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HOW DO FINANCIAL ASPECTS OF GEOTHERMAL COMPARE WITH OTHER ENERGY SOURCES?

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ABSTRACT

How does geothermal energy compare with other conventional sources of energy? Under which conditions does the harnessing of a geothermal resource become economically competitive? These are legitimate questions for entities undertaking the development of a geothermal energy project. The paper deals with cost analysis of geothermal power production. It provide insights on the main parameters influencing a business model for such projects and proposes a comparison with other energy sources.

1. INTRODUCTION

Each geothermal power plant is unique because each geothermal field is unique. Comparison of electrical energy from geothermal resources is a therefore complex as various parameters may have significant impact on the components of the "geothermal field-power plant" complex. Geothermal power plants are never plain "plug and play" units and always require a minimum of engineering to harness energy in the most efficient and sustainable manner. Geothermal projects are in this regard more complex than conventional power projects.

Geothermal fields suitable for harnessing energy may have temperature ranging from 120°C to 350°C. Drilling cost will vary greatly from one project to the other depending on the location, the underground features and how deep the resource is to be found. Furthermore, not all drilled wells may be successful and their performance may go from a few hundred kW up to 20 MW or even more. The risks involved in reaching the resource are significant and geothermal project are generally characterized by high upfront cost risks.

As a geothermal project usually takes 5-10 years to come to a full development, it is important to have from the beginning a good notion of the range within which geothermal energy may be economically competitive.

The paper discusses the investment, operation and maintenance costs of geothermal projects and proposes a comparison of energy prices from various sources.

2. COST OF GEOTHERMAL PROJECTS

2.1 Investment cost

Typical investment costs include (list non exhaustive):

- Preparation:
  - Civil works, roads, planning;
  - Environmental impact assessment;
- Exploration cost;
- Geothermal well field development:
  - Drilling of wells and well testing;
  - Gathering system for supply to the power plant:
    - Geothermal well pumps (pumped brine);
    - Piping;
    - Steam separation;
    - Well field control;
  - Reinjection system:
    - Piping;
    - Pumping;
    - Reinjection control;
- Power plant:
  - Civil structures, turbine hall, cooling tower basin etc.;
  - Mechanical installation;
  - Electricity and control;
- Indirect cost:
  - Engineering supervision and commissioning;
  - Owner's costs;
  - Leasing and permitting; and
  - Interest during construction.

Typical distribution of investment costs for geothermal power plants is presented in Tables 1 and 2 below.

Typical investment costs are:

- 3.650 USD/kW gross for steam plant 50 MW using 250°C geothermal fluid; and
- 5.300 USD/kW gross for binary plant 10 MW using 150°C geothermal fluid.

TABLE 1: Cost distribution for a typical geothermal steam plant (50 MW 250°C)

Cost Item	**%**
Preparation	2
Exploration	8
Geothermal well field development	50
Power plant	30
Indirect cost	10
Total	**100**
Total installation cost, USD pr. kW Gross	**3,650**

TABLE 2: Cost distribution for a typical geothermal brine plant (10 MW 150°C)

Cost Item	**%**
Preparation	2
Exploration	5
Geothermal well field development	44
Power plant	39
Indirect cost	10
Total installation cost, USD pr. kW Gross	**5,300**

2.2 Operation and maintenance costs

Typical operation and maintenance costs include:

- Personnel;
- Spare parts and plant consumables;
- Scheduled maintenance;
- Overhead and insurances; and
- Well replacement.

Operation and maintenance costs may vary greatly from one plant to the other depending on the size and type of plant, its location and the plant operation philosophy selected at the design stage by the plant owner.

Modern geothermal power plant operation is foreseen to be mostly automatic and unmanned. Sensors and surveillance will be provided to raise alarm on plant malfunctioning, working fluid leakage, in case of fire or unauthorized plant visitors, etc. During start-ups and scheduled shut-downs, operator attendance is however always required. Following automatic shut-down due to malfunctioning, operator attendance is also required to remove/correct the fault and reset the respective computer system modules.

Geothermal power plants are usually equipped with various human machine interfaces and PLC software to operate the plant and display trend diagrams and records plant parameters and alarms. The overview screen, at least, is visible from remote location and, in case malfunctioning occurs, fault alarms become visible/audible too. Plant start-up, warming-up, synchronization and loading follows an automatic programmed routine and same applies to plant shut-down, scheduled or forced. A daily plant operator visit is nevertheless necessary to look after systems and perform preventive maintenance and inspection tasks such as checking for noise, vibrations, leakages, strainer conditions, liquid levels, safety valves, etc.

About 1 to 2 weeks scheduled shut-downs are foreseen each year for general maintenance and 5-8 weeks every 3-6 year for major maintenance-related shut-downs. This influence the maintenance cost and also the expected utilization hours.

General maintenance includes inspection of the plant, instrument calibration, generator cleaning, strainer cleaning, mechanical seal inspection, insulation tests, etc. The geothermal wells, the gas separator and control valves are checked for scaling and cleaned. Outdoor maintenance is required on buildings and painted steel parts, equipment and piping supports, area fencing, etc.

Typical plant operation and maintenance costs are presented in Table 3. In general the cost is in the range of 1.5-2.5 % of the total installation cost.

TABLE 3: Operation and maintenance cost for a geothermal steam plant

Plant output	MW	1
Annual Gross electricity production	MWh	8,000
Fixed annual operational cost	**$/MW**	**43,000**
Supervision of machinery	$/MW	8,000
Maintenance work	$/MW	25,000
Supervision of reservoir	$/MW	10,000
Variable operational cost	**$/MWh**	**4.30**
Operation supplies	$/MWh	0.70
Maintenance drilling	$/MWh	3.30
Total O&M cost for 1 MW	**USD /year**	**75,000**

Similar values can be derived for binary plants.

