PRIORITIZATION IN THE DEVELOPMENT OF GEOTHERMAL FIELDS: THE KENYAN CONTEXT

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Abstract
Geothermal is considered to be a green, clean and one of the most reliable sources of energy globally for electric power generation and direct utilization. Kenya is endowed with vast high- and medium- temperature geothermal resources located mainly along the Kenyan rift, and parts of Coast, Central and Nyanza regions, with a potential in excess of 10,000 MWe. In the Kenya's 2011–2031 Least Cost Power Development Plan (LCPDP) geothermal resources are considered the choice for the future generating capacity. The optimum solution indicates that geothermal sources will contribute at least 5000 MWe out of the total projected 15,000 MWe by the year 2031. Currently, geothermal contributes a total of 212 MWe of power to the national grid accounting for 14 % of the total power generated. In order to achieve the projected 5000 MWe, additional geothermal prospects/fields have been identified and earmarked for development. This paper describes the determining factors of prioritizing geothermal prospects/fields for development in Kenya.

Key words: geothermal energy, prioritization, electric power, geoscientific, drilling, Kenyan Rift

1.0 Introduction

1.1. Geothermal Energy

The exploitation of geothermal energy as a sustainable and almost inexhaustible source of base load energy is regarded as a technology of the future. Geothermal energy has been used for electric power production, starting experimentally in Italy in 1904, and with the first commercial plant in 1913 at Larderello (Chamorro, *et al.,* 2012). This followed with plants in Mexico, New Zealand, and at The Geysers in the United States. Since those historic days, several countries have developed geothermal power plants using the relatively scarce high temperature hydro-geothermal reservoirs. Today, world installed electrical generation capacity is more than 11 GW (Gehringer & Loksha, 2012). Electric energy produced from geothermal resources represents only a small percentage, less than 0.5% of the world's electricity needs, but emerging exploitation technologies will allow a significant increase in the contribution of this renewable energy source in a near future (Bertani, 2005; 2010). In general terms, three main technologies are in use today to produce electricity from geothermal reservoirs, and they are Dry Steam, flash and binary plants. The technology used is directly related with the state of the fluid and its temperature, as it comes from the well of the geothermal reservoir (Yari, 2010).

1.2 Kenya's Energy Mix

According to a study report by the Ministry of Energy (2011) on Kenya's power industry generation and transmission system planning, Geothermal, Nuclear, Coal, Imports and Wind power plants dominate the energy sector development program. The study was undertaken on the basis of a 20 year rolling Least Cost Power Development Plan (LCPDP) that is updated every year. The report further notes that the optimum solution indicates that geothermal resource, which is considered the choice for the future source of power, is expected to increase to 5,530 MW in the planning period, equivalent to 26% of the system peak demand by 2031.

The interconnected system in Kenya had a total installed capacity of 1,593 MW as at June 2011; made up of 763 MW of hydro, 586 MW of thermal, 198 MW of geothermal, 5 MW of wind, 26 MW from cogeneration and 14 MW in isolated mini-grids. The total effective capacity was 1,479 MW during normal hydrology. Hydro accounts for around 49% of the total energy supply. Registered interconnected national sustained peak demand was 1,194MW (1,294 MW unconstrained) registered in May 2011 and 1,211.9 MW in January 2012 (Omenda, 2012).

1.3 Geothermal projects in Kenya

Kenya is endowed with vast geothermal resource potential along the world Kenya Rift that transects the country from north to south. Exploration reveals that geothermal potential exceeds 10,000 MWe (Ministry of Energy, 2011). Out of this potential, only 212.5 MWe and 18 MWt are being utilized at Olkaria and Eburru for indirect and direct uses, respectively (Omenda, 2012). Kenya Electricity Generating Company Ltd (KenGen) and Geothermal Development Company Ltd (GDC) have undertaken detailed surface studies of most of the prospects in the Kenya rift and active drilling is in progress in the Greater Olkaria field and at Menengai. The areas that have been studied in detail include Suswa, Longonot, Olkaria, Eburru, Menengai, Arus-Bogoria, Lake Baringo, Korosi and Paka. Other areas with not very detailed studies include Lake Magadi, Badlands, Silali, Emuruangogolak, Namarunu and Barrier geothermal prospects (Figure 1).

