GEOTHERMAL PROJECT TIMELINES

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ABSTRACT

East Africa rift is emerging as a one of the fastest growing geothermal areas in the world. Kenya is one of the countries that has made great strides in developing its geothermal resources. Ethiopia is following a similar pattern while other countries along the African rift are also looking forward to developing their geothermal prospects. It takes relatively longer time to develop geothermal energy sources as compared to other energy sources. This is attributed to the long time involved in exploration and feasibility studies, and the lengthy decision making and contract negotiation periods. This paper analyses geothermal projects' timelines, with examples from East Africa and Iceland. These project are compared to guidelines on project timelines in literature to find out how well they compare. It is found that project in this study rarely matched the guidelines. Developers should consider additional time for intended project in case of new fields.

1. INTRODUCTION

The East Africa rift is emerging as a one of the fastest growing geothermal areas in the world. Kenya is one of the countries that has made great strides in developing its geothermal resource. Ethiopia is following a similar pattern while other countries along the African rift are also looking forward to developing their geothermal prospects (Omenda, 2010). It takes seven years to develop a geothermal resource from resource identification to commercial operation (ESMAP, 2012). For many decision makers, a seven-year project timeline is too long, especially with limited office term of four years and pressure from the public to show progress. Despite the seven-year-time period being considered long, some projects still take even longer period. This poses a challenge to the funding of geothermal projects. This is because the government and other financial institutions are cautious about the longer time involved before realising returns on investment (ESMAP, 2012). It is therefore important for the industry to analyse the reasons for these delays, understand the risk and how it can be mitigated and how expectations can be managed. To analyse this, the paper compares the main timelines for different project in East Africa and Iceland to the reference timeline provided literature. The aim of this review is to determine if these guidelines can be used for all high temperature new geothermal projects and to provide recommendation to project developers on how to mitigate the risk of delaying geothermal project.

2. GEOTHERMAL PROJECT TIMELINES

Several publication have been made on Geothermal project development and its phases. A well know publication is the ESMAP's Geothermal Handbook (2012). The Geothermal Handbook provides a guideline for the project development phases ranging over a seven-year-period from start of preliminary studies to start of plant operation. The phases described are: Preliminary survey, Exploration, Test drilling, Project review & Planning, Field development, Construction and Start-up & Commissioning. These phases are described as commencing in a consecutive order with some overlap of activities between phases.

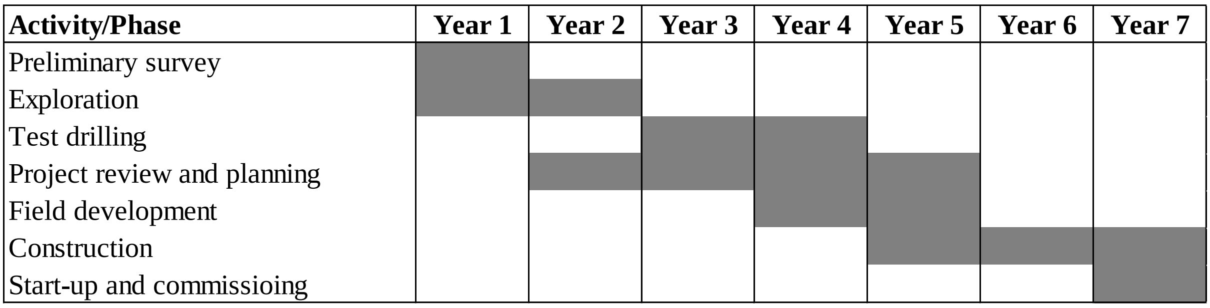

Figure 1: Project timeline and phases according to ESMAP's Geothermal handbook (ESMAP, 2012)

The Geothermal Energy Association (2010) categorizes geothermal project into four phases of development. These are: Resource procurement and identification, Resource exploration & Confirmation, Permitting & Initial development and Resource production & Power plant construction. No indication is given for a typical timeframe.

Dolor (2005) discusses geothermal project development in the Philippians where the project phases are described as: Project definition & Reconnaissance evaluation, Detailed exploration, Project feasibility stage, Loan application & Financial closing, Field development and Power plant bidding & EPC. These phases range over a five-year-period, see Figure 2.

