieved through testing of geothermal wells, drilling and monitoring power station construction and operation.

Tole (2015) cited that the power complex in Olkaria was situated insight Hell’s Gate National Park about 125 kms from the capital city of Nairobi. The park was gazetted in 1984. He noted that the piping infrastructure had visible interference to the natural landscape and would be likely to alter its fascination for good.

In Kenya, Mwangi (2013) had many reservations regarding the rapid development of geothermal heat sources. He explained that liquid wastes contained arsenic, drilling mud, and rock oil products from lubricants and fuel. This verified that geothermal wastewater may be an eco-toxicological risk if proper correct disposal methods were unheeded. In his analysis, he assessed that fluoride levels from all wells were high as regards the optimum limits permitted.

Hunt (2000) warned that despite the geothermic resource being thought to be benign to the surroundings, its ultimate exploitation should adhere to the principles of conservation. He argued that the impacts related to geothermal production had become huge to the extent that it limited development. This argument specifically outlined Olkaria's status.

Tole (2015) additionally established that the local people practiced pastoralism within the area with the average family having a median of 70 cows, 200 sheep, and eleven donkeys. The Ruppel's vulture had a nesting ground inside the park and was listed as an endangered species. This massive biodiversity, the Maasai cultural village, the gorge, natural fumaroles, and Hell's kitchen made combined fascinating features that had brought tourist visitation to the park of 100,000 people annually. The pressure from geothermal exploration had extremely degraded the park and the birds nesting grounds as cited in (Muchangi & Kagweni, 2014).

2.5 Empirical Literature Review

2.5.1Environmental Impacts of Geothermal Development

The impacts of geothermal heat use on environment have been studied in quite some detail in Kenya and most sensitive parts of major interest include; the eerie influences: like devastating cover crop due to soil erosion, noise pollution as a result of machineries, hindrances to migration of animal, visual defects as a result of exposure to steam, aesthetic beauty, land drift and sinking, micro earthquakes, magnetic attraction and the influences from living organisms: like obliteration of micro flora and micro fauna, environmental destruction hindrance to animal locomotion throughout grazing period of which may expose to toxicity inorganic substances and chemical influences: like emission of pollutant gases (e.g. CO_2, H_2S, and CH_4) into the air, and drilling affluent in solution with concentrated fluoride ions causing gingivitis on human teeth.

Barasa (2015) suggested that for a geothermic setting there ought to be a shift from reactive compliance supported on environmental management to proactive, impact predicting management. This prompted the thought that technologies in use had to be assessed upfront to make them environmentally benign within the face of climate change and its cascading effects.

Mark (2018) argued that the major influences of geothermic development on ecological system are associated with surface turbulences, the physical influences of fluid removal, heat impacts and acquittal of chemicals substances and these factors mentioned may have a negative influence on the ecosystem just like all industrial activities. Furthermore, there are also economic and social influences. A social control program was launched in Iceland in the 90's to review the ecological impact of developing geothermic sources. The task of tackling issues related to the effects of high temperature on ecosystem as a result of undergoing construction geothermic fields in Iceland.

DiPippo (1991) piloted an empirical study and suggested that underground heat resources were being used these days in twenty-one nations for the generation of reliable, economically sound, and safe electricity. For several alternative countries, particularly within the emerging economies across the world, geothermic energy might play a critical role of mitigating the deficit of electricity demanded. On the whole, geothermic power plants have a way less adverse impact on the environment than competitor plants. Geothermal reservoirs are able to produce fluids for a long period if properly accomplished, leading to long run affordable constant power to the economy with negligible environmental impact.

Rybach (2003) indicated that underground heat sources considered renewable based on the lifespan of technology and social systems that don't need geological spells of decaying fuel reservoirs like oil, coal and hydrocarbon gas. The recuperation of high-enthalpy basins is consummated at a similar location that heated liquid solution is obtained. Sustainable production can be achieved by use of doublet heat pump systems. Generally, the influences of geothermic power generation on environment are minimal, manageable, or negligible. There should be full compliance with environmental guidelines and regulations that changes from different countries. It should be succinctly understood that the consequences should be documented and monitored in the long run, rated and if necessary reduced. The impact on the environment includes; air emissions, pollution waterways, water quality among others.

2.5.1.1 Air Quality

The gases dissolved in geothermal fluids can be freed into the atmosphere thus compromising the composition of biosphere. The most pollutant gases that have greenhouse emissions comprise of Hydrogen sulphide (H_2S) and Carbon dioxide (CO_2) which are heavier than air thus flow closer to the earth surface and henceforth interfering with normal growth and development of biodiversity. These gases are a known hazard for people operating in geothermic stations or bore fields, and may even be a drag in urban areas. In Rotorua, New Zealand a variety of deaths are blamed on poisoning as a result of inhaling air contaminated with Hydrogen sulfide, mostly in hotel rooms and hot-pool enclosures (Goff, 2000). CO_2 is a greenhouse gas (GHG) attributing to major climate change. However, geothermic mining emits less greenhouse gases per unit of electricity generated than combustion decaying fossil fuels like coal or gas for the production of electricity.

2.5.1.2 Polluting waterways

A major environmental influence of the geothermal extraction is arsenic pollution emitted from the plant. The high levels of affluent containing arsenic in Waikato River almost exceed the (WHO) standards of 0.01 molecules per a million liters of drinking water. Hot springs that are natural are also a source of arsenic, which is released far away into the mainstream water appears like a colorful mineral which precipitate to form Ruby Sulphur, a yellowy-green orpiment whose major downside with the pigments is that they are extremely toxic, being arsenic compounds (KAPA, 2000).

2.5.1.3 Water Pollution

Geothermal electricity generating plants will always have an impact on the quality of water coupled with the usage behavior. Steam mechanically forced from underneath reservoirs usually has concentrated minerals containing salt and sulfur that dissolve in it making a homogeneous solution. The majority of geothermic amenities are installed with water systems that work on principle of closed-loop through which heated water emerging from the underneath reservoirs is re-directed back to the geothermic reservoir when it's been used for production of electric energy. In such systems, the water is contained inside steel well casings cemented to the encompassing rock. There exist no rumored cases of water contamination from geothermic plants in US (Goff, 2000).

Since all geothermic power facilities in the United States use wet-recirculation technology installed with cooling towers. Water is additionally employed by geothermic plants for re-injection and cooling. Depending on the cooling technology used, geothermic plants will need 1,700 to 4,000 gallons of fresh water per megawatt-hour (Best & Kahn, 2005). However, majority of geothermic plants need geothermal fluid and freshwater for cooling; the utilization of geothermic fluids instead of freshwater generally brings down the plant's overall water impact. Geothermic plants return the used water into the reservoir after being accustomed to the polluted water; this is so it doesn’t flow to the land surface as runoff. However, not all water from the reservoir is returned back by the eloped system and as a result, some water is lost as steam. Therefore, to regulate the capacity within the underground reservoir, the water outside should be used. The quantity of water required depends on the dimensions of the plant and hence the technology to be used; due to the fact that water trapped in underground tank is “dirty," it's usually unnecessary to consider using clean water for this purpose (World Bank, 1994).

In the age of higher environmental awareness geothermal energy utilization as an alternative source became a center of interest in developed and developing nations across the globe. Even though physical and biological influences of underground heat citing are conceptualized, socio-economic impacts are in a limbo and technological revolution is anticipated to unlock the stalemate. The need to clearly define social and ecological influences of developing geothermal sector will be accomplished through environmental and social influences monitoring and assessments throughout initiation to operation phase of the project. The international agreements and protocols governing bilateral policies among agencies and international institutions of finance are required for successful assimilation of public trepidations in planning, management and decision making of any geothermal establishment. One way to improve the competitive nature of geothermal as an alternative source of energy is by adopting the expense of environmental and communal benefits in the inclusive cost (World Bank, 1994).

The majority of geothermal sources worldwide are situated in rural scenic, wild and protected park reserves. The strategic social and economic influences connected to developing these resources comprise of clearing of bushes and construction of the location, in the process there will be loss of biodiversity and habitats for wildlife. The countries on the south of Sahara Desert rely mainly on the neighboring ecosystem to satisfy their medicinal, social and economic wants that are already insatiable with this scarce natural resource (KAPA, 2000). Because of this overreliance, advocacy for public responsiveness and apprehension on how innovative undertakings influence the socio-economic environment is attracting interest towards policy makers. And as much as geothermal energy undertakings are relatively innovative to majority of the nations in Africa it cannot used to subvert the law.

In Kenya geothermal energy expansion lies beneath the mind blowing vast and extensive, but culturally and ecologically sensitive Eastern African Great Rift. Geothermal energy is to a great extend clean energy, however there exists negatives accrued by the environment in its exploitation and are worth study. Naturally, areas endowed with geothermal resources have soils that are venerable and porous. Upon drilling and building of other infrastructure, surface disturbances can occur which can lead to some tremors (Mwangi, 2010). This can be risky in the long run and can have negative effects among the locals. In the region around Suswa, sinking of boreholes and simple pit latrines is futile because of the soil’s nature, hence it is necessary that several considerations be made before undertaking such projects because of the impacts they can have on the local communities.

The main environmental challenge from geothermal exploration is the effect of solid waste and other emissions; the emission of chlorofluorocarbons (CFC) gases among which Hydrogen sulfide (H_2S), a gas with an odor of a rotten egg at low concentration is comprised. Dumping of some geothermal affluent which may contain low concentration of toxic ingredients, are worrisome, although geothermal stations are proficient at delivering heat for countless decades. In the long run specific settings may be unruffled down (Bargagli, 1997). It has been established that arsenic metals can be traced in the emissions from geothermal plants. Their effects can be seen in animals and plants for example livestock deaths were attributed to such emissions in Kenya around Olkaria (Koissaba, 2017).

This concern around environmental disadvantages can be as a result of lack of a geothermal exploration specific law in Kenya (Mwangi, 2010). There is a great level of generalization in Kenya in such an area, where regulations on mining, forestry and environmental extractive issues are set without a specification to particular resources. The United States could be a very important benchmark on this policy dynamic. It is evident therefore that geothermal exploration can have effects on the environment and needs to be factored in both policy and practice.

