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Assessment of New Approaches in Geothermal Exploration Decision Making

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INTRODUCTION

Two of the most considerable challenges for increased geothermal development are 1) understanding when and how to proceed in an exploration program and 2) when to discontinue development of a site. Currently, exploration decision making relies on expert opinion, which can be biased (Bond et al. 2007). The aim of this project is to develop a methodology for more objective geothermal decision making, including more solid go/no-go decisions to be made at specific points in the process, and to reduce subjectivity and increase reproducibility. Two approaches are examined: 1) value of information analysis (VOIA) and 2) enthalphy-based exploration targeting analysis (ETA). These are additional tools that can help inform the process; neither method replaces trained geologists and detailed conceptual models.

METHODS

When considering a site for a production well, the primary decision around data has to do with the cost of obtaining information vs the value of that data to the project.

VOIA VOIA, which has been applied in many industries in the past, employs Bayesian Inference statistics and can be used with conceptual models in an exploration program. At each point in the process, potential actions could be to leave the field in question, drill the first production well with existing information, or collect additional data and then drill. Data acquisition is considered to be economic when the value of information collected is greater than the cost of exploration activity. (Figure 1)

ETA In exploration targeting, minimum exploration targets are calculated based on an expected project's internal rate of return (IRR). As new data are gathered throughout the exploration process, production estimates are compared to minimum IRR requirements to determine if the project is still thought to be profitable. This comparison can help aid in the go/no-go decision at each point in the exploration process, for each field being explored. (Figure 2) We conducted a sensitivity analysis to understand the sensitivity of the IRR due to five key input factors: temperate gradient, reservoir temperature, total capacity, price of electricity, and exploration cost. (Figure 3)

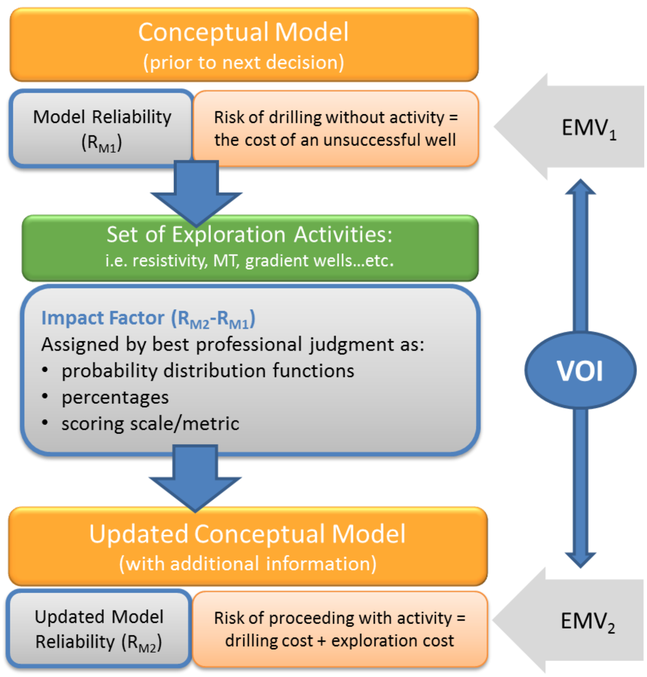

Figure 1. Decision making with VOIA (The initial conceptual model has a reliability (R_{M1}) and risk value which results in an expected monetary value (EMV). A set of new activities is expected to make an impact on the model to reach a higher reliability (R_{M2}) and EMV.

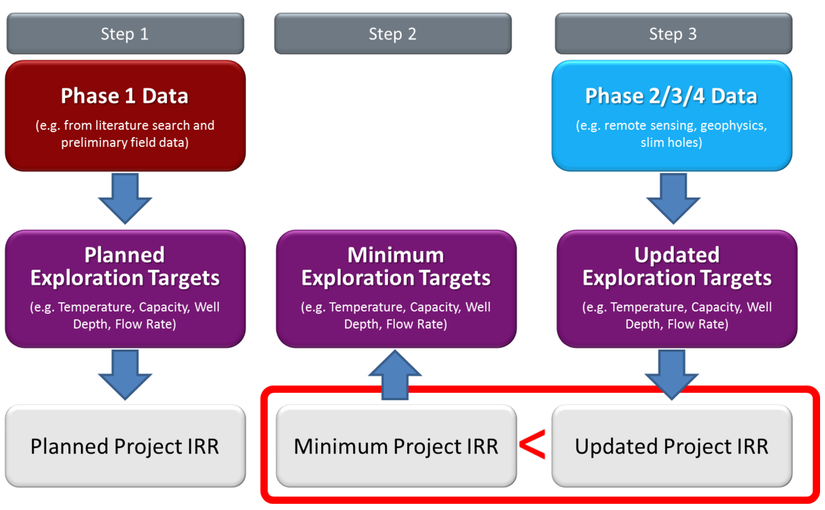

Figure 2. ETA decision flow chart (Step 1 - Initial targeting; Step 2 - Defining Go/No-Go decision points; Step 3 - Updating model with new data and cross correlating calculated project IRR with minimum IRR)