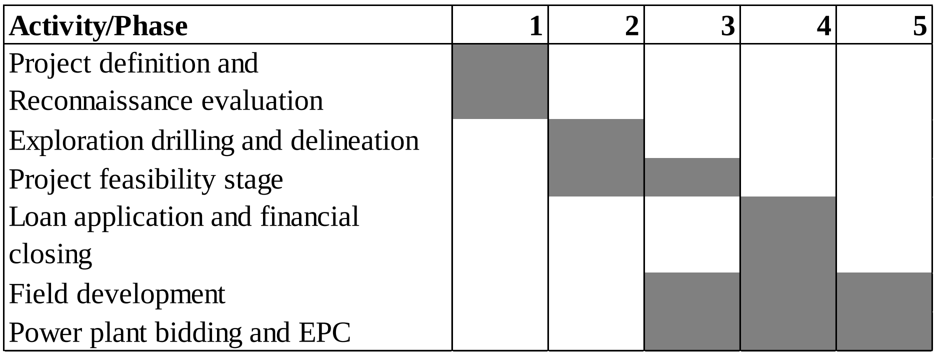

Figure 2: Project timeline and phases according to Dolor (2005)

Time period given by Dolor is two years shorter than in the Geothermal handbook. As can be seen from Figure 2, the time given to the early stages of development is reduced compared to the Geothermal handbooks timeline and the field development is considered to take three years in parallel to the to the plant construction. Dolor (2005) states that geothermal projects of the size of 40 to 100 MWe can be completed in 5 years without the problems associated with financing and highlights the loan application and financing as a major activity.

Several other publication are available but their general consensus is a seven-years development period or less. Description of project phases is similar between publication. For this study the project phases have been divided into the following:

- Resource identification
- Surface exploration
- Exploration drilling
- Plant construction and production drilling

The above phases are most in-line with the Geothermal Energy Associations (2010) description of phases. A short description of the activities in each phase is provided below.

Resource identification
This is the first phase of a geothermal resource development. This activity revolves around choosing a concession/field to develop. The selection is based on the presence of surface manifestations such as geyser, fumaroles or evidence of a volcanic activity. Once a decision has been made to carry out surface exploration and concession licenses acquired, the phase is considered to have ended. Activities in this phase are often conducted at regional or national government level and public entities are involved.

Surface exploration
Surface exploration is the second phase in geothermal resource development. It includes thorough geological, geophysical and geochemical exploration of the field. Some shallow drilling is often carried out. This phase ends with the start of exploration drilling. It should be noted that surface exploration as an activity is also part of the further field development which involves further information gathering for well site targeting.

Exploration drilling
This phase involves drilling two to six exploration wells to confirm the resource potential and its characteristics. This is the first capitally intensive phase, but is considered to carry high risk. As a result it is often challenging to fund. (Dolor, 2005)

Plant construction and production drilling
This phase is the most capitally intensive phase of the project and does not allow for many changes in the projects scope and definition, without significant impact 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.

Major milestones
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.

3. PROJECT TIMELINE EXAMPLES

For this study projects in Iceland and Kenya are analyzed based on the published information. One example from Ethiopia is discussed as well. Projects in Iceland have been consistently developed over the last two decades and information on these projects is available on public domain. Projects in Kenya have been developed in the last two decades as well. These projects have mainly been in the Olkaria field and information on project development can be found in many publications. Such information provides insights on how these projects have developed.

The Icelandic projects investigated are Krafla, Nesjavellir, Reykjanes, Svartsengi, Hellisheiði and Þeistareykir. A short summary is given on each project with regards to these project phases below.

Krafla
Installed capacity: 60 MWe
Resource identification and surface exploration: 1973
Exploration drilling: 1974
Construction start: 1975
Completion of first unit: 1978 (30 MWe)

The initial output in Krafla was only 7 MWe from Unit 1 rated 30 MWe due to steam shortage. Further drilling till 1984 led to increased steam supply and production from Unit 1 reached its full capacity. In 1996, a decision was arrived to develop Unit 2 which had been procured at the same time with Unit 1. The unit was commissioned the following year. During this period, additional wells were drilled to augment the available steam. The turbine hall and infrastructure for Unit 2 were already in place during this time as they had been constructed with Unit 1 in 1978. (Neilsen, 2000).

Nesjavellir
Installed capacity: 60 MWe, 200 MWth
Resource identification and surface exploration:1946
Exploration drilling: 1986
Construction start: 1989
Completion of first unit: 1990 (only heating)

The Nesjavellir project is combined with both heat and power production. The first commissioned unit was only for heating. The first power producing unit was commissioned in 1998. This was 12 years after first drilling had started and close to five decades after first investigations were completed (Ballzus, 2000).