2.5.2 Socio-economic impacts of developing geothermal projects

Mariita (2012) conducted direct field surveys on the social and economic influences of expanding geothermal projects in Olkaria, visiting the Maasai homesteads, and interviewing individuals found in the Olkaria area. Here several respondents noted the positive advantages, for example, water, shops, and school. Community elders and the Chief of the locality were interviewed. Fundamental evaluation of the field outcome revealed that the ecosystem of the people living within the vicinity of Olkaria has particularly been negatively distressed by the energy accomplishments. A correct management of operational is in situ to stop conflicts with the neighboring local people, and the action is perceived to entail fencing the facility area to avert any circumstance of locals and their livestock accessing the premises which could pose a danger to unauthorized entry of unguided persons, this can be achieved by encouraging frequent engagement between the local community elders living in Suswa and the establishment's operational managers. The Maasai were convinced the project should have empowered them economically through the provision of employment opportunity. Majority of the respondents felt that the establishment ought to continue, whilst some others were wary. They were particularly grateful to KenGen for giving them piped water, which acted to reduce cases of water-borne diseases like the epidemic cholera, typhoid, and other infectious diseases. The noise and gas emissions from the project, as stated by many respondents did not discomfort them, nor their livestock. Some even claimed that bathing in the KenGen effluent waters had assisted them in dealing with forms of dermatitis.

Mwangi (2013) gave his reservations about the rapid development of geothermal energy sources. He noted that liquid wastes contained arsenic, drilling mud, and fossil oil products from lubricants and fuel. This, therefore, proved that geothermal energy waste materials may well be an eco-toxicological risk if proper disposal methods were neglected. In his analysis, he evaluated that fluoride levels from all wells were higher than the maximum permissible limits.

Muchangi and Kagweni (2014) confirmed that Hell's Gate ought to be degazetted from its National Park status since half of it had already been debilitated by geothermal drilling. This meant that its sustainability as a National Park was at risk, despite environmental legislation.

Okkonen and Lehtonen (2016) considered the social and economic impressions of geothermal power establishments in Northern Scotland. During this analysis, regional input and output sculpting is applied to the analysis of the social and economic impressions. The outcomes show important social and economic advantages of re-investing revenues for social purposes. Strategic re-investments of income return in homegrown community services can return close to, an additional 10% in the form of employment and income. The socio-economic survey identified that locally owned social businesses are an auspicious elucidation for local-based development within the European northern perimeter.

Lesser's (2016) viewpoint was that the expansion of energy amenities could have varied social and economic impressions on native areas. In addition to the hypothetical environmental influences, like noise, water, and air pollution, increase may also have a negative effect on native and national economies. In distressed areas, expansion could have useful impression by opening up job opportunities for the area residents, who are possibly unemployed or are part-time staff.

When this happens, it provides tax revenues for enhancement of infrastructure. However, some extensive establishment may have "boom town" influence leading into increase in the desire for locally offered services such as social amenities. Once those establishments are finalized, the short-term desire for these amenities will fall steadily, putting more effort on the locals. A study conducted in Olkaria by Arévalo (2007), noted the energy plant employs approximately 425 staff on a permanent basis. Other menial services like cleaning, security and other forms of casual labour are sourced through contracts to the local community especially during the plant's construction and maintenance. KenGen, in accordance with its CSR (Community Social Responsibility) programs, has sponsored 6No. (six) learners through high schools and 8No. (eight) learners to institutions of higher learning and is focused on increasing these figures in the future. KenGen, Orpower4 and Oserian Flower co. have supported the construction of classrooms in faraway schools not within the vicinity of Olkaria. Orpower4 pays for a number of teachers' services in those schools. For this purpose, KenGen is presently arranging to spend about US$900,000 from the Community Development Carbon Fund (CDCF). The funds will be utilized for the expansion of the water supply and dispensary start-ups. There's no public transport for the area south of the Olkaria Project. To this end, KenGen and Orpower4 provide free rides for the people needing the said services. Further, KenGen provides a bus on Saturdays all year round for use by the locals during their shopping. Transport is also provided to the locals during immunization drives, health, education, or any other government initiatives.

Appraisals into the environmental, economic and social influences of geothermal energy on the impoverished in Kenya with a focus on Olkaria geothermal energy disclosed that the landscape alteration throughout the implementation of the project had a sweeping impact on the neighboring communities (Mariita, 2002). The report established that soil erosion was usually severe unless the land is properly managed. The severity of drought and floods substantially rely on the level of resource exploitation within the area. These environmental disasters have had a negative impact on the local community living in the area whose main source of livelihood is pastoralism.

The historical factors of the Greater Olkaria Geothermal area are tenacious and have influenced its current socio-economic status. This place has undergone tremendous land-use changes, especially in the last 10 years, where this has been accelerated. This area is cosmopolitan unlike several counties of Kenya in which the native people are united by the same traditions, spoken language or race, causing the social and economic impression of development unable to be a representative replication of activities in rural suburbs in the Republic of Kenya. A number of the crucial socio-economic impressions as witnessed in Olkaria are mentioned in the developing story below;

Despite the rise in the number of firms and related people engaging in floriculture activities, the government remained with insignificant interest to mitigate the demand for additional learning institution. There are some floret granges that have noted this challenge and constructed learning institutions in an attempt to mitigate the need created by huge labour force (De Jesus, 2005).

2.5.2.2 Agriculture

Horticultural farming was introduced near the lake in the late 1970s and has since evolved into giant export businesses. Before and soon after independence, the growing of food and fodder crop was done around the lake through irrigation for the local market and very little export. Horticultural cultivation is currently focused on the foreign markets in Europe resulting to significant development and a modification in land utilization from fallowed ranching and wildlife grazing to commercial farming. The factor sector is an attraction to the investors due to the convenience of enough fresh water from the Lake Naivasha

Expansion of agricultural accomplishments in the area is connected to the pioneer South Lake road that was constructed during the launching of the Olkaria phase I power station. The access road development initiative enhanced opening up the interior area and created prospects for agricultural expansion. Kenya at the moment has outdone Israel in cut florets and horticultural products for export. Naivasha contributes close to 75% of the total export and brings into the country estimated 110 US million dollars p.a. (Kollikho and Kubo, 2001). KenGen undertook many survey tests on farms as pilot studies with an aim of determining the influences of cooling the tower plume and steam ejectors on the flowers. The outcome of those surveys revealed particularly H_2S does not cause any hazard on florets and horticultural crops as confirmed by activities in places like Iceland where geothermal water is used in greenhouses for heating (ALRMP/GoK, 2004).

The Oserian flower farm has developed a system for utilizing the heat and gases to warm 30 hectares of greenhouses as a way of regulating temperatures and humidity. This stops fungi growth and reduces the use of pesticides and is effectively able to meet the tough European market standards on residual plant chemicals. The farm is further injecting CO_2 from geothermal into the greenhouses to speed up the rate of photosynthesis and production with loads of success (Kollikho and Kubo, 2001).

Kenya is the number one African nation to get power from the earth's crust and use it for national development. This power is tapped at Olkaria East by the Kenya Electricity Generating Company (KenGen), whilst Olkaria West is drilled by OrPower4. KenGen is a public company whilst OrPower4 is an Independent Power Producer (IPP). Superheated water and steam are used to produce a total of 53 MW of electricity by both entities (Simiyu, 2013).

2.6. Literature Research Gaps

Although researchers have undertaken rigorous efforts for an environmental impact assessment on energy projects, the geographic scope of the studies has been restricted. The region-specific studies have yielded mixed results. The literature on geothermal exploration that is accessible has offered minimal information on the specifics with reference to the local communities. Development narratives particularly by the geothermal exploration corporations don't seem tailored to the traditional ways of the communities bringing avoidable challenges like in the Menengai plant example. Scholars like (Kanyinke, 2015) and (Koissaba, 2017) have ferreted out some of these challenges particularly where inconsiderate approaches were used by the government and the geothermal exploration corporations, however, this is a domain that still has scanty literature.

The technicality associated with geothermal exploration has been brought into sharp focus on; the feasibility studies, the most appropriate technology, the use of the energy resource, and the recurring and unexplained mishaps. Unfortunately, there is very little done on the impacts to the immediate people living within such areas (Teklemariam & Beyene, 2005), as noted in an example in Ethiopia. The occupants of these areas have a great attachment to the calderas and this might be one of the major reasons for the conflicts and disputation over the energy activities. The lifestyle of communities is influenced by their culture and traditions. In this context, it is important to investigate how rights to such cultural resources are thought about and considered. This is as far as the environmental effects that culminate in the socio-economic status of the Maasai community in such a locality. Such a nexus has seldom been provided quality research guidance but has been studied as stand-alone concepts and impacts under geothermal exploitation.

2.6 Theoretical Framework

The study was underpinned by the Socio-Ecological Model (SEM) that was first introduced in 1979 as a theoretical model for understanding human development. The model holds that a person's development was affected by everything in their surrounding environment and seeks to understand the vital connections between people and their neighboring ecosphere, identifying behavioral and organizational influences and the effects of the different environmental systems that they encountered. Later on, in the 1980s the person's environment was divided into five different levels; the microsystem, the mesosystem, the exosystem, the macrosystem, and the chronosystem, which were depicted by encircling the various systems that surrounded the individual from within the center.

