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Phases of Geothermal Development

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ABSTRACT

The exploration, development and utilization of geothermal resources is growing. Geothermal resources have been identified in nearly 90 countries and electricity is produced by geothermal energy in 24 countries. For the next few years is expected to increase the participation in local energy market with geothermal energy in countries that have already begun to generate electricity based on it. The scheduling and planning of geothermal development has different phases that can vary in costs depending on the sites. The report gives a quick and general overview of phases involved in a geothermal project. Also, covers an idea of time and estimated cost for each phase.

1. INTRODUCTION

Electricity generation from geothermal energy made a modest start in 1904 at Larderello in the Tuscany region of northwest Italy with an experimental 10 kW-generator. Since then, there has been interest in developing and exploiting geothermal resources around the world and, today, electricity from geothermal energy (a worldwide renewable energy source) has grown to 10,898 MW in 24 countries, producing an estimated 67,246 GWh/yr. The share of geothermal power balance of the world is small but is modest when compared with other renewable technologies.

However, the exploitable geothermal energy potential in some countries is greater than the current utilization, which indicates that there is so much to do for geothermal.

Geothermal resources have been identified in nearly 90 countries and electricity is produced by geothermal energy in 24 countries. Iceland and El Salvador have the highest share of geothermal power in their country, generating about 25 percent of their electrical power demand.

Additionally, the geothermal utilization growth can be founded by the World Bank or another multi-lateral organization focused on early risk mitigation.

2. GEOTHERMAL POWER DEVELOPMENT PROCESS

Geothermal projects can be divided into a series of development phases before the operation and maintenance (O&M) phase initiate. It takes approximately five to seven year to develop a typical geothermal power plant with, for example, a 30 or 50 MW as a first stage. The project development time may vary, depending on each site or country. Some reasons are the relevant country's geological conditions, information available about the source, institutional and regulatory climate, politics, financings and other factors.

The phases for geothermal development are classified as follows:

- Preliminary survey;
- Exploration;
- Test drilling;
- Project review and planning;
- Field development and production drilling;
- Construction;
- Start-up and commissioning; and
- Operation and maintenance.

A full-size geothermal power plant project typically takes from 5 to 10 years to complete. Due to this long 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 strategy. Many of the risks of geothermal development are essentially the same as in any grid-connected power generation project: delay risk, price risk, operational risk, and regulatory risk. However, there are additional risks specific to geothermal. The test-drilling phase, can be considered the riskiest parts of geothermal project development. The test drilling phase is much more capital intensive than all the previous phases, while still with significant uncertainty. Important investment is required before knowing whether the geothermal resource has enough potential to recover the costs.

2.1 Preliminary survey

The preliminary survey phase is a first reconnaissance of a geothermal area based on a national or regional available from previous studies. If no geothermal studies are available, conduct own studies based upon available literature and data, or execute own reconnaissance work to select the areas of interest. This phase is usually the studies of the geothermal activity found on the surface in the area under investigation. Also, a reconnaissance trip to the area is part of this phase to evaluate the scientific and environmental considerations. The reconnaissance would include the assessment of access roads, local communities, accommodation and security. And no less important is explore the feelings of the communities surrounding geothermal areas.

Methods included in this phase are visual inspection of activity, photogeological survey, aeromagnetic survey and infrared survey. The main goal for this phase is to study fissures, long lineaments, circular patterns and other tectonic structures, the underground geological structures and heat radiation from the ground surface.

Depending on the regulation for this phase the owner has already the concession or has begun the process to obtain it. Costs for this first phase are generally estimated at US$ 0.5 to 1 million assuming that the basic information is available. Depending of the available information and the conditions of the sites, this can increase to as much as US$ 5 million. For these reasons, preliminary survey usually takes from several months up to one year to complete.

2.2 Exploration

The exploration study starts with collection and critical review of existing geological, geophysical, geochemical, heat flow measurements, hydrogeology and baseline environmental data obtained for the area. The detailed multidisciplinary exploration program is defined and executed. The exploration phase consists of surface surveys to further confirm the preliminary resource assessment.

For this phase the program usually includes various surface exploration methods, which can include the following exploration methods:

- Geological survey is a base of all surveys aimed at searching for geothermal resources, and is designed to study on distribution of geological formation, geological structures and alteration. The geological studies would include lithological mapping, structural geology, volcanism, hydrogeology, geo-hazards and environmental geology.

- Geophysical survey includes gravity, seismic and magnetic measurements. For geothermal exploration the most important geophysical methods are the resistivity surveys. Various resistivity methods are applied including Schlumberger, TEM (Transient Electro Magnetic) TDEM (Time Domain Electro Magnetic) and MT (Magneto Telluric). The TEM survey delineates the uppermost one km of the reservoir and the MT survey may detect heat flow zones at greater depths, up to tens of km. The resistivity anomalies are used to outline the probable extent of the geothermal field and define upflow and outflow zones. Geophysical Exploration with Bouguer gravity measurements complements MT and TEM measurements. Results of geophysical survey combined with geological data, can lead to the location of the heat source and define the potential drilling targets.

- Geochemical survey is designed to study the basic environment of geothermal reservoir by sampling and analysing surface water, underground water, hot water, natural steam and gas. The result allows determine temperature of hot water at the depth of the reservoir based on its chemical elements in solution, estimate speed of circulating hot water and clarify history of hot water (fluid´s origin and recharge). This information gives an idea the degree of permeability associated with the reservoir.

