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High Performance Utilization of Lower Grade EGS Resources – Connecting Thermodynamic and Economic Criteria

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To achieve maximum performance of any operating geothermal system the exergy or availability of the produced fluid needs to be considered along with the thermal sustainability of the reservoir over the long term. This paper evaluates the economic impacts of both of these performance metrics for lower grade EGS resources where average geothermal gradients of /km or less are present to depths of 4 to10 km. With the second law of thermodynamics limiting the maximum conversion of thermal energy into electrical work, a premium is placed on providing heat at temperatures close to where it is actually used. This naturally leads to co-generation designs that provide both heat and power. Economic principles for Engineered Geothermal Systems (EGS) resources normally suggest that the capital costs associated with surface utilization equipment are balanced with the costs of producing the geothermal fluid which are in turn coupled to drilling and reservoir stimulation costs. Given that drilling costs are strongly dependent on well depths which optimally are determined by applying these tradeoffs for specific resource and reservoir productivity conditions. In general when resource grades are low, optimum drilling depths will occur when there is a balance between the cost of producing fluid at the wellhead and the cost of converting the energy to a form where it can be used. Typically one is trading off drilling fewer, more costly wells that are deeper and hotter against capital equipment costs for the surface plant which will depend both on end use (electricity and/or direct use) and on fluid temperature (exergetic efficiency). These economic tradeoffs are evaluated for a range of EGS resource and drilling technology conditions.

In addition, maintaining reservoir performance in terms of produced mass flow rates and temperature are also critical in determining economic feasibility because geothermal reservoirs can be depleted during production if recharge rates are insufficient to overcome local cooling of rock and losses of fluid pressure. With proper reservoir management balancing production rates with recharge rates, hydrothermal reservoirs have been shown to be productive for long periods of time. The situation is quite different for EGS reservoirs. With no record of long term field testing, the renewability of EGS is often questioned. In fact, many analyses of EGS specify thermal drawdown rates and minimum produced fluid temperatures to define redrilling or restimulation frequency. To quantify the effects of EGS reservoir performance we evaluated a conduction-dominated, model EGS reservoir as a representative "worst case" to estimate heat extraction during production and thermal recovery following shut down. The model system is one where water is injected at specified rates and temperatures into discrete fractures of different dimensions surrounded by impermeable hot rock. During the extraction phase, water moves along the fractures extracting heat from the adjacent rock matrix leading to local cooling and thermal drawdown of the reservoir. When the water injection is stopped, conductive heat transfer from the surrounding hotter rock regions leads to recovery of the cooler zones in the reservoir with the rate of recovery controlled locally by the temperature gradient induced during the thermal drawdown. To close, the combined effects of drilling cost reductions and reservoir productivity improvements along with reduced uncertainty of reservoir rock properties, including in situ stresses, heat flow and temperature gradient are examined.