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A hybrid geothermal energy conversion technology: Auxiliary heating of geothermally preheated water or CO_2 – a potential solution for low-temperature resources

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Safe, sustainable, and economic development of deep geothermal resources, particularly in less favourable regions, often requires employment of unconventional geothermal energy extraction and utilization methods. Often "unconventional geothermal methods" is synonymously and solely used as meaning enhanced geothermal systems, where the permeability of hot, dry rock with naturally low permeability at greater depths (4-6 km), is enhanced. Here we present an alternative unconventional geothermal energy utilization approach that uses low-temperature regions that are shallower, thereby drastically reducing drilling costs. While not a pure geothermal energy system, this hybrid approach may enable utilization of geothermal energy in many regions worldwide that can otherwise not be used for geothermal electricity generation, thereby increasing the global geothermal resource base. Moreover, in some realizations of this hybrid approach that generate carbon dioxide (CO_2), the technology may be combined with carbon dioxide capture and storage (CCS) and CO_2-based geothermal energy utilization, resulting in a high-efficiency (hybrid) geothermal power plant with a negative carbon footprint.

Typically, low- to moderate-temperature geothermal resources are more effectively used for direct heat energy applications. However, due to high thermal losses during transport, direct use requires that the heat resource is located near the user. Alternatively, we show here that if such a low-temperature geothermal resource is combined with an additional or secondary energy resource, the power production is increased compared to the sum from two separate (geothermal and secondary fuel) power plants (DiPippo et al. 1978) and the thermal losses are minimized because the thermal energy is utilized where it is produced. Since Adams et al. (2015) found that using CO_2 as a subsurface working fluid produces more net power than brine at low- to moderate-temperature geothermal resource conditions, we compare over a range of parameters the net power and efficiencies of hybrid geothermal power plants that use brine or CO_2 as the subsurface working fluid, that are then heated further with a secondary energy source that is unspecified here. Parameters varied include the subsurface working fluid (brine vs. CO_2), geothermal reservoir depth (2.5-4.5 km), and turbine inlet temperature (200-600°C) after auxiliary heating. The hybrid power plant is numerically modeled using an iterative coupling approach of TOUGH2-ECO$_2$N/ECO$_2$H (Pruess, 2004) for simulation of the subsurface reservoir and Engineering Equation Solver for well bore fluid flow and surface power plant performance. We find that hybrid power plants that are CO_2-based (subsurface) systems produce more net power than the sum of the power produced by individual power plants at low turbine inlet temperatures and brine based systems produce more power at high turbine inlet temperatures. Specifically, our results indicate that geothermal hybrid plants that are CO_2-based are more efficient than brine-based systems when the contribution of the geothermal resource energy is higher than 48%.