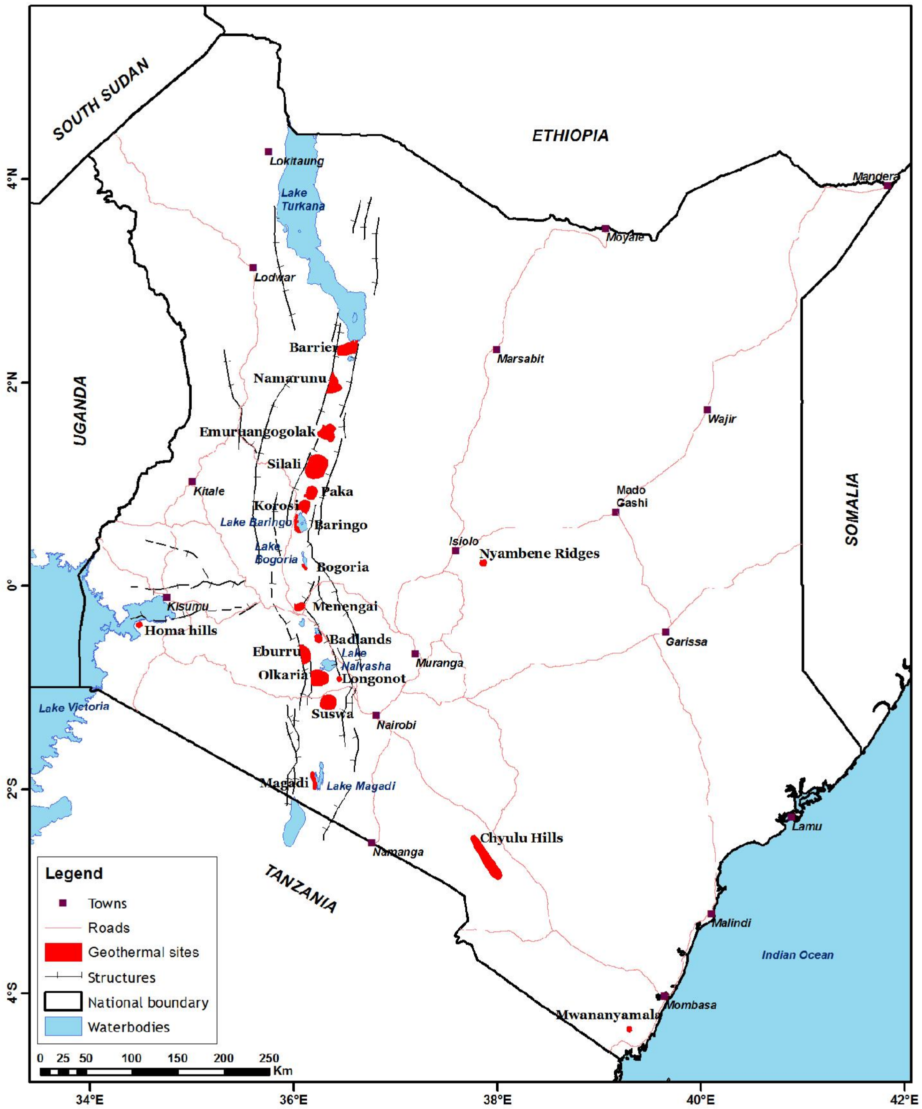

Figure 1: Location of geothermal prospects/fields in Kenya

According to Simiyu (2010), exploration for geothermal energy in Kenya started in the 1960's with surface exploration that culminated in two geothermal wells being drilled at Olkaria. In early 1970's more geological and geophysical work was carried out between Lake Bogoria and Olkaria. This survey identified several areas suitable for geothermal prospecting and by 1973, drilling of deep exploratory wells at Olkaria commenced and was funded by United Nation Development Programme (UNDP). Moreover, from the recent past, the Government through the Ministry of Energy, GDC, KenGen and other partners has undertaken detailed surface studies of some of the most promising geothermal prospects in the country.

