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Techno-Economic Evaluation of Hot Sedimentary Geothermal Systems using GEOPHIRES-X

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Summary

The geothermal potential of hot sedimentary basins has been studied for some Western US States (Johnston et al, 2020). Johnston et al used the GEOPHIRES v2.0 tool developed by the National Renewable Energy Lab (Beckers 2019) to evaluate the techno-economics of the Marys River Basin in Eastern Nevada. RESPEC used GEOPHIRES-X, the 2023 successor to GEOPHIRES v2.0, to study another US sedimentary system. The Python open-source tool proved its versatility through simple customizations to adapt to geo-pressures and custom unit cost assumptions. The additional metrics for project economics and the use of a Monte-Carlo analysis to predict the probabilities of possible outcomes were also very handy. We also discuss the possible benefits of using GEOPHIRES for pre-feasibility evaluations, feasibility studies and due diligence evaluations. It is our opinion that the methodology used for this study could be extended to other hot sedimentary geothermal systems.

Code Verification

The resource calculations and cost assumptions built into the GEOPHIRES tool were verified against those included in a publicly-funded US Trade and Development Administration (USTDA) bankable feasibility study in Turkey. It was found that the resource calculations checked out, but that some minor adjustments for capital expenses (CAPEX) were required. The operating expenses (OPEX) assumed in GEOPHIRES, however, were found to significantly differ from those used in the USTDA project because the US labor costs are significantly more expensive than in Turkey. Adjustments to the wells, gathering system and plant CAPEX, as well as OPEX, are easily made in GEOPHIRES using adjustment ratios.

Code Modification for Hot Sedimentary Systems

The GEOPHIRES tool has been originally developed for fault-hosted geothermal systems found in the Western US or for Enhanced Geothermal Systems (EGS). However, thanks to its open-source nature, it could easily be modified for Hot Sedimentary Geothermal Systems. For example, the temperature drawdown was assumed to be nil with proper well spacing. For geo-pressured reservoirs, the parasitic load calculations were modified to remove load from production pumps and re-injection into shallower reservoirs was allowed with the definition of a secondary reservoir with its own temperature and pressure. Once these code modifications are made, the code runs within a few seconds and inputs can be modified very quickly, which allows for many sensitivity runs that can be used in a Tornado chart (Figure 1). Finally, GEOPHIRES can also run the TOUGH reservoir simulation package (it is called internally) provided that the TOUGH executables are provided. The TOUGH input files can be generated and easily modified within

GEOPHIRES which allows the economic model to be coupled with a TOUGH model for a geothermal doublet for example.