- Seismic survey, determine underground structures and bedrock condition by using seismic waves generated by a natural or artificial earthquakes. The main goal is to map faults and fractures, which are important because they often are conduits for hot geothermal fluids.

- Other surveys like Heat Flow Survey and Temperature Gradient Hole.

During this phase the data collected is utilized to define priority areas and possible reservoirs with geothermal interest, the first approach to the conceptual model of geothermal system and drilling targets for the next phase. At the conclusion of this phase, a detailed geo-scientific report is developed covering the explored area, including a conceptual model of geothermal field. The report should present recommendations as well as preliminary development strategies for the area.

Costs for exploration depend on the size and accessibility of the geothermal site and the available equipment. Costs are generally estimate at US$1 to 2 million. In total, the second phase can take up to two years, depending on the size and accessibility of the geothermal field and the data already available.

2.3 Test drilling

This exploratory phase has the main goal to confirm the existence and potential of the geothermal reservoir. Also, with this phase the borehole geology, thermodynamic properties and borders of the reservoir are known. A drilling program is designed, usually a set of three to five full size, 2500 to 3000 meters deep, geothermal wells are drilled based on the conceptual model. It is worth mentioning that drilling plans have to be evaluated continuously during the drilling activity due to results from well testing. Location of drill pads will depend on environmental considerations in the area. The first well is perhaps the most critical as it is meant to maximize downhole information.

If the first well does not produce steam, downhole data is evaluated in conjunction with the initial detailed geological, geochemical and geophysical studies before deciding on the next target drill site. If the first exploration well is a success, a step-out well is drilled. The succeeding step-out wells should not be too distant from the first well and should normally target fractures and other geological structures. Well logging and discharge tests follow after the completion of drilling. Results of the well surveys and tests may confirm the resource and together with the earlier investigation results, a more defined conceptual model can be developed. Wells often do not readily discharge after drilling even if there sufficient indications of permeability and high temperature. In such cases, well stimulation is resorted to by using a high pressure, high volume air compressor to induce well discharge. The results from this phase will enable the project developer to finish a feasibility study. Besides all these activities at this phase the Environmental Impact Assessment (EIA) needs to be prepared and obtain permits with the appropriate entities.

Depending on the location and depth of drilling target, a full size well would usually cost between US$ 4 to 6 million. The costs of opening new access roads and build well pad are generally estimated at US$1 to 1.5 million.

Drilling slim holes for reservoir confirmation, temperature, and chemistry, is another option as such wells can be drilled to 1,500 meters at less cost of a similar depth regular well.

2.4 Project review and planning

In this phase the exploitable size of the resource is established based on the conceptual model of the heat source, geological structure, circulation fluids and reservoir characteristics. A development strategy has to be done together with the conceptual design of the fluid collection and re-injection system. The power station initial design, location and interconnection to the power grid are established at this stage. The feasibility study will show project cost estimates, development timelines and the economic and financial analyses under probable power demand scenarios.

At this stage, in accordance with national environmental laws and regulations, an EIA is prepared. Public consultations with local residents; local government and other stakeholders are also undertaken as part of the approval process of the geothermal project implementation. The final output of this phase is a complete technical and financial feasibility study that can be used to solicit funding from financiers for the development of the project.

2.5 Field development and production drilling

This phase involves the drilling of production and reinjection wells needed to complete the strategy of field development according to the power capacity target. Also, marks the beginning of the detailed design, procurement and construction of the pipeline and separation station in the well pad to connect the production wells to the power plant and reinjection systems. Depending on the drilling program and the well drilling pad, one or more drilling rigs are required. A commonly used rule of thumb is that every successful production well will produce 5 MW of electrical power in the power plant. Nowadays, the design of well pad permits drill up to four directional wells with their bottom targets deviating away from each other. This scheme of development results in a very compact production field and can be highly applicable in rugged and mountainous terrain.

The detailed engineering, procurement and construction of the geothermal power plant and associated substation and transmission lines are done simultaneously with the production and reinjection well drilling.

In most geothermal projects, over 50 percent of the total investment for a geothermal development will be related to exploration and drilling phase. The field development and production drilling program depend on how much time takes to drill well and how many well are required. The range of investment for a geothermal development is 1.2 to 2 million per megawatt installed; these costs can vary considerably from installation to installation.

2.6 Construction

The completion of the steam gathering system is coordinated with any necessary civil works and infrastructure to allow the power plant to be constructed. The electricity generated is sent to a substation and from there to the transmission grid. Power plants are often constructed using Engineering Procurement and Construction contracts.

2.7 Start-up and commissioning

Start-up and commissioning of the power plant is the final phase before the plant starts commercial operation. This phase usually involves solving many technical and contractual issues with the supplier of the plant. The main focus is to optimize the production and injection system to enable the most efficient energy recovery and utilization.

Fine tuning the efficiency of the power plant and all other equipment, including the pressures from the wells, etc., can take several months to complete.

2.8 Operation and maintenance

Operation and maintenance can be divided into the O&M for the steam field (wells, pipelines, infrastructure, etc.) and the O&M of the power plant (turbine, generator, cooling system, substation, etc.). Proper maintenance of all facilities ensures a high availability factor and capacity factor for the power plant, and to ensure steady steam production from the geothermal wells. The operations of power plant need well-trained technical staffs, for a fully automated 30 MW geothermal power plant approximately 20 technicians are required. This does not applies in all countries, because for energy demand reasons when a power plant trip occurs and the geothermal participation is highly important, this power plant needs to be reestablished as soon as possible, and this conditions demands technicians available on-site.

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