2.0 Methods and Materials

This is a literary review of factors that determine prioritization of geothermal prospects/fields for development in Kenya. In this regards, it presents the technical and socio-economic considerations made during planning, geoscientific surveys, exploration/production drilling, power plant construction and power transmission.

2.1 Prioritization of Geothermal Prospect

2.1.1 Stages of Geothermal Development

Geothermal projects have seven key development phases before the actual operation and maintenance (O and M) phase commences. It takes approximately seven years to develop a typical full size geothermal project with, for example, a 50 MW turbine as a first step (Gehringer & Loksha, 2012). However, the project development time may vary, depending on the relevant country's geological conditions, information available about the resource, institutional and regulatory climate, access to suitable financing, and other factors. Each phase of geothermal project development consists of several tasks. After each milestone, the developer—either a project company or a country's institution will have to decide whether to continue developing the project or not. The first three phases, or milestones, take the developer from early reconnaissance steps to field exploration to test drillings.

This first part of the project development (which could be broadly called the exploration stage) either confirms the existence of a geothermal reservoir suitable for power generation or not; it is usually seen as the riskiest part of project development. If the result from the first three phases, including the test drillings, is positive and the geothermal potential is confirmed, Phase 4 is initiated with the actual design of the power project, including the feasibility study, engineering of components, and financial closure. Phases 5 to 7 comprise the development of the project itself, consisting of the drilling of geothermal production wells, construction of pipelines, construction of the power plant, and connection of the power plant to the grid.

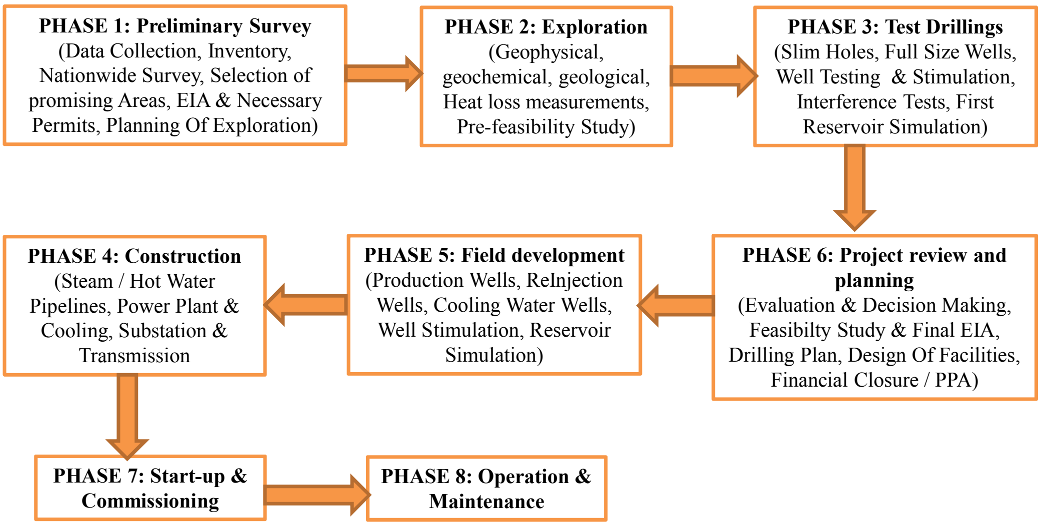

Figure 2: Geothermal project development phases (edited after Gehringer and Loksha, 2012)