Reykjanes
Installed capacity: 100 MWe
Resource identification and surface exploration:1953
Exploration drilling: 1997
Construction start: 2004
Completion of first unit: 2006 (50 MWe)

Exploration activities in Reykjanes field started about fifty years before the construction phase was initiated. Between the first exploration and the exploration drilling start, many decades past. During this time number of shallow wells were drilled and further studies where done. In 2003 a Power Purchasing Agreement (PPA) was signed with an aluminum smelter to supply power by mid-2006. The contract initiated the work on the power plant, which was completed on time. (HS Orka)

Svartsengi
Installed capacity: 75 MWe, 150 MWth
Resource identification and surface exploration: Unclear
Exploration drilling: 1971
Construction start: 1975
Completion of first unit: 1976 (only heating)

The Svartsengi plant consists of is six units. Unit 1 has been decommissioned and was used to power district heating pumps for the main hot water supply from the plant. Unit 2 is a direct contact heating plant. Unit 3 is a single back pressure turbine. Unit 4 is an ORC cycle which utilizes steam from Unit 3. Unit’s 5 and 6 are condensing steam turbines with integrated heating cycles for water heating. The Power plant was built up in several stages and is continuously adding production from sources of steam that have become available through make up drilling. (HS Orka)

Hellisheiði
Installed capacity: 303 MWe, 133 MWth
Resource identification and surface exploration: Unclear
Exploration drilling: 2001
Construction start: 2005
Completion of first unit: 2007

The time from start of exploration drilling until star of construction in Hellisheidi was four years and from construction start until the first commissioning about two years. Following the commissioning of the first two units, 45 MWe each, development of a low pressure unit was completed in 2007. Two unit, 45 MWe each, where added in 2008. In 2010 a 133 MWth unit was commissioned and in 2011 the last two units where commissioned, 45 MWe each. The combined capacity of the units is 303 MWe (Gunnlaugsson, 2012). The power plant is a combined heat and power plant similar to Nesjavellir and Svartsengi. The development of the plant differs from the two in that the first unit was a power production unit.

Þeistareykir
Installed capacity: 45 MWe (in 2017)
Resource identification and surface exploration: Unclear
Exploration drilling: 2002
Construction start: 2015
Completion of first unit: in Construction

Like the Reykjanes power plant, the start of construction in Þeistareykir was linked to signing of a Power Purchase Agreement (PPA) with a smelter. After the resource had been confirmed in the exploration drilling phase, the developer intended to sign a power purchasing agreement (PPA) with an aluminum smelter for 180 MWe. The PPA changed to an agreement with a silicon metal smelter in 2012. At the contract signing the developer planned to commission the first unit in 2015 (Landsvirkjun, 2012). According to the developers webside (Landsvirkjun, 2016) the smelter and the plant will be commissioned by mid-2017. Construction of both is well underway and close to completion. The project has therefore seen delays for two years between decision to proceed and planned actual completion. Until 2015 no reports where made on construction start of any major activities or procurement of turbine generators. It can therefore be assumed that no major capital expenditures had been made until that time. Projects financial close was reported in 2015.

The Projects in Kenya reviewed in this study are in Olkaria and Menengai. Olkaria has several power plants within the same field, whereas Menengai is in construction phase. Eburu is another field that has been developed in Kenya. Eburu consist of a single 2.5 MWe power plant. Due to the small size of the plant, Eburu is not analyzed in this study.

Olkaria
Estimated total installed capacity:

- Olkaria I: 45 MWe
- Olkaria II: 105 MWe
- Olkaria III: 139 MWe
- Olkaria IV: 140 MWe
- Olkaria IAU: 140 MWe
- Cumulated capacity from multiple well head generators: ~60 MWe

Resource identification and surface exploration: Unclear
Exploration drilling: 1973
Construction start: 1979
Completion of first unit: 1981

The Olkaria field is considered a single development in this study. It can be argued that it is separate developments as there are many plants within the field. However, as they are operated mainly by the same plant owner, with the exception of Olkaria III and some well head generators, they are considered to be one development in this study.

The time period from the first exploration drilling to commissioning of the first unit was eight years. This was followed by commissioning of two other units within the same plant over a four year period (Ouma, 1992). Following the completion of Olkaria I, development of the field has continued and is still on-going. Several well head generator are under construction and other large scale (large than 10 MWe) condensing plants are in planning phase.