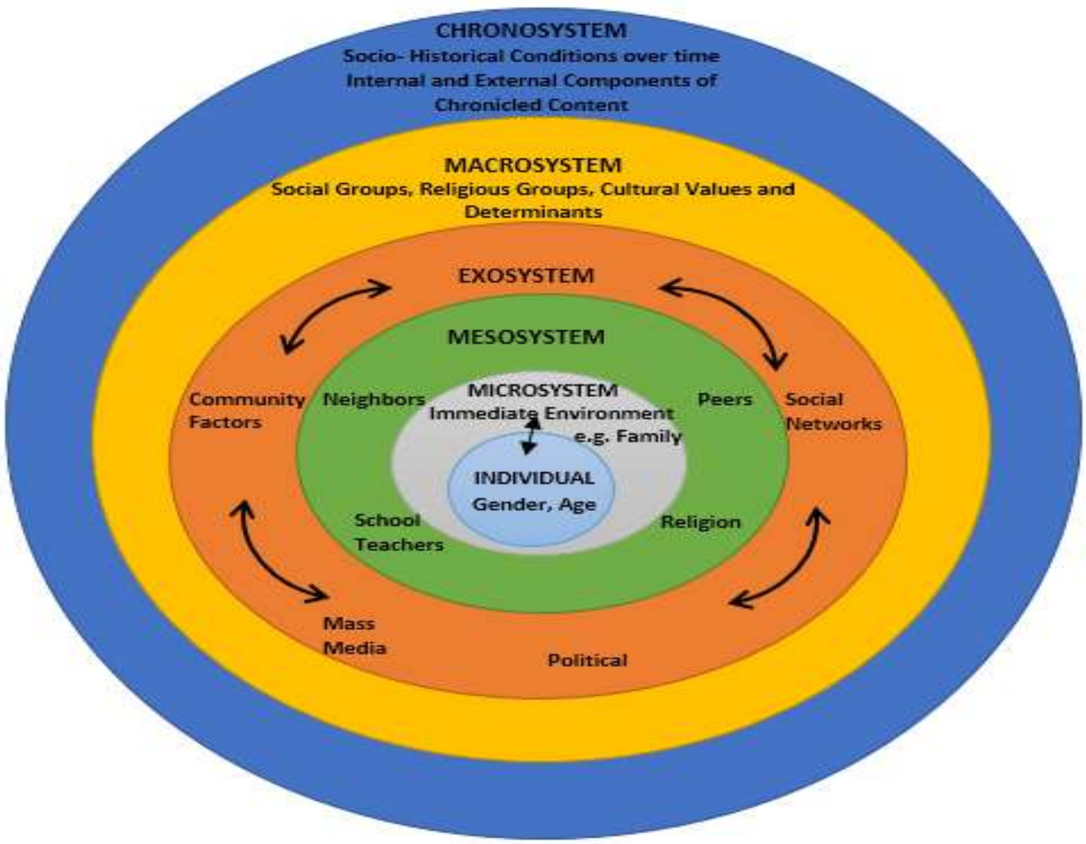
First the Micro system contains the strongest influences and encompasses the interactions and relationships of an individual's immediate surroundings e.g. the direct contact with nuclear and extended family which can have an influence on the individual, and affect their behavioral characteristics. The theory holds that individuals are not simple receivers of the involvements of socializing with the people in their micro system environment, but contribute to the creation of such environment.

Secondly the Mesosystem comprises the associations between the microsystems in an individual's life and the next stage of development. It portrays that upbringing could affect the individual's attitude, which would then be linked to the individual's school experiences e.g. a negative or positive attitude towards their teacher's, peers, and neighbors.

Thirdly the Exosystem is the situation in which the individual is not directly affected and doesn't have an active role, but the linkages of social networks, political and community factors affect them nonetheless and exert both positive and negative interactive forces on the individuals. Furthermore, the Macrosystem is the cultural values and determinants, e.g. ethnicity of an individual. This cultural circumstance is such as the socio-economic status of the individual and/or their family e.g. race, poverty levels etc.

Lastly the Chronosystem includes the oscillating changes in the individual's lifecycle. As well as the environmental events and socio-historical contexts that are likely to influence the individual, e.g. the influence of policy in redrafted models and significant life changes over time i.e. going from rags to riches or vice versa.

Figure 2.1: Theoretical Framework



Source: Urie Bronfenbrenner's Socio-Ecological Model (SEM)

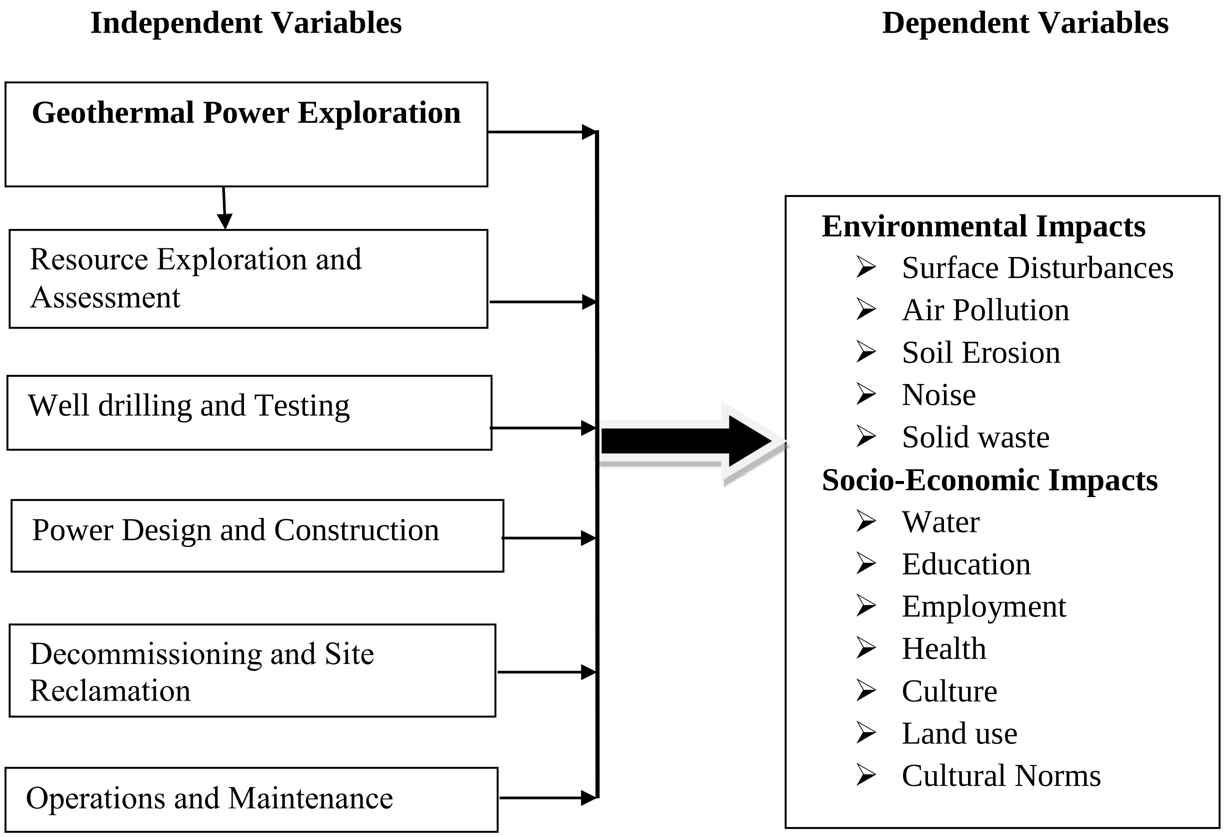
The Socio-Ecological Model depicted above has five hierarchical levels highlighting the Individual, the Immediate environment, The Community, The Linkages, The Social and Cultural values and the change of Environments over time, that deals with the impact people have had on the world as well as the consequences of that impact.

This theory is relevant to this study in that the Ecological Systems Model (SEM) expresses the wide range of factors that have an effect on the environment and socio-economic issues, their interrelationships and the fact that each impacts the other, be it positively, negatively or neutrally. Hence the SEM refers not only to the environment or the individual, but this ecological thought process can explain the complex human phenomena such as those discussed in the potential environmental and socio-economic effects of geothermal exploitation on the local community in Suswa.

2.7 Conceptual Framework

The facilities for Geothermal power have integrands impression on the surroundings and communities like boreholes reinjection, connection of delivery conduits, powerhouse silencers and cooling towers. The resultant effect on the environment varies, some being temporary e.g. during construction or demolition; whilst others ran throughout the duration of the power plant operation e.g. the noise nuisance. The geothermal development phase is generally divided into five (5) phases and every phase can give totally varied impacts to the environment and socio-economic well-being of the neighboring communities: resource exploration and assessment, maintenance coupled with operation, testing and well drilling, power design and construction and decommissioning and Site Rehabilitation. In view of the above, a conceptual framework was developed where geothermal exploitation was the independent variable, and the environmental/socio-economic impacts were the dependent variables as shown in Figure 2.2.

Figure 2.2: Conceptual Framework



CHAPTER THREE

RESEARCH METHODOLOGY

3.1 Introduction

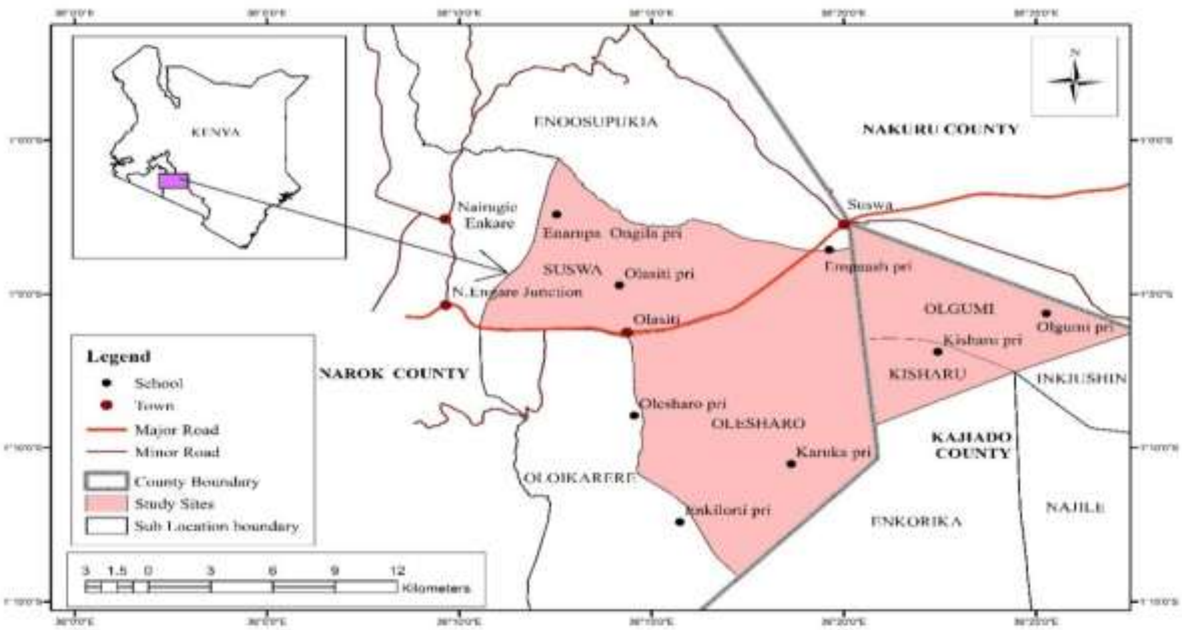
This chapter covers the research methodology, design, locale, target population, sample size, sampling techniques, research instruments, data collection, data analysis and ethical consideration. The study used descriptive research methodology. This methodology best fits to search for an answer to the problem which is in terms of geothermal exploration that has been below par. The researcher used the deductive approach and start by theoretical discussions which will further be tested and explored in practice. Secondary data will also be exploited to assess the environmental impression on exploitation of underground heat energy on socio-economic effects in Suswa, Kenya.