2.3 Net electricity production

Geothermal power plants generally use their own electricity production to cover the parasitic load. The parasitic load is not listed as operational cost; it only reduces the amount of energy sold to the grid.

The parasitic power for a geothermal steam plant is in the range of 2-5 % but can reach 20-40% for some binary plants.

In normal operation mode, each unit should run and stay on line for more than 8000 hours/year, allowing 1 to 2 week for annual scheduled maintenance and up to 7 days/year of unforeseen outages. Also, as mentioned before major shut-downs for maintenance purposes should be programmed for 5 – 8 weeks every 3-6 year.

3. COMPARISON WITH OTHER TECHNOLOGIES

The feasibility of a geothermal power project does not only depend on the technical issues previously introduced. Decision on the development of a geothermal project will also be dependent on the economic justification of the geothermal resources involved in the project. Table 4 proposes an overview of typical costs for various types of power plants:

- Geothermal:
  - Steam turbine plants: harnessing energy from geothermal fluids at temperature above 180°C.
  - Binary plant: the binary technology allows for production of electricity from low temperature resources that could otherwise not be used for such purpose, typically at reservoir temperatures below 180°C.
- Medium speed diesel: this type of power plant typically operates on heavy fuel.
- Steam turbines: typically operating on coal for the purpose of this paper.
- Combustion turbine typically operating on gas for the purpose of this paper.
- Nuclear.
- Wind: similarly to geothermal power plants, wind turbines are site specific.
- Hydro:
  - Large dam hydropower plants, designed to have a high capacity factor.
  - Other hydropower plants, with smaller dams and a lesser capacity factor.

TABLE 4: Typical costs for power plants and

Plant	Investment cost MUSD/MW	Annual operational and maintenance cost		Typical load factor
		Fixed USD/MW	Variable USD/MWh Gross	
Geothermal, steam	3.60	43,000	4.3	90 – 95
Geothermal, binary	5.30	43,000	1.0	85 - 95
Large wind	2.00	35,000	2.0	35 – 40
Nuclear	4.05	90,000	15.0	80 – 90
Large hydro	2.80	15,000	1.0	80 - 90
Gas Turbines	0.80	12,000	90.0	50 - 60
Coal	2.10	70,000	60.0	70 - 80
Diesel	1.50	60,000	120.0	30 - 40

Typical capacity, or load, factors are also indicated for each type of power plant in Table 4. The capacity factors indicated depend on availability of the source, for intermittent renewable sources of energy such as wind or hydropower, and on the fuel costs. Geothermal power plants are generally considered one of the power production means with the highest capacity factor as the energy may be available 24 hours a day almost all year round and may in some cases be above 95%.

It is possible to compare the economics of different energy sources by considering the various cost elements such as: investment cost, fuel cost, operation and maintenance costs, economic lifetime and efficiency. An Equity Research on "Alternative Energy" conducted by Credit Suisse in 2009 aimed at comparing Levelised Cost of Electricity for various sources of energy, see Figure 1. According to these estimates, geothermal plants are the least expensive form of power.

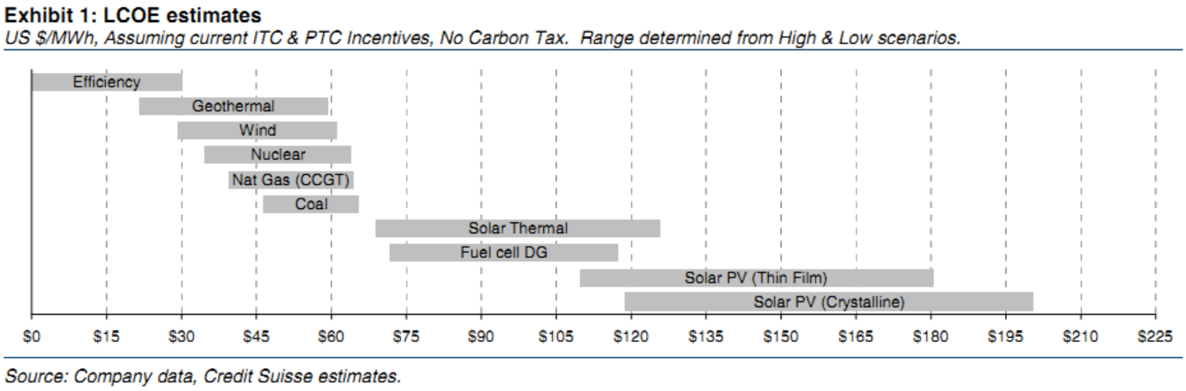

FIGURE 1: LCOE estimates for various sources of energy (Credit Suisse, 2009)

Countries may develop and maintain a least cost development plan for a given timeframe with the purpose to identify the resources that are the most economically feasible. The result of such exercise is often shown in the form of so-called screening curves that show the total costs associated with the development of each plant per kW as a function of the capacity factor. These curves are an interesting tool for comparing various types of power plants in different capacity factor context.

4. CONCLUSION

Geothermal electricity, while limited in scalability and geography, compares well with other options and scores among the least expensive sources of energy. Investment costs for geothermal power plants are high, 3-7 MUSD/MW, compared to other technologies whereas the operation and maintenance costs are low, due to the fact that once the plant has been installed, no fuel or little external source of energy is required to run the plant. This is among the main reasons why geothermal power plants are considered competitive. They furthermore generally contribute to cut CO_2 emissions and reduce dependence on fossil fuels.