In most cases it is difficult to estimate when exploration drilling starts for each field separately. Therefore it is difficult to estimate the timeline for the other plants in Olkaria separately. However, Musonye (2015) states that for Olkaria IV, exploration drilling started in 1998 with three exploration wells drilled. Further drilling did not commence until 2007. Reasons for the long period between drilling activities was lack of funding for the project. Following continued drilling activities in 2007, the plant was commissioned in 2014 (Musonye, 2015).

Menengai
Installed capacity: 105 MWe (Planned)
Start of exploration: 2004
First exploration drilling: 2011
Construction start: 2013
Completion of first unit: in Construction

The First drilling activity commenced in 2011. In 2012, the developer planned to have 400 MWe installed by 2016 (Onyango, 2012). In 2014, it was reported that construction of steam gathering system and power lines had started (Francisco, 2014). Further, in 2015, the developer claimed in media that the first commissioning would be the end of 2015 (Francisco, 2015). First phase of the Menengai project is constructed by the public developer GDC and private developers (IPP's). GDC secures steam from drilling and supplies it to the IPP's, who build own and operate the turbine generator system (Onyango, 2015). Construction and operation of the steam gathering system will be done by GDC.

During the end of 2015 it was reported that the project was delayed until mid-2017. The reason given was failure by the government to provide partial risk guarantees in time to the IPP's. The time for constructing the plants was stated as being 18 months (Richter, 2015). As of mid-2016 no report has been made to state that the construction of the turbine generator system has been started. It is therefore assumed that the project is further delayed until at least 2018.

Ethiopian geothermal project
Corbetti is geothermal field in Ethiopia, south of Addis Ababa. The project was licensed to a private developer, Reykjavik Geothermal. In 2013, the developer reported that it planned to develop 500 MWe by 2018 with exploration drilling starting in 2014 (Doom et al, 2013). As of mid-2016 no reports were found on drilling activity start in Corbetti. However, reports were found claiming that the intended first phase is to be a 20 MWe development in four well head generator. (Verkis, 2016)

A small geothermal power plant is in Aluto langano in Ethiopa. Aluto consist of a 8.5 MWe power plant. The plant is owned and operated by the Ethiopian Electric Power Company (EEPCO) (Merga, 2010). Due to the small size of the plant its development was not studied in this report.

4. PROJECT TIMELINES COMPARISON

From the above analysed projects' time lines, none of the project wholly compares well with the ESMAP geothermal handbook timelines or other timelines in literature.

In the he first two phases, resource identification and surface exploration, the start is more than a decade before the project completion, sometime many decades before. These examples do therefore not provide a good support for the timelines proposed in literature. It can be assumed that the activities carried out in this phase do not take several years, rather that the decision making process of transitioning over to the next phase is what can take several years. Considering the experience from the projects examples in this study the literature guidelines should not be used to estimate the time for this phase. In the case of Krafla, which transitioned quickly through these two phases, the initial production was only 7 MWe when commissioned, instead of the intended 60 MWe. This indicates that transitioning to quickly through this phase can reduce probability of reaching the project goals.

In the third phase, exploration drilling, the project timeline in the project examples did not compare well with the timelines in literature. In the case of Krafla, the time for this phase was only one year. In Menengai, it was two years, same as in the ESMAP's timeline. For all other projects it was three years or more. Again as with the first two phases, it can be assumed that the additional time is not because the drilling activities in the phase are taking more time, but rather that the decision process to transition to the next phase is taking more time. The two project that did transition to the next phase within two years did not achieve intended project goals. Based on this, it can be stated that at least three years should be allocated to the exploration drilling phase to improve the probability of meeting project goals.

The last phase, construction, compared well with the guidelines in the literature. Only one project reported to have significant delay in during the construction phase, that is the Menengai field. Other projects transitioned through this phase in two to four years. The geothermal project that started with only heating, such as Nesjavellir and Svartsengi, constructed within two years. Heating power plants are simpler and do not have the same long lead items as power producing plants and can therefore be assumed to take less time for the construction phase, around two years. In Figure 4, a new timeline is proposed for new geothermal development based on the findings in this study.

