

Development Phases of Olkaria IV Geothermal Power Plant Project, Kenya

George Ngomi

Kenya Electricity Generating Company Limited

gngomi@kenген.co.ke

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ABSTRACT

Recently, Kenya has been among the most active regions for geothermal development especially after commissioning the 280MW geothermal power plant project in 2015. The project, which was a combination of two power plants namely Olkaria IV and Olkaria I Additional Units, underwent the different development phases uniquely to emerge as the single largest geothermal power project in the world. The development phases encompass resource exploration, assessment, plant construction and operation. Globally, geothermal professionals have conducted studies on these development phases. However, these studies indicate varying timelines considering the uniqueness of the projects governed by different political, environmental, social, technological, economical and legal factors. A 5 to 10 year period from new field development to commissioning a single unit is considered ideal. Olkaria IV was developed in approximately 22 years inclusive of an 8 year break caused by delayed financing. Other challenges that led to an extended timeframe include land acquisition, expropriation of project affected persons and plant commissioning bottlenecks. A discussion of these challenges form the basis of this paper.

1. Introduction

Geothermal energy development is a capital intensive technology that has the capacity to replace the thermal-based electricity generation coupled with the minimal environmental impacts associated to its exploitation. A full size geothermal development project typically takes from 5 to 10 years to complete (Dolor, 2005; ESMAP, 2012; Steingrimsson, 2014; Gudmundsson, 2016), 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 (Gehring and Loksha, 2012). Due to their capital intensive nature, geothermal projects have to go through feasibility in economic and financial perspectives prior to their execution. Project sponsors conduct financial analysis so as to confirm project viability in terms of generating enough income to meet their initial investment. Therefore, development of geothermal energy requires keen management to ensure appropriate

dispensation of resources and efficient management of time for the intended results to be attained.

2. Geothermal Project Development Phases

Development of geothermal resources can be categorized in various ways. The Geothermal Energy Association (2010) categorizes geothermal projects into four phases namely resource procurement and identification, resource exploration and confirmation, permitting and initial development and resource production and construction. ESMAP, (2012) describes the phases as preliminary survey, exploration, test drilling, project review and planning, field development, construction, start-up and commissioning. For purposes of this paper, a geothermal energy development project can be divided into five phases namely resource exploration, resource assessment, power plant construction, operations and decommissioning (Modified from Ngugi, 2008).

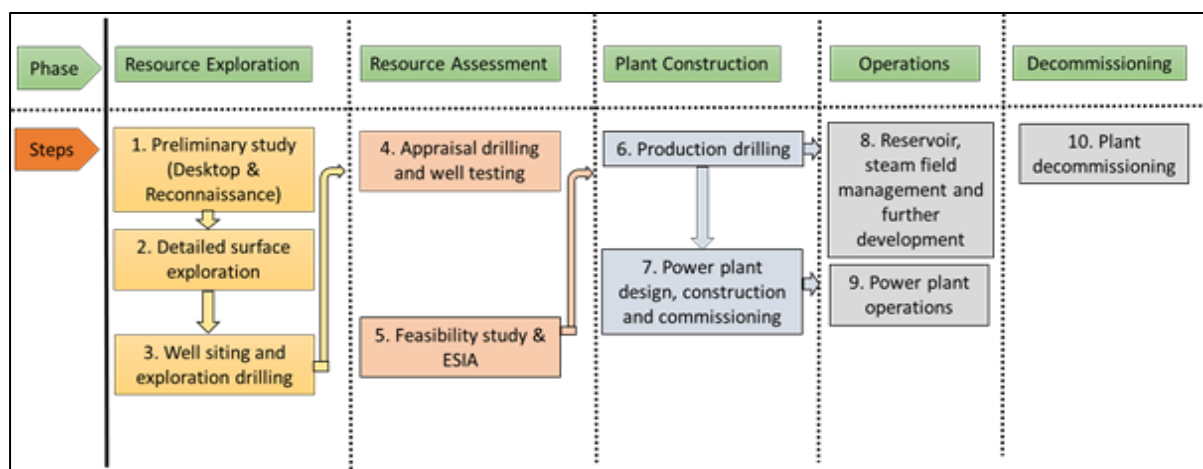


FIGURE 1: Geothermal development project phases (Modified from Ngugi, 2008)

2.1 Resource Exploration

Resource exploration entails conducting a preliminary study, detailed surface exploration and exploratory drilling. Available data is collated overtime with a view of identifying gaps. A desktop study and further analysis is undertaken with an aim of developing an inception report recommending detailed surface work. This report acts as a guide to providing all information such as work program and resource requirements.