RESULTS

In the scope of this study, two approaches were investigated to develop a best-practices methodology for objective geothermal exploration decision making at a given location, including go/no-go decision points to help developers and investors in deciding when to give up on a location. Among those two approaches ETA is found to be less subjective than value of information analysis.

VOIA has a high degree of subjectivity in assigning probabilities, but this can be decreased by using historical data collected from analogous geological settings and geothermal play types, or by creating a scoring scale metric for a specific set of activities.

We found ETA to be less subjective than VOIA because numerical inputs come from collected data. However, the input variables used herein are not always definite numbers and ETA still has significant uncertainty. Monte Carlo simulations can be used to show statistical distribution of values from an analysis.

A sensitivity analysis was conducted to determine the variation in the results of IRR due to changes in five key input factors: temperature gradient, reservoir temperature, total capacity, sales price of electricity, and exploration cost. The sensitivity analysis demonstrated that:

- Temperature gradient, reservoir temperature, and electricity sale price have the most significant effect—while exploration cost has a very minor effect—on IRR
- Drilling cost has a major impact on project IRR—greater than the effect of electricity sales price
- Total capacity estimate has a smaller effect on IRR than reservoir temperature and thermal gradient

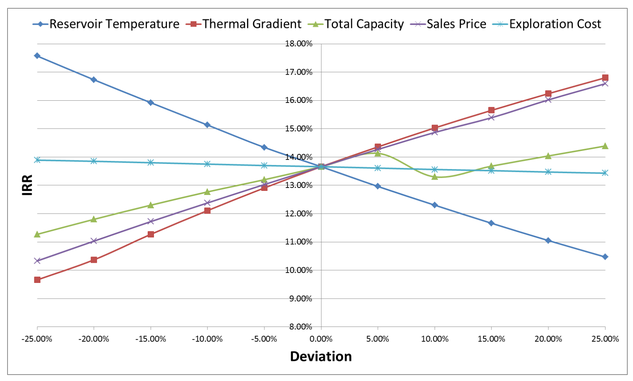

Figure 3. Sensitivity analysis for the 13-MW production capacity geothermal power plant project at drilling phase.

LIMITATIONS

All calculations in this ETA spreadsheet are illustrative only, and not intended to be representative of either general geothermal exploration or exploration for a specific site. Currently, the spreadsheet excludes the drilling risk and assumes 100% equity financing. The Geothermal Electricity Technology Evaluation Model (GETEM) and the System Advisor Model (SAM) can be used for a financial estimate. Before starting an exploration project, developers should determine their own risk tolerance.

CONCLUSIONS

To help stakeholders arrive at more informed geothermal decisions and to make the process more objective, VOIA and ETA can be used as complementary studies in the evaluation of a new geothermal resource. It may be a better approach to start with a VOIA approach in the early stages by checking parameters and results—because exploration targeting method is so dependent on flow rates—and it is not practical to estimate flow rates in early stages. If calculations show unrealistic flow rates with definite temperature estimates, the developer may decide to discontinue exploration. Net present value (NPV) of the project may also be estimated using the ETA approach, and that value may be used in the probabilistic calculations of VOIA. In later stages, the decision making may then switch to ETA to make decisions on drillings and implementation of the project. Thus, use of VOIA and ETA methods, with control of the IRR, can be a useful decision-making tool in geothermal exploration projects. It may also help to facilitate communication between project managers and exploration geologists in making objective go/no-go decisions throughout a project's phases.

FUTURE WORK

These proposed methods could benefit from additional work and modifications to make them more accurate. Because this initial work demonstrates that VOIA is highly subjective in assigning probabilities, future work could utilize historical data statistics collected from analogous geological settings and geothermal play types or could establish a scoring scale metric for specific set of activities. For ETA, future work could use more Monte Carlo simulations to reduce uncertainties of input variables. The use of GETEM, SAM or some other geothermal financial tool could help to better account for considerations such as drilling risk and equity financing.

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