3.2 The Study Area

3.2.1 Location

Suswa has a potential of development of power and therefore has been identified by the government among other sites in the Rift Valley. Suswa is found in the Rift Valley area of Kenya, it is a shared area by Kajiado County: Ngong Division; Kisharu and Olgumi sub-locations and Narok County: Mau Division; Olesharo and Suswa sub-locations. It is estimated to about 80 km from Nairobi the Kenyan capital City and it is accessed through four earth tracks existing and branching from Mai-mahiu-Narok (B3) to the direction of the south up to the conservancy of Mt. Suswa under the hilltop and connected with a single track to the top of the hill. The full-length under study is estimated to be 750km^2. The temperatures are high ranging at 285 and 300 ºC and the resistivity low of about 10 to 15 Ohm-m with losses of heat greater than 3000 MW 1 m depth.

Figure 3.1: The Study Area



Source: Survey of Kenya, 2011

Figure 3.2: Showing Mt. Suswa in Narok County, Kenya (Nation Media Group, 2019)

The caldera is estimated to be approx. 12 x 8 kms. (Beatrice, Levin & Thecla, 2014).

3.2.2 Demographics

The population of people living in Suswa area is recorded as 12,000 people according to the 2019 national census, (Kenya Population & Housing Census, 2019). The community around are mainly pastoralists. Livestock keeping and trading in livestock is their main activity and subsequently complimented with purchasing and selling of livestock on major markets of Ewuaso and Suswa and sale of meat to places like Naivasha and Nairobi. Therefore the local community manage animals, needing water for these animals and grazing areas including forage thus any activity to be undertaken in this area must be considerate of the environmental and social economic impacts.

3.2.3 Cultural Sites

Mt. Suswa is bestowed with numerous caves and tunnels. During one of the visits the researcher was able to experience the dark caves and the role they played, as a tourist attraction. Inside the dark caves was the famous "Baboon Parliament" where a huge baboon population gathered to *"deliberate issues"*. The caves also have some ancient significance to the Maasai community. These caves are used for traditional activities and the inner crater, is believed to be God's domicile. The United Nations has considered such cultural sites not appropriate for exploitation (Beatrice, Levin & Thecla, 2014).

Figure 3.3: The Researcher during a site visit to the Suswa caves

3.2.4 Climate

Two seasons of precipitation are experienced in Suswa area; the short showers fall in the months of October and December; however, the long rains are from March to May. The annual precipitation is between 680mm and 1180mm (ESIA Report - Suswa). Temperatures vary between a high of 34^0 C and a low of 22^0 C (ESIA Report - Suswa).

3.3 The Research Design

The research study adopted a descriptive survey design to ascertain the social, economic and environmental effect of geothermal exploitation on the local community. A descriptive design is effective in addressing characteristics of a normal population like opinions, perception of exploration development and beliefs. The descriptive design is also preferable when doing a case study.

3.4 Target Population

The research targets the local community living around the geothermal project in the Suswa area. According to the 2019 population census, the population within the area under study was 12,000. The census numbers were used for the research, as the population changes have minimal impact on the research sample.

3.5 Sampling

A representative sample of the population was picked for the research. This took into account equal representation in different strata, namely; women, men, and youth from the whole population. Equal proportion stratified sampling was therefore the ideal sampling method. For determining the sample size, the formula shown below shall be used.

n=N/ (1+Ne2)

Where

N= The Total population in the target area

n= The Sample size for the study area as desired

e= Anticipated margin error

Since the study was dealing with a population exhibiting normal characteristics it was logistically difficult to deal with a larger sample size and hence a reasonable margin error of 0.062 was selected (Mugenda & Mugenda, 2003).

Therefore, the sample size was derived as follows:

n=12000/ (1+12000*0.062)

n=290

For the questionnaire, survey samples were chosen using simple random sampling, whilst purposive sampling was applied in obtaining key informant interviews and participants for the focus group discussion by getting the list of intended participants from the geothermal office and the administrative offices.

3.6 Data Collection procedures

The study relied on both primary data which included raw data from the field collected using questionnaires, scheduled interviews coupled with focus groups; it also relied on the secondary data which entailed deriving relevant information from research work of other scholars, journals and other learning sources. Secondary data was garnered from a desk-based review of literature on the subject. The field collection of the data involved the use of questionnaires. The questions on Environmental impacts relating to surface disturbances, air pollution, soil erosion, noise, solid waste as well as socio-economic impacts relating to water, education, employment, health, culture and land use were presented on a five point Likert scale and nominal form where composites indexes were computed by averaging the items on each question in the entire response rate for the purposes of computing their mean scores and hypotheses testing. The questions were translated to the local language, especially for illiterate informants and administered to local community randomly.

There were Focus Group Discussions (FGDs) and Key Informant Interviews (KIIs) for the professionals and local leaders. Each FGD had ten (10) participants for simple management (Creswell, 2009). The researcher used the local administration and community-based organizations (CBO) within Suswa to identify informants. The FGDs and KIIs are essentially for qualitative data collection where the researcher used questionnaires.

	Questionnaire (Quantitative)	FGD (Qualitative) each 10 pax	KII (Qualitative)
	15	2	3
	15	3	3
Number of Days	15	2	3
	15	3	3
	15	2	3

Table 3.1: Data Collection Matrix

Figure 3.4: Researcher administering questionnaires to the local community

3.7 Method of Data Analysis

This study generated qualitative and quantitative data. The qualitative data that was collected using KIIs and FGDs was analyzed hinging on themes and dispensed as narrative excerpts within the report. This was crucial in capturing the particular content and expectations of the sample under study. As soon as the questionnaires were returned by the respondent, they were serialized and edited for completeness and consistency. Quantitative data was analyzed by using descriptive statistics and inferential analysis employing the statistical package for social science (SPSS). This method gave straightforward summaries regarding the sample data and dispensed quantitative descriptions in a manageable form (Gupta, 2004). In conjunction with simple graphics analysis, descriptive statistics forms the basis of virtually every quantitative analysis to data (Kothari, 2004). The association between independent and dependent variables was measured using the Chi-square test ($\chi 2$) through hypotheses testing, which was done at a 5% level of significance, using SPSS.

3.8 Ethical Considerations

The researcher upheld ethics, by briefing all the respondents before undertaking the research, the briefs included; the objectives of the study, the research instrument, and the way in which the findings of the study were to be utilized. The intention was to avoid possible misunderstandings that might arise during the interviews. Further, voluntary participation and selection of electronic recording of the target respondents was requested before the interviews; the wishes of those unwilling to take part in the interviews were respected. The researcher additionally guaranteed the respondents of anonymity and the choice to withdraw any prior information given. Finally, the researcher got approval before conducting this research from the management of the Mt. Suswa Conservancy, the GDC, and the Ministry via the National Council of Science, Technology, and Innovation (NACOSTI).

Figure 3.5: Researcher consulting with the Mt. Suswa Conservancy Management

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Introduction

This section focused on the outcome of the field study owing to research questions arising from study objectives on the environmental, economic and social effects of geothermal exploration on the local community in Suswa. Pertinent data, concerning the research objectives and study variables are analyzed, presented and interpreted using methods identified in chapter three (3). The analysis is accompanied by an extensive discussion on the interpretation of the findings.

4.2 Demographic Information

Comprehensive and tactful questionnaires were designed and handed over to the respondents. For analysis, to be more exhaustive 290 questionnaires were prepared and issued to the prospected respondents. Midst the 290 questionnaires administered, 176 translating to 65.19% a response rate, they were then correctly filled and returned for coding and analysis. With respect to the postulation of Mugenda & Mugenda (2003), this return rate was good. The researcher then conducted Focus Group Discussions (FGDs) and Key Informant Interviews (KIIs) for the professionals and local leaders.

4.2.1 Gender Distribution

The study found it imperative to assess the sex of the plaintiffs so as to ascertain whether there was gender parity in the responses. Gender equality is a very important attribute as it gives a signal on the generalization of the study findings to both genders. A society that is gender-responsive provides a conducive working environment for both genders to fraternize in their quest for social suppositions.

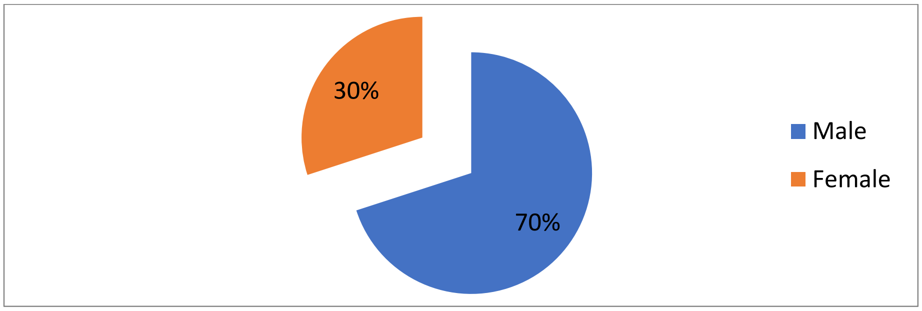


Figure 4.1: Gender Distribution Source: Field Survey, (2019)

Figure 4.1 shows that 70% were male while 30% were female hence the study considered the views of both genders.