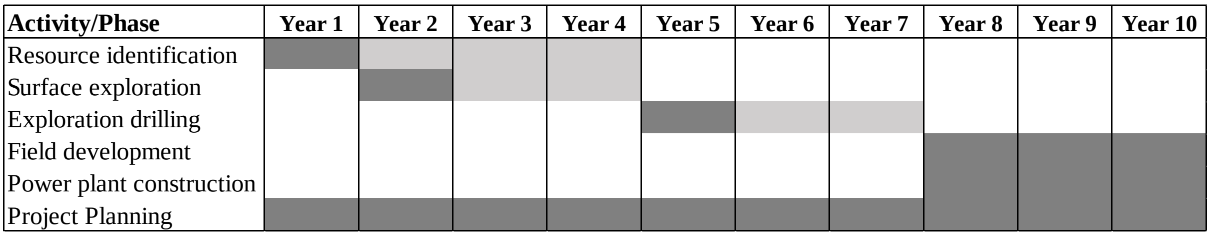

Figure 4: Proposed timeline, based on project examples in Kenya and Iceland. Light grey area indicates time allocated to decision making process between phases.

The timeline comparisons in this study focus on the time required to develop a new field up to, at least, a single unit commissioning. Most geothermal projects continue to develop more units or even more plants in the same field. The time between first and second unit commissioning in the project examples of this study ranged from within a year to more than a decade. The reason why emphasis is put on the first unit in a new field, is that expanding a developed field is not considered to involve the same level of risk in development as developing a new field. Further exploring a developed field is often seen as part field management. Field management is generally regarded as part of operational cost rather than new investments.

4. CONCLUSION AND RECOMMENDATIONS

Through the cases studied in this article it has been shown that many geothermal project do not follow the timeline guidelines proposed in literature. Most projects delay in the early faces of development. Delay in the early phases do not necessarily have high impact on the outcome of the project. In Figure 5, Project risk and cumulative cost over the project lifetime is presented.

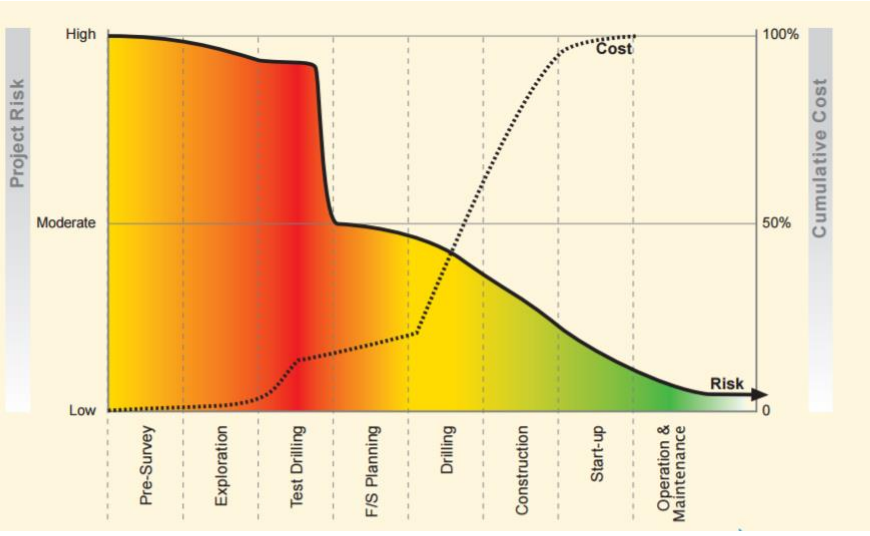

Figure 5: Geothermal project risk and cumulative investment cost (ESMAP, 2012)

Figure 5 is presented in ESMAP's geothermal handbook to highlight the change in risk during the project. What can be interpreted from the figure is that there is high risk of both cost overrun and delay in the early stages of the project. However, during the early stages of the project, the amount of investment in the project, relative to the total project cost is minimal. Therefore additional cost associated with significant delay in early stages of the project will have minimal impact on the overall project cost. All the project examples that delayed in the early phases did not experience any significant delay in the later project phases.

Krafla did not experience any significant delay in early phases or the construction phase but only delivered 7 MWe of the intended 60 MWe. For any investment that can be considered catastrophic in terms of feasibility.

The Menengai project did not experience delays in the early stages but is experiencing delays in the construction phase. From Figure 5, it can be seen that accumulated cost in the Menengai project is likely above 50% of the total project cost. Cost of delays during the construction phase can therefore be assumed to have significant impact on the total project cost.

Based in this study the following is recommended:

- Development in a new field needs more than seven years to commission the first unit
- Time required to develop the first unit in a new field is around 10 years or more
- The additional time is required in the early phases of development to reach the next phase
- If additional time is realized in the early phases of the project it can be considered to reduce risk in the project going forward
- If a project fast tracks through the first phases of the project, it should be considered to have higher risk of delay in the later stages.
- Additional time in the first phases allows more time for better project planning

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