A detailed surface exploration is then carried out with the scope of work being field measurements, sample testing, environmental study and analysis. The output is a conceptual model with recommended exploration well sites. After identification of well locations, exploration wells are drilled. Drilling these wells primarily mark the beginning of physical development of geothermal prospects.

2.2 Resource Assessment

Resource assessment entails appraisal drilling, well testing and environmental and social impact assessment. Appraisal drilling aims at sizing the resource in terms of possible output that is necessary for plant sizing and obtaining drilling requirements, wellhead pressures and

reservoir fluid characteristics. This data is obtained in preparation of the feasibility study which is a desktop study.

Between each of these phases there are major milestones that have to be reached. The most important milestones are tied with financing. Financing of geothermal project requires a feasibility study based on the information acquired during the project. Environmental Impact and Social Assessments (ESIA) are carried out at the same time as the feasibility studies and are also essential for financing. These activities form part of project planning which runs through the whole project.

2.3 Plant Construction

This phase is the most capital intensive phase of the project and does not allow for many changes in the projects scope and definition, without significant impacts on project cost. It includes drilling most of the production wells, construction of steam gathering system, turbine generator system and power lines. The phase ends with the commercial operation of the plant.

2.4 Operations

In this stage, monitoring of the reservoir is carried out where regular measurements of well productivity and wellhead pressures are taken. It also involves operation and maintenance of the power plants to ensure continuous power generation.

2.5 Decommissioning

This stage involves geothermal project abandonment after its useful life. Following decommissioning, the site is restored to approximate its original condition or to some standard that results in stable environmental conditions. Decommissioning involves closure of all plant facilities, wells, removal of all above ground components such as steam lines, recontouring the ground surface and re-vegetation.

3. Geothermal Development in Kenya

Kenya was the first African country to establish the utilization of geothermal power and is the eighth largest geothermal electricity producer in the world. Despite early progress made in the 1970s and early 1980s, developments in Kenya were slow in the late 1980s and 1990s. More recently, however, attitudes towards geothermal energy have changed. Concerns over climate change, the volatility of commodity prices, the need to address energy security and the desire to support economic development through improved provision of clean, reliable and affordable base-load electricity means that geothermal resource development is high on the political agenda for many countries where potential exists (Zakkour, 2016).

During the financial year 2014/15, Kenya Electricity Generating Company (KenGen) completed the commissioning of 280MW geothermal expansion project. This project consists of two power plants which are Olkaria IV and Olkaria I (Units 4 and 5). These plants are located in the Kenya Rift Valley, about 120km from Nairobi and form part of the Greater Olkaria geothermal field. The Olkaria geothermal field is inside a major volcanic complex that has been cut by N-S trending normal rifting faults. It is characterized by numerous volcanic (mostly rhyolitic) domes, some of which form a ring structure, which has been interpreted as indicating the presence of a buried volcanic caldera.

4. Olkaria IV and the Development Phases

Olkaria IV was co-financed by the Government of Kenya (GoK) through KenGen and by a series of development partners, including World Bank (IDA), Japan International Cooperation Agency (JICA), European Investment Bank (EIB), Kreditanstalt Für Wiederaufbau (KfW) of Germany and Agence Francaise de Development (AFD). This power station has two Units with a design rating of 74.9MW but contracted capacity of 70MW each. This plant cost KSh11.5 billion to build and was designed to have a typical lifetime of 25 years.



FIGURE 2: Aerial view of Olkaria IV power plant in Kenya

4.1 Resource Exploration

Detailed geo-scientific work for Olkaria Domes field commenced in 1992 and was completed in 1997. The detailed study informed the decision of siting and drilling three exploratory wells namely OW-901, OW-902 and OW-903 which were drilled between 1998 and 1999 (Ouma, 2011).

4.2 Resource Assessment

Extensive geophysical work and data review of the three exploratory wells resulted in the siting of six appraisal wells in 2007 which were drilled to depths ranging from 2800m to 3000m. Well testing of these wells was conducted concurrently with the drilling processes. According to Musonye (2015), all these wells showed acceptable results with some having temperatures of over 300°C. They also showed acceptable wellhead pressures and reservoir fluid characteristics. The pre-feasibility study was conducted in 2009 by West Japan Engineering Consultants and the final report availed in August the same year. In 2010, Gibb Africa Consultants conducted the Environmental and Social Impact Assessment (ESIA) and submitted a final report in April the same year.