2.2 Risks Versus Costs in Geothermal Development

A full-size geothermal development project typically takes from 5 to 10 years to complete, and due to this long project development cycle, geothermal power is not a quick fix for any country's power supply problems, but rather should be part of a long-term electricity generation strategy (Gehringer & Loksha, 2012). Geothermal power projects suffer from a number of risks not found in other thermal power generation projects e.g. coal fired power projects, in particular financing risk due to higher up-front costs, regulatory risk cost by separate regulation of steam and power generation, completion or delay risk, off-take risk, market demand or price risk and operational risk (Delmon, 2009; Gehringer & Loksha, 2012).

The exploration phases and especially the test-drilling phase, can be considered the riskiest parts of geothermal project development. This phase is much more capital intensive than all the previous phases, while still troubled with uncertainty, and thus substantial investment is needed even before knowing whether the resource has enough potential to recover its costs. Figure 3 indicates that test drilling can account up to 15% of the overall capital cost, which is required at a point when the risk of project failure is still high.

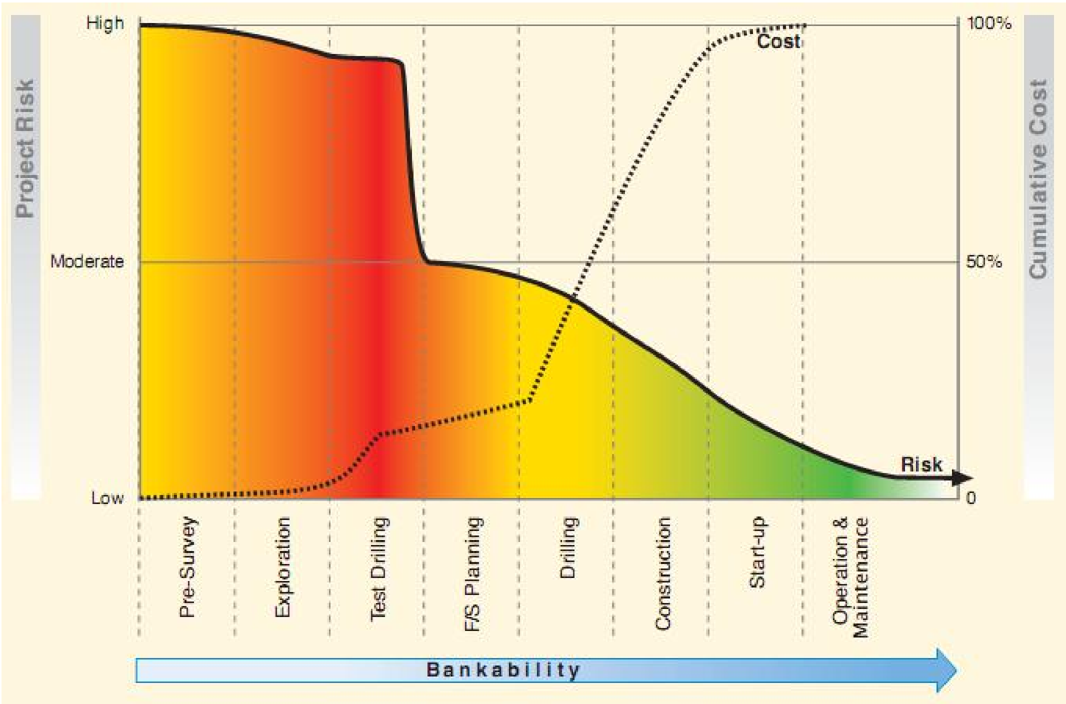

Figure 3: Project Cost and Risk Profile at Various Stages of Development (Gehringer & Loksha, 2012)

2.3 Modes of Development

2.3.1 Government Involvement

Following the enactment of the Energy Act No. 12 of 2006 after the adoption of the Sessional Paper No 4 on Energy in 2004, the energy sector was restructured to bring on board more players in line with the new functions. Accordingly the functions unbundled into generation, transmission, distribution, oversight and policy functions. The Ministry of Energy (MOE) is responsible for policy and overall guidance of the sector while the Energy Regulatory Commission (ERC) oversees all regulatory functions including coordination of the development of indicative energy planning, tariff setting and oversight, monitoring and enforcement of sector regulations. Energy Tribunal is the sector dispute resolution entity largely involved in settling disputes arising from decisions made by the Energy Regulatory Commission.