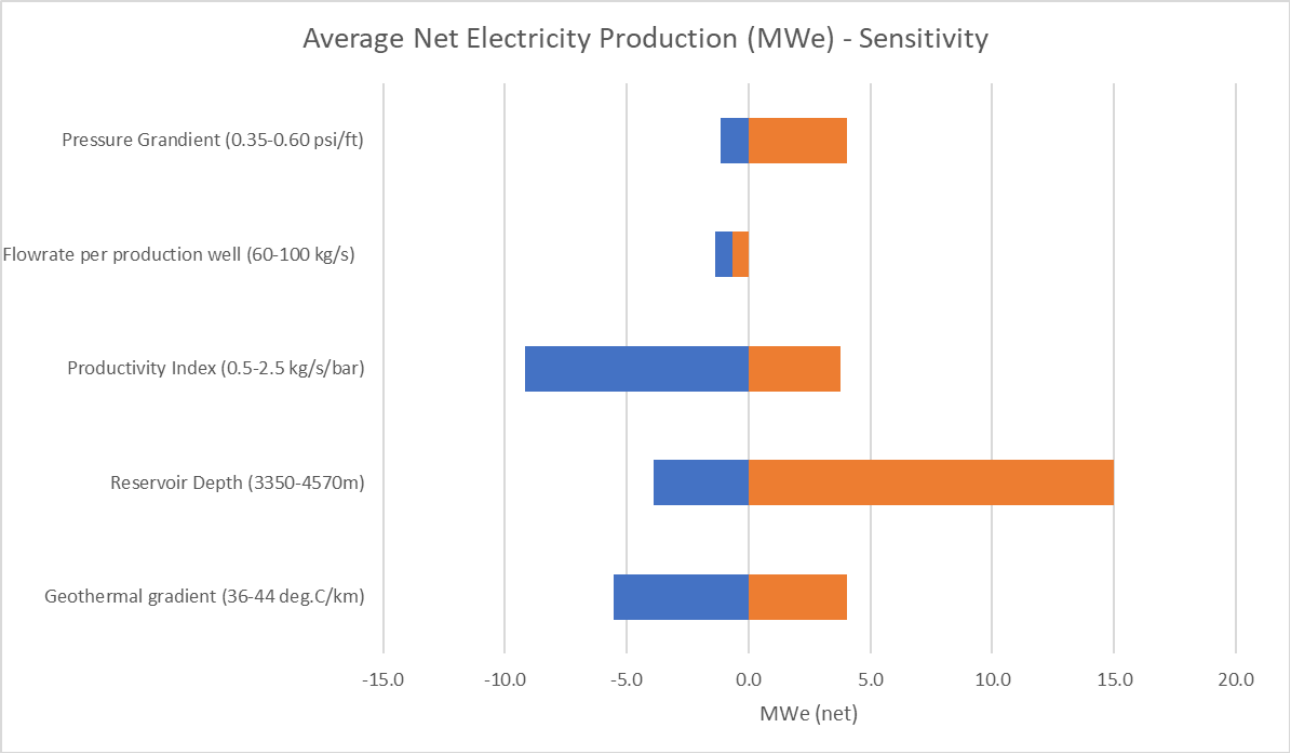

Figure 1: Example of Tornado Chart for a Hot Sedimentary Geothermal System using GEOPHIRES

Improvements of Economic Module with GEOPHIRES-X

GEOPHIRES-X is the 2023 update to GEOPHIRES v2.0. The code architecture has been significantly modified and a comprehensive economic module added. This module allows considerable flexibility in the economic assumptions such as the revenue from sales time series. The tool now includes all the regular project economic metrics such as Net Present Value (NPV) Internal Rate of Return (IRR), capital efficiency, etc. in addition to the Levelized Cost of Electricity (LCOE).

Monte-Carlo Analysis with GEOPHIRES-X

GEOPHIRES-X also includes the capability for Monte Carlo analysis through the use of the GEOPHIRES input file that was used for a single deterministic run and a simple text file that specifies the probabilistic distributions. The computer processing is very efficient through parallel processing allowing a large number (for example: 10,000) realizations. The probabilistic distributions for the output parameters are stored in the code and statistics / charts for these distributions can easily be made through customization of the code. A future improvement to the code would be to allow GEOPHIRES to run a Monte-Carlo analysis on a GEOPHIRES model using TOUGH for the reservoir simulations.

Conclusions

The open-source nature of GEOPHIRES allows some relative simple customization for engineers with some intermediate knowledge of Python thanks to a good documentation throughout the code. The most recent version, GEOPHIRES-X, offers significant improvements compared to GEOPHIRES v2.0 including a comprehensive set of economic metrics and the capability of Monte-Carlo analysis.

The GEOPHIRES tool runs fast on a standard laptop and is particularly suited for pre-feasibility / scoping studies with an appropriate level of detail and inputs that can be very quickly modified. This was verified against an existing USTDA bankable feasibility study in Turkey. GEOPHIRES could also be used to double-check the calculations of usually very complex economic model spreadsheets, for example in the case of due diligence reviews.

References

Beckers, Koenraad F. and Kevin McCabe. 2019. "GEOPHIRES v2.0: Updated Geothermal Techno-Economic Simulation Tool." Geothermal Energy 7 (5).

Johnston, Henry, Amanda Kolker, Greg Rhodes, and Nicole Taverna. 2020. Sedimentary Geothermal Resources in Nevada, Utah, Colorado, and Texas. Golden, CO: National Renewable Energy Laboratory. NREL/TP-5500-76513.