4.2.2 Distribution by Age

The study determined distribution with respect to Age of the plaintiffs. The purpose was to perceive the understanding by adults regarding the effects of geothermal exploitation on their socio-economic and environmental matters.

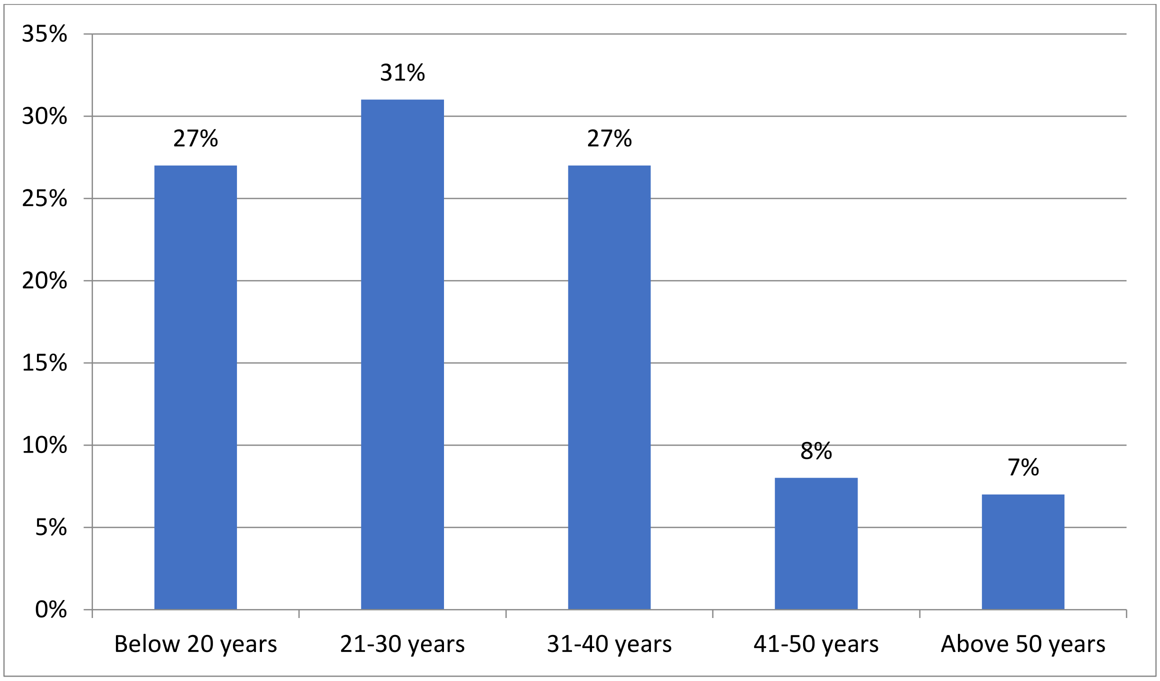


Figure 4.2: Age Distribution Source: Field Survey, (2019)

The outcome of the ages revealed majority i.e. 75% were forty (40) years and below 31% were in the range of 21-30 years; 27% were noted to be between 31-40 years and below 20 years respectively. In addition, only a few 8% indicated being 41-50 years and 7% beyond age 50 which depicted clearly that significant population of population had attained the maturity age of 18 years, hence could comprehend the effects of geothermal exploitation on the socio-economic and environmental area.

4.2.3 Distribution with respect to Level of Education

The analysis of the outcome ascertained the respondents' level of education. This was to establish the local communities' literacy levels with respect to geothermal exploitation and the possible effects on their socio-economic and environmental impacts.

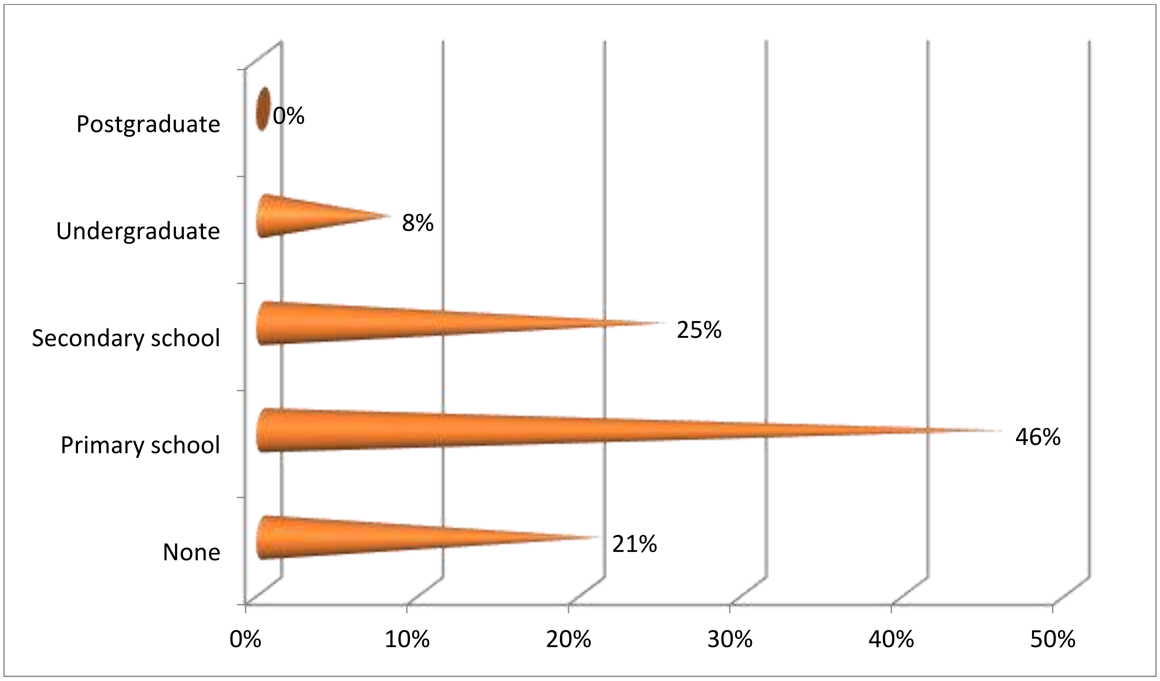


Figure 4.3: Level of Education

In terms of education, Suswa fraternity levels of education are very low, yet most learning institution in prospect geothermal drilling zone are community initiatives within Suswa. A few educators had been seconded by TSC a national government entity whilst parents supplement the deficit of teachers through the (PTA) associated. In this area, there was no existence of Tertiary institutions e.g. a village polytechnic or college. Majority of the learning institutions in Suswa are built as temporary structures with basic sanitation being inadequate in all the schools. The majorities circa 46% of those interviewed have had primary basic formal education, 25% went to secondary school, 8% had undergraduate degrees, 21% had no formal education and none had postgraduate degrees. Despite low levels of education, they have the basic knowledge that they can use to understand the socio-economic and environmental changes resulting from the geothermal exploitation.

According to the GDC key informants, there exists a department within GDC that has the mandate of execution of all community relations and processes in all geothermal fields. Before the onset of any operation, the department moves to the ground to sensitize the community on the intentions of the company. Early engagement through sensitization meetings, leaders' forums, and stakeholder meetings was done for the Suswa prospect. GDC in the Suswa prospect met community leaders, development partners, cultural groups, government agencies, opinion leaders, as well as the elite class as the community entry point. So far, GDC has enjoyed support and affirmation from the Suswa Community through partnerships and frequent jointly held meetings. However, there's still the fear of loss of land and other environmental and social-economic effects associated with the geothermal power plant that could cause conflicts to arise, between the company and the local communities.

Our current findings are in tandem with those of Sinclair Knight (1992) who interviewed a local community living within the surroundings of a power plant, regarding the community's attitude towards the geothermal project, where the survey indicated that the interviewees generally had a favorable and positive attitude towards the proposed project.

4.3 Potential Environmental and Socio-Economic Impacts

4.3.1 Consultation by Geothermal Development Company (GDC)

The respondents confirmed that they had been approached by Geothermal Development Company (GDC) at least once. However, the respondents noted that the consultations were unsatisfactory.
Key interviews conducted with GDC professionals who worked closely with the communities surrounding the prospect areas acknowledged the importance of bringing all participants on board, as this is a crucial and integral part of the sustainability of the project.

The local community are mainly the Maa peoples. The other key stakeholders who were consulted include; the County governments of Narok and Kajiado, the National Land Commission, and Kenya Electricity Generating Company (KenGen) and research institutions that are engaged in geothermal research. The other stakeholders that GDC has engaged in various consultative forums include key opinion leaders, landowners, and development partners. The meetings were held from time to time to discuss specific problems concerning the direct potential impacts the project may have on the community.

4.3.2 Diseases that may arise as a result of geothermal activity

The families interviewed specified that when the geothermal becomes operational, they were fearful of a feasible increase in breathing ailments e.g. asthma, colds, flu, and eye problems. That the power plant could pose a health risk to the community living in the surrounding area and the staff working in the proposed Suswa geothermal plant, that could be caused by breathing in of contaminated air as a result of emissions by the geothermal facilities. The hazardous component of air as elaborated in previous paragraph include and not limited to; benzene, hydrogen sulfide, mercury and CO_2. Excessive emission of H_2S is responsible for putrescent odors; atmospheric oxidation of hydrogen sulfide can bring about vesicatory reactions and negative health effects such as premature deaths and miscarriages of both human and livestock. Another consequential pathway is the usage of water with cytotoxic solute dissolved, originating from either underground reservoir or surface runoff i.e. arsenic extracted from geothermal waste affluent.