4.3 Plant Construction

Roughly, 30 production wells had been drilled at the Olkaria Domes field at the end of 2011. Scientific data obtained from these wells buttressed presence of adequate resource to support a 180 MWe power plant. In November 2011, the construction phase of the power plant commenced with the signing of the contract between KenGen and the contractors. The power plant civil works commenced in January 2012 while the steam field commenced in July 2012. The power plant commissioning was carried out systematically after completion of mechanical,

electrical, instrumentation and structural installations. The generating Units at Olkaria IV were commissioned in July 2014 and August 2014 respectively (Langat and Ngomi, 2017).

Task Name	Start Date	End Date
Contract Signing	7 th November 2011	
Performance Certificate	2 nd September 2014	
Steam field		
Construction and Commissioning	July 2012	April 2014
Power Stations		
Construction	January 2012	June 2014
Commissioning (Both Units)	September 2014	

FIGURE 3: Project commissioning schedule

4.4 Operations

Prior to handing over, performance and reliability tests were done by the Contractor. These tests verified that the units can be operated in accordance with KenGens' dispatch requirements for a continuous period of 30 days without maintenance intervention. The reliability run tests also included 72 hours continuous operation at not less than 95% of the unit rated capacity. Commercial operation of the plant began in August 2014 and since then staff operating and maintaining this power plant have ensured best engineering practices are followed. This power plant encompasses various systems which include steam gathering, circulating water, waste water treatment, chemical dosing, service and potable water, compressed air, firefighting, steam turbine and generator, electrical and power evacuation.

5. Olkaria IV Project Development Timescale

The Figure 4 below indicates a summarized timescale of Olkaria IV project. The timescale indicates that resource exploration was conducted between 1992 and 1997. Three exploratory wells namely OW-901, OW-902 and OW-903 were then drilled between 1998 and 1999. So as to expand resource development, access to funding was delayed by financiers as they awaited results of the Olkaria Optimization Study (Ouma, 2011). This project was not expanded up until 2007 when extensive geophysical work and data review of the three exploratory wells resulted in the siting of six appraisal wells. Production drilling was conducted up until 2011 and the power plant was commissioned in 2014. The total time taken is approximately 22 years.

Activity/Phase	1992	1993	1994	1995	1996	1997	1998	1999	2007	2008	2009	2010	2011	2012	2013	2014
Resource Exploration																
Well siting and Exploration Drilling																
Appraisal Drilling																
Well Testing																
Pre - Feasibility Study																
ESIA																
Production Drilling																
Power Plant Construction																

FIGURE 4: Olkaria IV Project timescale

6. Discussion of Challenges Faced

Experiences with geothermal development worldwide show that developing a geothermal industry can be slow. Progress can be hampered by lack of public funding, institutional, regulatory and legal constraints, a lack of technical and human capacity, as well as economic, financial barriers among others. Olkaria IV was developed in approximately 22 years and faced challenges such as delayed funding, land acquisition, expropriation of project affected persons and plant commissioning bottlenecks as discussed below.

6.1 Access to Financing

Success in geothermal project development in Kenya has relied on various financial partners who include government incentives, concessional funds from international donors, private equity, long term debts from commercial sources or balance sheet financing by a large developer. By and large, this is so that they can share the high risks involved in this venture. Due to the complex and risky nature of geothermal projects, financiers conduct financial analysis so as to confirm project viability in terms of generating enough income to meet their initial investment.

In 1996, donors introduced energy sector reforms in Kenya some of which became conditional to further funding for the construction phase (Ouma, 2011). Funding was approved in 1998. KenGen commenced construction of Olkaria II power plant in the year 2000 and it was commissioned in the year 2003. Further drilling of Olkaria IV wells did not commence until 2007 leading to an 8 year break. Since then, the government of Kenya had been committed and involved in the geothermal sector thus making it a lot easier to attract foreign cash inflows in the later project stages where results had been proved and therefore resulted in less risky ventures. Olkaria IV power plant project which was co-financed by the Government of Kenya (GoK) through KenGen and by a series of development partners, including World Bank (IDA), Japan International Cooperation Agency (JICA), European Investment Bank (EIB), Kreditanstalt Für Wiederaufbau (KfW) of Germany and Agence Francaise de Development (AFD).

