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Finding a way to optimize drilling depths in clastic aquifers for geothermal energy

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Clastic aquifers generally are marked by decreasing porosity and associated permeability with depth. Uncertainties in porosity of a few percentages can result in an order of magnitude change in permeability. Further, temperature increases with depth and is marked by an uncertainty of about 10-20%.
Monte Carlo performance calculations, adopting variable temperature and porosity distributions, along with other natural uncertainties and engineering options for drilling, show that performance in doublet power and levelized costs of energy (LCOE in EUR/GJ) is most sensitive to changes in the temperature gradient and the porosity. As the temperature increases with depth while the porosity decreases with depth, these relationships show a trade-off in performance, such that a theoretical optimal depth can be found for a specific temperature gradient and porosity-depth curve, and associated porosity-permeability relationship. The optimal drilling depth is at the depth level where the LCOE are minimal.
In mature oil and gas basin areas, such as the Netherlands, it is possible to obtain relationships of porosity and underlying permeability as a function of depth. Therefore, the applicability for establishing and using an optimal depth has been tested for a clastic aquifer in the Rotliegend stratigraphic group in the Netherlands. This aquifer has high geothermal potential and is subject to many exploration activities. Temperature gradient and porosity-depth trends (and underlying uncertainties) for this aquifer have been adopted from the national geothermal information system ThermoGIS (www.thermogis.nl). For the performance calculation of doublet power and LCOE an in-house techno-economical performance assessment (TEPA) tool called DoubletCalc has been used.
The results show that optimal depth corresponds to a pronounced and sharp minimum in LCOE. Its depth depends strongly on the actual porosity-depth relationship and ranges between 1.5 and 3 km. Remarkably, variations in the temperature gradient between 29 and 35 °C/km have only a minor influence on optimal depth. Our findings show that it is important to include porosity-depth characteristics in geothermal exploration for optimizing the subsurface reservoir location. Particularly in cases where subsurface aquifers have strong variations in depth over short distance, defining optimal depth can assist in optimising exploration and production.