4.3.3 Potential effects of Geothermal activities on Livestock

The respondents worried that the Suswa geothermic power plant have an effect on their livestock i.e. shoats, donkeys, and cows. The community living around Suswa being pastoralists practice free-range grazing which is the most commonly used for pasture. The land is generally communally owned, therefore restricting rotational grazing.

Paddocking is a common means of exploiting pasture, water, and livestock herds, particularly for milkers. However, overgrazing was detected to be a major drawback facing the grazing ranges, during famine and drought. The rangeland is a definite source of herbs used for curative measures against all sorts of human and livestock diseases. The respondents also stipulated that possible resettlement and displacement might have an effect on their pasturelands. In addition to all this, the numerous and unforeseen dangers of water contamination may have an effect on the health of the eutheria. Conservation groups are normally very concerned by these risks as they prioritize the dependency on clean and available water and land resources.

The geothermal project at Suswa was opposed by some residents siting the above reasons. They asserted that the disadvantages far outweighed benefits, or were unevenly distributed. For instance, it would be difficult to weigh improved access to a medical clinic against loss of fertile land for eutherian grazing. Community pastoralists inhabit the outer caldera with the main socio-economic activity in the outer caldera being pastoralism. The inner caldera is not inhabited or accessible due to its dense forest cover. Drilling would need careful handling of all waste streams to eradicate possible contamination and hence poisoning of all those that might consume it. Despite the fact that the prospected geothermal drilling project would alter the present socio-economic profile of the local area, livestock poisoning accidents would definitely undermine the enjoyed local support of the project, especially as the locals place a high premium on their livestock.

Figure 4.4: Livestock source of water from pans in the area.

4.3.4 Potential Benefits of Suswa Geothermal Project to the Local Community

The potential benefits of geothermal exploitation in Suswa include but not limited to economics, infrastructure, and health. There are four health centers at Suswa, Ewuaso, Olgumi, and Najile. The various medical facilities are quite far from the community homesteads, forcing the people to travel long distances on donkeys, which are used as ambulances. Therefore, if dispensaries would be increased in the area, then the local communities stand to benefit greatly. In addition, improved road networks would enhance access to the health facilities. Also, a known health benefit of geothermal is its brine. In Olkaria, the local Maasai people use the brine to heal skin conditions. Low incidences of waterborne diseases like cholera and typhoid are attributed by the locals, to the use of water from the fumaroles.

The development of geothermal resources could turn out to be a significant boost and record appreciable gains in the Suswa area, such as the development of more schools; a detail the local community accepts, since the area has only a few schools, which are widely dispersed. These include and not limited to the elementary institutions, that is, Kisharu , Karuka Olgumi Adventist Primary School, Olngosua Primary Schools, also there is Maasai Soila Girls high School and Empaash, Olesharo, Enkiloriti, Olodungoro Primary Schools however, it should not be assumed that all of the institutions mentioned herein have pre-unit programs for the children.

Figure 4.5: The Road from Suswa Market to the prospected Geothermal drilling area.

The findings agree with the Environmental and Social Impact Assessment (ESIA) study report prepared by GDC in 2013 which pointed out improved access to water to be used by the community as a benefit. Further benefits would be derived after the initial drilling phase of the first well, improving road infrastructure within the project area and its environs, and increasing employment opportunities for the locals, leading to improvement of community living standards and hyperbolic urban development within the local urban centers.

These would have a dominoes effect of providing housing for the staff, increased tourist visitation to the Mt. Suswa Conservancy, the Calderas, and the Suswa Caves for all tourists, more so the domestic tourists. Education opportunities for the local community youngsters, would be enhanced, from improved school faculties and including boarding facilities. The fundamental initiative to supply and distribute electric power by the national government to the native jua kali artisans creates more opportunities hence earning and uplifting the livelihood of the locals within Suswa. Refocused preservation and safeguarding of the Maasai sacred place like ancestral shrines and areas used for graduation celebrations of the Maasai Morans, to preserve their culture and cultural sites. The Mount Suswa Conservation would be better placed to promote their merchandise in conjunction within the circuit Maasai Mara tourist. In addition, markets for their products like dairy and farm produce would usher in a leap in economic empowerment for the local people.

4.3.5 Potential Environmental Impacts of Suswa Geothermal Project

The respondents were given with statements relating to the environmental matrix (air, water, ground, ecosystems) so as to rate on a 5-point Likert using the following scale. 1-Not at all, 2-Small extent, 3-Moderate extent, 4-Great extent and 5-Very great extent. Based on the findings, the respondents agreed that the following environmental matrix will be affected to a great extent; surface-visual effects (M=3.9099, SD=1.02212), physical effects (M=3.8026, SD=.93836), acoustic effects (M=4.0021, SD=1.39693), thermal effects (M=3.9079, SD=1.02212) as well as chemical effects (M=4.0132, SD=1.27010).

Table 4.2: Impacts of geothermal development on environmental matrix (air, water, ground, ecosystems)

Environmental impacts	Mean	Standard Deviation
Surface-visual effects (land use, landscape, flora and fauna).	3.9099	1.02212
Physical effects (induced seismicity, subsidence, geological hazards).	3.8026	.93836
Acoustic effects (noise during drilling, construction and management).	4.0021	1.39693
Thermal effects (release of steam in the air, ground heating and cooling for fluid withdrawal or injection).	3.9079	1.02212
Chemical effects (gaseous emissions into the atmosphere, re-injection of fluids, and disposal of liquid and solid waste).	4.0132	1.27010

The findings of the study coincide with the findings of Mark (2018) who claimed that the most ecological impressions on geothermal Expansions are associated with surface disturbances, the physical effects of fluid withdrawal, heat effects, and discharge of chemicals. All these factors can also have an effect on the biological environment. Like in all industrial activities, it has been established that there are some social and economic effects.

In addition, the study sought to find out the environmental outcomes and impacts as a result of potential geothermal exploitation in Suswa. In step with the findings depicted in table 4.3, the respondents agreed that Geothermal exploitation would lead to; wanton land dilapidation as a result of the exploratory project, causing soil erosion and thus land degradation (M=3.9216, SD=1.056), the Suswa community's ecosystem balance would be interrupted by the Geothermal exploration projects (M=3.9316, SD=1.03076), geothermal exploratory projects might result in increased air pollution (M=3.7447, SD=.93387), waste disposal in the Geothermal exploration sites will lead to contamination of available water sources (M=3.8610, SD=1.01980), there will be huge deforestation as a result of the creation of access routes to new areas and sites thus minimizing sources of pasture (M=3.4658, SD=.92859), environmental pollution caused by geothermal drilling can result to destruction of livelihoods of local communities (M=3.9605, SD=1.22682).

Table 4.3: Environmental Outcomes and Impacts as a Result of Geothermal

Environmental impacts	Mean	Standard Deviation
Unrestrained land dilapidation as a result of the exploratory project, causing soil erosion and hence land degradation	3.9216	1.05600
The Suswa community's ecosystem balance will be interrupted by the Geothermal exploration projects	3.9316	1.03076
Geothermal exploratory projects might lead to increased air pollution	3.7447	.93387
Waste disposal in the Geothermal exploration sites will lead to contamination of available water sources	3.8610	1.01980
There will be massive deforestation as a result of the creation of access routes to new areas and sites thus minimizing sources of pasture	3.4658	.92859
Environmental pollution caused by geothermal drilling will result to destruction of livelihoods of local communities	3.9605	1.22682

The findings are supported by Arnorsson (2004) who stated that negative effects on the ecosystem including degradation of scenic dwelling places; hot springs running dry; fertile soil humus being eroded downstream; excessive noise beyond the standard wavelength and organic pollution of the atmosphere and mainstream and underground waters. The exploitation of geothermic resources may increase seismic activity and cause land subsidence. Numerous controls have been successfully utilized in an attempt to reduce the negative environmental influences on geothermal energy usage. The foremost notable ones are directional injection of geothermic affluent into cleaning units before re-emptying into the mainstream. The community members of the area were asked to rate the extent the construction of the geothermal plant would impact the community amenities.

Supported by the results shown in Table 4.3, the respondents indicated that following amenities would be affected to a large extent; Tourism (M=4.0421, SD=1.31709), Cultural centers (M=3.9605, SD=.85543), Water pipeline (M=3.8947, SD=1.13817), Employment at Power Project (M=3.8421, SD=1.14371), Health center(M=3.8026, SD=1.05855) and Schools (M=3.5789, SD=1.37853). The respondents however showed that the following amenities would be affected to a moderate extent; entertainment centers (M=2.5895, SD=1.07475), small businesses (M=2.6974, SD=1.37618) and small shops (M=2.9079, SD=1.54210).