6.2 Land Acquisition

Olkaria IV project site was located on privately owned land belonging to Kedong Ranch. There were Maasai settlements within the land area designated for the project such as Olo Nongot, Olo Sinyat and the Cultural Centre. During community consultations, including all Maasai settlers, it was clear that there was conflict of land ownership between the Maasai community living within the project area and Kedong Ranch Limited. This land had a leasehold title for a term of 999 years registered in the name Kedong Ranch Limited (Gibb Africa, 2010). In a court case that had commenced in the year 2010, the Maasai community wanted entitlement to this land by adverse possession of over 12 years which is applicable under Laws of Kenya, Limitation of Actions Act, section 8.

KenGen acquired 3610 acres for project area thus necessitating involuntary resettlement of the local community. However, ahead of the General Election in the year 2013, local politicians encouraged residents to claim the land as a way of campaigning. Under stewardship of politicians, residents blocked the Narok-Suswa road to demonstrate against what they called invasion of their land. In this regard, KenGen was entangled in court battles which delayed project commencement. After government intervention and following several court cases such as Petition 57 of 2014 filed by Parkire Stephen Munkasio & 14 others v Kedong Ranch Limited & 8 others, the High Court in Nakuru ruled that the Maasai community had no legal right to

occupy the land and therefore dismissed their case. KenGen therefore conducted public consultation and disclosure of intention to set up a power plant via consultative meetings at district and local levels included discussions with the provincial administration, village elders, KenGen staff, specialists and key informants.

6.3 Expropriation and Compensation of Project Affected Persons

Expropriation and compensation of Project Affected Persons (PAPs) was a challenge. This is because the PAPs expressed fears of KenGen's ability to expropriate people given previous experience where the local community were forcibly removed from the land without due consideration of the historical problems they had faced (Gibb Africa, 2010). They also expressed fears on embezzlement of funds meant for the exercise. Various community consultative and public meetings were organized so as to initiate project buy in by the communities. Due to the sheer size of the project, expropriation and compensation was governed by information collected via participatory rural appraisals. However, considerable time was lost before the PAPs and KenGen agreed on the number and the quality of the resettlement facilities.

To ensure that this exercise was successful, KenGen was guided by the principle objectives that the affected people had their former living standards which had to be restored or improved. 1,700 acres of land located about five kilometers from Olkaria IV project area was purchased for this resettlement. A resettlement and compensation plan was developed and it involved conducting a valuation of existing assets such as schools, churches, manyattas and land within the proposed project area. This action was carried out in accordance with land administration Laws of Kenya and World Bank Policies.

6.4 Plant Commissioning Bottlenecks

Several challenges were experienced during commissioning of Olkaria IV power plant project. They include damaged glass reinforced polyester pipes, underperformance of steam turbine and internal faults of the steam scrubber. These challenges led to the extension of the planned project time as they required detailed repairs and interventions of specialists.

6.4.1 Glass Reinforced Polyester Pipes

During Olkaria IV glass reinforced polyester pipe installation, heavy down pour causing flash floods accessed the unprotected site. This led to destruction of all laid pipe work and compromise of the integrity of some underground foundations. Pipe repairs were lengthy and involved excavation, filling bed material and lamination.

6.4.2 Underperformance of Steam Turbine Generator

The plant provisional performance test gave a net power output of 66.8 MW which was significantly below the requirement. Toshiba, who are the Original Equipment Manufacturers (OEM) found excessive pressure drop through the main steam strainers and turbine first stage nozzles (Judkins, 2015). New strainers were installed and the desired net power output of 70MW was obtained. However, the turbine efficiency or steam rate did not meet contract requirements. This led to modification of the first stage nozzles which extended the project timescale by a month after which all other Units were then modified by the OEM accordingly (Langat & Ngomi, 2016).

6.4.3 Steam Scrubber Internal Faults

Unusual reverberations in the steam scrubber revealed that the vortex tube and smoothing sleeve weld seam had failed. This was after complete installation of the steam scrubbers. A comprehensive repair methodology was adopted in conjunction with the OEM thus affecting the total project duration.

7. Conclusions

Experiences with geothermal development worldwide show that developing a geothermal industry can be slow. These studies indicate that different projects have their distinct fair share of challenges. Olkaria IV project progress was hampered, by among others, delayed funding, land acquisition, expropriation and compensation of Project Affected Persons and plant commissioning bottlenecks. This project was developed in approximately 22 years from 1992 to 2014. Part of the critical success factors for KenGen success is government's commitment and involvement in research in the geothermal sector. This is through introduction of institutional, regulatory, economic, financial and legal enablers for extended development of geothermal projects.

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