2.4 Private Sector Involvement

In a number of countries, the government have borne the upstream risk of developing geothermal fields by undertaking exploration activities. For instance the governments of Philippines and New Zealand have addressed the issue of upstream risk in the geothermal sector by undertaking the exploration of fields themselves, and once the fields were proven, the government would then offer them to private developers for power generation.

The geothermal electricity generation in Kenya is still largely dominated by KenGen, which is largely a state utility with installed capacity of 157.5MW distributed at Olkaria (155MW) and Eburru (2.5MW) (Omenda, 2012). The second largest plant at 55MW is privately owned by Orpower4 Inc., a subsidiary of Ormat International and has been in operation since 2003. The government has also licensed several geothermal fields to private sector developers, where test drilling is yet to be undertaken in all these areas.

3.0 Factors Influencing Prioritization of Geothermal Prospects

3.1 Exploration Findings

The developability of geothermal resources is highly dependent upon cost in relationship to other resources, and cost is, in turn, dependent upon a host of variables including: accessibility, resource location, availability of transmission, availability of cooling water, required environmental protection measures, and, of course, the characteristics of the resource (Bloomquist, 1983). All possible geothermal prospects as inferred from general geological regime, surface manifestations and other indicators needs to be considered. Geothermal resources are ranked on the basis of geo-scientific indications as if likely resource is available, proximity to potential marked and likelihood of utilization within near future (Árnason & Gíslason, 2009).

In this regard, a thorough evaluation for every prospect needs to be performed both with respect to the likelihood of an exploitable resource being present, its accessibility and how the resource could be utilized. The result of this phase is ranking of prospects that will help earmark some of them for development. In Kenya, at least 14 high enthalpy prospects/fields that have been identified are at different stages of studies/development and one of the critical factor is developing a known successful prospect first.

3.2 Infrastructure

Geothermal fields are many a times located in very steep and rugged terrains with no meaningful, or none at all and therefore logistical arrangements are required in the development of infrastructure in a geothermal field. Generally accessibility of geothermal potential areas is difficult until these fields are opened up to ease mobility into and within the prospects. There are various infrastructural developments that are required in a geothermal field before actual drilling can be undertaken. These include; Access roads network, water supply connections, well pads and circulation ponds construction, electricity connections and provision of lay down areas (Rutinu, 2010).

In order to ease mobility within a geothermal field, access roads network is vital. Due to the lugged nature of these geothermal fields, cutting of these access roads take quite a lot of time, money and machine power. In addition, drilling of geothermal steam cannot be achieved if water is not available in plenty. One drilling Rig consumes as much as 2000 litres per minute of water, and thus consideration should be made on the costs associated in availing the needed infrastructure.

3.3 Local Community Support and Land

Obtaining full support from local communities living in or areas adjoining geothermal prospect has been identified to be critical here in Kenya. Most funding agencies embraces community social responsibilities and therefore lack of community consent in any project my deter development. Development of natural resources provides benefits to the nation and community when conducted in a responsible manner (Slamet & Moelyono, 2000). It enhances the standard of living for many people, including those not directly associated with the project.

Positive, or at least neutral, community perceptions about, and reactions toward, geothermal development activities are desirable and necessary from exploration permit acquisition throughout the life of a project. Developing an informal network of contacts throughout the impacted and adjacent communities with which to initiate and maintain meaningful dialogue and feedback can be a valuable tool toward this end (Nakaji, 1990).