Table 4.4: Impact of Geothermal Activities on Local Community Amenities

Facility/Outcome	Mean	Standard Deviation
Entertainment centers	2.5895	1.07475
Cultural centers	3.9605	.85543
Health center	3.8026	1.05855
Employment at Power Project	3.8421	1.14371
Water pipeline	3.8947	1.13817
Tourism	4.0421	1.31709
Small shops	2.9079	1.54210
Small businesses (sale of milk/animal products)	2.6974	1.37618
Schools	3.5789	1.37853

Figure 4.6: Locally made Steam jet extraction structures that are used for water collection by the locals

4.3.6 Potential Socio-Economic Impacts of Geothermal Exploitation in Suswa

The statements shown in Table 4.5 discuss the socio-economic impacts as a result of geothermal exploitation in Suswa. The respondents were needed to rate using the following Likert scale: use 1-not at all, 2-small extent, 3-moderate extent, 4-great extent, and 5-very great extent. The respondents were in agreement that the project might create increased dust levels and smells that might expand towards their homesteads as shown by a mean of 3.8553 and a standard deviation of 1.02897. The respondents also were in agreement that geothermal activities may lead to; an increase in respiratory diseases e.g. asthma, colds, flu's and eye problems, (M=3.9711, SD=1.11221), displacement/ resettlement from their present homes (M=3.9632, SD=.99154), reduction in land size(s) because of the project expansion (M=3.8632, SD=1.12982), reduction in grazing land for their livestock (M=4.0042, SD=1.17995), reduction in family sizes due to the gradual decrease in land sizes (M=3.0421, SD=1.07148), increase in miscarriages of both humans and livestock or children being born with deformities or retarded if the project expands (M=3.8211, SD=1.09684) and erosion of Maasai cultural values due to influx of outsiders (M=3.1711, SD=1.32049). 2

Table 4.5: Potential Socio-Economic Impacts of Geothermal Exploitation in Suswa

Socio-Economic impacts	Mean	Standard Deviation
The increasing dust levels and smells the project could bring if it swells towards their homesteads.	3.8553	1.02897
A rise in respiratory diseases, eye problems, colds and flus.	3.9711	1.11221
Displacement/ resettlement from their present homes.	3.9632	.99154
The reduction in land size(s) as the project expands.	3.8632	1.12982
The reduction in grazing land for their livestock.	4.0042	1.17995
A reduction in family size due to the gradual decrease in land sizes.	3.0421	1.07148
An increase in miscarriages or children being born with deformities or retarded if the projects expand.	3.8211	1.09684
Maasai cultural values being eroded by the influx of outsiders	3.1711	1.32049

The findings are substantiated by Zepeda and Rodriguez (2005) who looked at socially accountable geothermal development in El Salvador. The findings discovered that environmental and social impacts from geothermal projects can be quite significant, particularly to the neighboring communities. In order for energy developments to be sustainable within the long run and accepted and supported by general society, firms should consistently adopt socially accountable practices, together with responsible market practices, environmental governance, ethical accounting practices and ensure to engage the community. The adverse influences that mostly focused on in Suswa are those related to ecological functions and valued resource reservoirs; these negatively impacted on communal values.

Figure 4.7: Maasai women selling traditional Maasai wares to local tourists

4.4 Test of Hypotheses

This section presents and talks about the results of the hypotheses obtained from the specific objectives of the study. These hypotheses were tested at a 95% confidence level (α=0.05), hence decision points to reject or fail to reject a hypothesis were based on the p-values. Where $p<0.05$, the study failed to reject the hypotheses, and where $p>0.05$, the study rejected the hypotheses. The study tested the hypothesis by conducting a Chi-square test for different environmental and socio-economic effects. The results showed both significant and non-significant relationships for various factors.

H_0 There is no significant difference between geothermal power generation and environmental effects on the local community in Suswa.

Table 4.6: Chi-square analysis of responses on geothermal power generation and environmental effects on the local community in Suswa

	Value	Df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	.488[a]	1	.485		
Continuity Correction[b]	.319	1	.572		
Likelihood Ratio	.487	1	.485		
Fisher's Exact Test				.507	.286
Linear-by-Linear Association	.486	1	.486		
N of Valid Cases	176				

a. 0 cells (.0%) have expected count less than 5. The minimum expected count is 36.38.

b. Computed only for a 2x2 table

Chi-square critical value

Where a = 0.05 and n=176

χ^2_a=3.841

Chi-square Computed

The sum of the last column gives (χ2c) = 0.488

At the 95% confidence level and a degree of freedom of = (2-1) (2-1) = 1, χ2a=3.841. The rule of thumb is that when chi-square computed (χ2c) is less than chi-square critical value (χ^2_a), null hypothesis is rejected and alternative hypothesis accepted and therefore since χ2c < χ2a, we fail to accept the null hypothesis H_0 *and accept the alternate hypothesis and conclude that there is evidence to suggest that geothermal power generation has environmental effects on the local community in Suswa.*

The second hypothesis formulated was that

H_0 *there is no significant difference between geothermal power generation and the socio-economic status of the local community in Suswa.* The results are presented in Table 4.6

Table 4.7: Chi-square analysis on geothermal power generation and the socio-economic status of the local community in Suswa

	Value	Df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	.964[a]	1	.046		
Continuity Correction[b]	3.375	1	.066		
Likelihood Ratio	4.058	1	.044		
Fisher's Exact Test				.064	.032
Linear-by-Linear Association	3.953	1	.047		
N of Valid Cases	176				

a. 0 cells (.0%) have expected count less than 5. The minimum expected count is 22.47.

b. Computed only for a 2x2 table

Chi-square critical value

Where a = 0.05 and n=176

χ^2_a=3.841

Chi-square computed

The sum of the last column gives (χ^2c) =.964

At the 95% confidence level and a degree of freedom of = (2-1) (2-1) = 1, χ^2_a=3.964. The rule of thumb is that when chi-square computed (χ2c) is less than chi-square critical value (χ^2_a), null hypothesis is rejected and alternative hypothesis accepted and therefore since $\chi^2_c < \chi^2_a$, we reject the null hypothesis H_0 and accept the alternate hypothesis and conclude that there is evidence to suggest that geothermal power generation affects the socio-economic status of the local community in Suswa.

CHAPTER FIVE

SUMMARY OF FINDINGS, CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

This section summarizes the finding of the research survey making conclusions and commendations based on the objectives of the study. It gives the implications from the findings and suggesting areas that may need further research.

5.2 The Summary of the Outcomes

The study was conducted by dispensing 290 detailed and well thought through questionnaires that were designed and distributed to the respondents. Further interviews were conducted for professionals and local leaders via FGDs and KIIs. Through the key interviews conducted with GDC professionals, it was established that they engaged the communities surrounding the prospect because it recognizes the importance of bringing them onboard, however, the local community at the Suswa geothermal project who are mainly the Maa speaking community, indicated that the consultations were not satisfactory.

According to the key informants, there exists a department in GDC that has the mandate of execution of all community relations and processes in all geothermal fields before the onset of any operation, the department moves to the ground to sensitize the community on the intentions of the company. Early engagement through sensitization meetings, leaders' forums and stakeholder meetings was done in Suswa prospect. GDC in Suswa prospect used community leaders, development partners, cultural groups, government agencies, opinion leaders and the elite class as the community entry point. The findings indicate that GDC has enjoyed support and acceptance of the Suswa Community through partnerships and engagements which form an integral part of the sustainability of the project.

The first objective was to determine the potential environmental effects of the exploitation of geothermal on the local community in Suswa. Based on the findings, the environmental matrix that could be affected to a great extent are surface-visual effects, physical effects, acoustic effects, thermal effects as well as chemical effects. According to the findings shown in Table 4.3, it was found that geothermal exploitation could lead to; land dilapidation causing soil erosion and massive cutting down of trees without replanting as a result of the creation of access routes to new areas, reduction in grazing land for their livestock, waste disposal hence contamination of available water sources. The findings indicated that environmental pollution would result in the destruction of livelihoods of the local communities and interference with Suswa community's ecosystem balance.

The results of the hypothesis that there is a significant difference between geothermal power generation and environmental effects on the local community in Suswa at the 95% confidence level $\chi 2a=3.841$ and since $\chi 2c = 0.488 < \chi 2a$, substantiated rejection of null hypothesis H0, thus embracing the conclusion suggesting that geothermal power generation affects environmental effects on the local community in Suswa.

The second was to determine the conceivable economic and social consequences of the exploitation of geothermal on the local community in Suswa. The findings revealed that the local community feared that the proposed Suswa geothermal plant could pose health risks e.g. respiratory diseases caused through increased dust levels and breathing poisonous emissions from geothermal activities. The Maasai who mainly practice pastoralism feared that the Suswa geothermal plant could be a hazard to themselves and their livestock causing miscarriages and premature deaths and that the geothermal activities could bring displacement and/or resettlement from their present homes.

Furthermore, the outcomes of the research study revealed that the prospective projects of excavating geothermal energy would eventually affect the normal socio-economic status of Suswa area. The potential benefits include economic growth, infrastructure development in terms of health dispensaries, roads, and education centers. The geothermal brine's health benefits known worldwide to be used for skin ailments could benefit the local community. The results of the hypothesis that there is a significant difference between geothermal power generation and the socio-economic status of the local community in Suswa showed that at the 95% confidence level Chi-square computed ($\chi 2c$) =.964 and $\chi 2a=3.964$. Since $\chi 2c < \chi 2a$, the study rejects the null hypothesis H0 and accepts the alternate hypothesis and concludes that there is evidence to suggest that geothermal power generation affects the socio-economic status of the local community in Suswa.

The third hypothesis was to determine the potential effects of the geothermal exploitation on land use by the local community in Suswa. Geothermal exploitation is costly and involves the drilling pads , opening up of access roads and power setting up the power plants al this involved activities can negatively affect the leading to alteration of cover crops and inorganic matters with insects causing imbalance in the ecosystem of the surrounding region, such adverse outcomes are; vegetation change and losses ,landscape modifications, alteration of natural features, soil erosion, vegetation change and losses, surface water pollution and change in land boundaries hence leading to land ownership disputes. As a result, it has led to heated disputes and uncertainties amongst communities living in the area on issues like displacement without compensation, diminution of their land size(s) as compared to what one previous owned owing to the project expansion, minimization of in grazing land for their herds.

On the other hand, such socio-economic activities those are likely to affect land use comprised but not limited to cultural sites, economic usage of the lands, social facilities like water lines, roads, and schools. The potential new grouping of the land by the ministry i.e. rural agricultural or urban settlement and reserves non-potential and some land declared government land thus reducing the grazing and agricultural area of the locals. Further, reaction often grows against landscape modifications and alteration of natural features of cultural or historical interest, caused by civil and construction works and changes in the use of public areas resulting from project activities. The hypothesis formulated was that there is a significant difference between geothermal power generation and land use by the local community in Suswa. The results show that Chi-square computed ($\chi 2c$) = 1.348 and $\chi 2a$=3.841 at the 95% confidence level. Since $\chi 2c < \chi 2a$, the study rejects the null hypothesis H_0 and accepts the alternate hypothesis and concludes that there is evidence to suggest that there is a significant difference between geothermal power generation and land use by the local community in Suswa was supported.

5.3 Conclusion

From the summary of the findings, the study concluded that GDC has continued to interact and re-engage the communities making a cordial relationship and reducing conflict, hence garnering support from the community. The study concluded that the local community was wary of the potential geothermal project. The pertinent conclusion of the study based on the findings is that the potential socio-economic and environmental effects of the geothermal project still need further efforts to ensure a win-win situation for both the GDC and the local community living in the vicinity for the Suswa geothermal plant.

5.4 Recommendations

Based on the finding as revealed by the study, the researcher believes that if the below recommendations are well implemented, it will go mile stones will help enhance achievement of successful exploitation geothermal energy on the local.

Albeit social and economic impacts being inevitable in any development of geothermal power, they should be minimized by holding consultative forums with the community and taking their interests, fears and concerns into consideration. For example, Tole (1997) has shown that long-term monitoring of the welfare of displaced residents is effective. He has also suggested that for the residents that remain in the vicinity of a project, it is essential for them to be provided with social amenities so that they can identify with the project. This is important because the land on which the project stands in Suswa is the ancestral and inheritance of the Maasai community living there. This study also recommends that the project operators participate in community development activities e.g. regular donations in cash or in kind through Corporate Social Responsibility programs (CSR). An option would be to formulate an integrated ecotourism plan for Mt. Suswa Conservancy.

The policy makers must make every attempt to minimize any displacement or relocation of the local community during the exploratory phase, until the geothermal potential is established to be viable and commercial and only then can the settlements within the vicinity of the drilling wells be relocated as required and the local community compensated. It is also recommended that there should be proper land use planning and minimization of surface leveling e.g. the greenery, to be used for stores, buildings and vehicle parking by the institution; as this would obliterate the sprawling scenery and go against the development of eco-tourism of the Mt. Suswa Conservancy as suggested in the present study.

GDC has the responsibility of Environmental Monitoring of the geothermal resources and the impacts that may affect the health of the local inhabitants and should create public awareness, inform and educate the community members on general geothermal matters e.g. safety measures.

It is recommended that the potential negative impacts of geothermal developments should be mitigated through establishment and implementation of sound environmental management and operation systems and taking due regard of the local communities. The recommendations are that many social and economic benefits associated with the geothermal development should benefit policy makers, scholars and the local communities in their localities. This will assist to a large extent gain acceptance of the project.

5.5 Recommendations for Further Research

The study focused on the potential social and economic effects of geothermal exploitation, a case of Suswa Geothermal plant. The study recommends that future studies should

i) Focus on the impact of geothermal activities on tourism around the prospected Suswa Geothermal plant and
ii) Undertake a study on the environmental management methods that can be applied to minimize the potential negative impacts of geothermal development in Suswa.

It would be a useful exercise to further research into the following Since the research project conducted by the researcher is a case study, there is need for further research in other Devolved Units in order to establish whether the conclusions arrived at in this study hold for other Counties.

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APPENDICES

Appendix 1: Questionnaire

Thank you for taking the time to be a part of this research that seeks to establish the potential environmental and social effects of geothermal exploitation in the area. The questionnaire has sections ONE and TWO. Please take note that your participation is voluntary and highly appreciated.

SECTION ONE: GENERAL INFORMATION

1. Name (Optional) ________________________________

Gender: Female ☐ Male ☐

2. Occupation_____________________________________

3. Age:

- Below 20 years ☐
- 21-30 years ☐
- 31-40 years ☐
- 41-50 years ☐
- Above 50 years ☐

4. Level of Education:

- None ☐
- Primary School ☐
- Secondary School ☐
- Undergraduate ☐
- Postgraduate ☐

SECTION TWO: POTENTIAL ENVIRONMENTAL AND SOCIO-ECONOMIC IMPACT

5. As a local have you ever been involved in any consultation by Geothermal Development Company (GDC). If yes, Describe Briefly ………………………………….........................

…………………………………………………………………………………………………..

6. Are you satisfied with the consultations that are undertaken between the GDC and the local community?

Yes ☐ No ☐

7. Does any conflict exist or do you anticipate it to arise between the locals and the Company or amongst the locals on the planned project?

Yes ☐ No ☐

Explain

…………………………………………………………………………………………………

…………………………………………………………………………………………………

8. How has the conflict resolved? Or if it arises in future how do you think will be the best solution?

………………………………………………………………………………………………..

………………………………………………………………………………………………..

9. Do you think there will be conditions/diseases that may arise as a result of geothermal activity emissions?

………………………………………………………………………………………………

………………………………………………………………………………………………

10. Do you think geothermal activities may affect your animals (sheep, donkey, goat, and cows)? Why do you think so, please describe?

………………………………………………………………………………………………

………………………………………………………………………………………………

………………………………………………………………………………………………

11. Do you have any approximate/exact number of local people who have been involved in working for the company so far? Women and Men

Specifications………………………………………………………………………………

12. Do you know of any projects you have heard that the company will undertake?

……………………………………………………………………………………………….

What is your opinion about their viability and importance to the community around? ……………………………………………………………………………………………………

……………………………………………………………………………………………………

13. So far have any projects been initiated or completed?

Yes ☐ No ☐

14. If any, could you kindly rate the projects?

Excellent ☐ Good ☐ Above Average ☐ Poor ☐ Very Poor ☐

Kindly give reason for your answer……………………………………………………….

……………………………………………………………………………………………..

15. Which of the commodities/services below is the most critical to the Suswa Community?

Water ☐ Health ☐ Roads ☐ Education ☐ any other……………………………….

16. Has there been a positive change on any of the above commodities/services upon the anticipation of the establishment of the Suswa Geothermal Plant?

……………………………………………………………………………………………….

………………………………………………………………………………………………

17. Which is the main socio-economic activity of the Suswa Community? Has it been affected by the establishment of the Suswa Plant? …………………………………………………….…….

……………………………………………………………………………………………….

……………………………………………………………………………………………….

18. How is the land owned in the Suswa Area? Is it Communal or Private? Have there been any changes on how you use the land …………………………………………………….....….

………………………………………………………………………………………………..

19. Does any tourist site exist within the Suswa Area? If yes, how is it run?

………………………………………………………………………………………………………

………………………………………………………………………………………………………

20. Has the County Government been involved in any activities concerning the geothermal exploitation? ....

……………………………………………………………………………………….….

21. Would you wish to see the project expanded or terminated?

……………………………………………………………………………………………….

……………………………………………………………………………………………….

22. Geothermal development may have an impact on any environmental matrix (air, water, ground, ecosystems). Rate the extent to which the following environmental matrix might be affected by the Suswa Geothermal project.

Use 1-Not at all, 2-Small extent, 3-Moderate extent, 4-Great extent and 5-Very great extent.

	1	2	3	4	5
Surface-visual effects (land use, landscape, flora and fauna)					
Physical effects (induced seismicity, subsidence geological hazards)					
Acoustic effects (noise during drilling, construction and management)					
Thermal effects (release of steam in the air, ground heating and cooling for fluid withdrawal or injection).					
Chemical effects (gaseous emissions into the atmosphere re-injection of fluids, and disposal of liquid and solid waste).					

23. The following statements concern the environmental outcomes and impacts as a result of geothermal exploitation in Suswa. Rate using the following scale: Use1-Not at all, 2-Small extent, 3-Moderate extent, 4-Great extent and 5-Very great extent.

Environmental impacts	1	2	3	4	5
1. Unrestrained land dilapidation as a result of the exploratory project, causing soil erosion and hence land degradation					
2. The Suswa community's ecosystem balance will be interrupted by the Geothermal exploration projects					
3. Geothermal exploratory projects might lead to increased air pollution					
4. Waste disposal in the Geothermal exploration sites will lead to contamination of available water sources					
5. There will be massive deforestation as a result of the creation of access routes to new areas and sites thus minimizing sources of pasture					
6. Environmental pollution caused by geothermal drilling will result to destruction of livelihoods of local communities					

24. In your own view, what might be the environmental effects of geothermal exploitation in Suswa…………………………………………………………………………………………..….

25. Rate the extent to which the development of the geothermal would impact the local community amenities. (Tick appropriately). Rate using the following scale: Use 1-Not at all, 2-Small extent, 3-Moderate extent, 4-Great extent and 5-Very great extent.

Facility/Outcome	1	2	3	4	5
Entertainment centers					
Cultural centers					
Health center					
Employment at Power Project					
Water pipeline					
Tourism					
Small shops					
Small businesses (sale of milk/animal products)					
Schools					

26. The following statements concern the socio-economic impacts as a result of geothermal exploitation in Suswa. Rate using the following scale:

Use 1-Not at all, 2-Small extent, 3-Moderate extent, 4-Great extent and 5-Very great extent

Socio-Economic impacts	1	2	3	4	5
The increasing dust levels and smells the project could bring if it expands towards their homesteads.					
A rise in respiratory diseases (asthma), eye problems, colds and flus.					
Displacement/ resettlement from their present homes.					
The reduction in land size(s) as the project expands.					
The reduction in grazing land for their livestock.					
A reduction in family size due to the gradual decrease in land sizes.					
An increase in miscarriages or children being born with deformities or retarded if the projects expand.					
Maasai cultural values being eroded by the influx of outsiders					

Appendix II: Research Permit

UNIVERSITY OF NAIROBI

DEPARTMENT OF GEOGRAPHY AND ENVIRONMENTAL STUDIES

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P.O. BOX 30197-00100
NAIROBI
KENYA

Sept. 12th 2019

The Director,
National Commission for Science & Technology
Nairobi, Kenya.

Dear Sir/Madam,

RESEARCH PERMIT: MS. LYDIA NANEU MASIKONTE

This is to confirm that the above named is a Master of Arts student (Registration Number – C50/65999/2013) at the Department of Geography and Environmental Studies, University of Nairobi registered.

Ms. Masikonte is currently undertaking research on a topic titled: **The Potential Environmental and Socio-economic Effects of the Geothermal Exploitation on the Local Community: A Case of Suswa Geothermal Plant.**

Any assistance accorded to her will be highly appreciated.

CHAIRMAN
Department Of Geography
and Environmental Studies
UNIVERSITY OF NAIROBI

Dr. Boniface Wambua
Chairman, Department of Geography & Environmental Studies

Appendix III: Nascoti Permit

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