According to de Jesus (2000), in several instances worldwide, poverty as a result of resettlement has been identified as a major impact of energy projects. Thus, equal attention to infrastructure, institutions, and human resources are requisites to a project's sustainable development. Some of the measures for co-existence and sustenence of resettlement programs are acurate baseline information, public participation, empowerment of resettler community, as well as, integration with the host community, amon others (de Jesus, 2000).

3.4 Environmental Factors

The development of geothermal resource requires compliance with relevant National and International laws and regulations to ensure sustainability. There are several Acts of Parliament that collectively regulate and guide geothermal resource use in a sustainable manner. The two laws that specifically deal with geothermal development in Kenya are Geothermal Resources Act of 1982 and its supplementary legislation of 1990 and the Environmental Management and Coordination Act of 1999 with its associated regulations (Mwangi-Gachau, 2011).

The other laws and regulations do not directly apply to geothermal but their implications affect geothermal development at various stages and in various ways. Prioritizations of geothermal fields depend on whether it has met these legal requirements. For instance, Lakes Baringo and Bogoria are 2 of the 5 places in Kenya found within the Ramsar List of Wetlands of International Importance, governed by intergovernmental laws, which limit any future attempt to exploit geothermal resources in these areas.

3.5 Evacuation of Electricity

The distance between electricity markets or centers of heat demand and geothermal resources is a factor in the economics of power generation. When making development choices, there is sometimes a trade-off between the quality of hydrothermal resources and their remoteness from secure grid connections or demand centers (Erbas, *et al*., 2011). Identifying the location of a buyer(s) for the resource to be delivered and the possible transmission paths available are key initial milestones in the process of planning a transmission project.

The institutional challenges of a transmission project begin when assessments of the initiating and planning processes are developed and a list of project stakeholders drafted. Recognizing a need exists and committing the resources to begin the project planning and execution are key decision points that can be motivated by issues including market demand, business need, customer request, renewable energy portfolio standards, technology advances or legal considerations (Torgerson, Dracker, & Woodford, 2006). Transmission line construction costs can be quite high depending on its location from the next available connection lines. It might not be economical to construct a transmission line in a remote community where the available market is not able to pay back the investment.

3.6 Security in the Prospect Area

Geothermal resource is in many cases found in remote locations, some of which are inhabited by hostile communities. For instance in Kenya, some of the high enthalpy geothermal areas are found in the northern part of Rift Valley in places occupied by warring communities. Hence, penetrating such environments may not be easy and eventually this normally leads to unwarranted delays.

3.7 Political Good Will

Political and economic events can have an impact on a geothermal project that is more profound than exploration success (Nevin, 1992). Geothermal deployment will be supported, politically, by a CO_2 mitigation strategy, through establishing incentives for market penetration of geothermal energy supply technologies. These incentives can include, for example, subsidies, guarantees, and tax write-offs to cover the risks of initial deep drilling. Policies to attract energy-intensive industries to known geothermal resource areas can also be useful. Feed-in tariffs with confirmed geothermal prices have been very successful in attracting commercial investment in some countries (Erbas, *et al*., 2011).

In Kenya, the Central Government has played a leading role in fast-tracking development of geothermal energy by absorbing initial risks that are encountered during exploration. The government has been able to acquire its own drilling rigs, a show of commitment towards realizing vision 2030 (Ministry of Energy, 2011). However, despite Central Government's commitment, the Country Government from where some of these prospects are situated is yet to demonstrate their full commitment.

4.0 Summary and Conclusions

The Kenya geothermal installed capacity is still very low compared to the overall geothermal energy potential existing. The reasons for this are a long lead time, high risk and high cost for development of geothermal fields. Recent social concern about environmental problems encouraged the promotion of geothermal energy development. However, there many other factors that need careful considerations and some of these factors have been discussed. They include exploration findings, infrastructure, local community support, security, electrical evacuation, political good will, among others.

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