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ABSTRACT

A Hot Dry Rock Geothermal Energy Concept Utilizing Supercritical CO2 Instead of Water

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A novel renewable energy concept -- heat mining using supercritical CO_2 (SCCO2) for both reservoir creation and heat transport -- is here proposed. This concept builds on the earlier, very extensive Hot Dry Rock (HDR) research and development effort conducted by Los Alamos National Laboratory at Fenton Hill, NM. This previous field testing very convincingly demonstrated the viability of the HDR concept based on the results obtained from the production testing of two separate confined reservoirs for almost a year each. However, using SCCO2 instead of water in a closed-loop HDR system offers three significant advantages over the original Los Alamos concept:

1. The very significant wellbore density difference between the cold SCCO2 in the injection well (about 0.96 g/cm3) and the hot SCCO2 in the production wells (about 0.39 g/cm3) would provide a very large buoyant drive (i.e., thermal siphoning effect), markedly reducing the circulating pumping power requirements over those of a comparable water-based HDR system.
2. The inability of SCCO2 to dissolve and transport mineral constituents from the geothermal reservoir to the surface would eliminate mineral scaling effects in the surface piping, heat exchangers, and other surface equipment.
3. Higher reservoir temperatures could be utilized without the problems associated with silica dissolution as the reservoir temperature approaches 374°C, the critical temperature for water. This would potentially provide increased thermodynamic efficiency by allowing the development of deeper and hotter HDR geothermal reservoirs.

This new HDR concept would employ a binary-cycle power plant with heat exchange from the hot SCCO2 to a secondary working fluid at the surface for use in a Rankine (vapor) power cycle. Thermodynamic and systems analyses show that in the overall sense, SCCO2 is a superior geofluid to water when used for heat mining from a confined HDR reservoir. For equivalent reservoir operating conditions of surface injection pressure, reservoir flow impedance, and reservoir production pressure, the rate of geothermal energy production using SCCO2 would be some 20% greater than that for water .

This performance advantage obtains because of the very unique properties of CO2 in the supercritical region. To a first approximation, the mass heat capacity of SCCO2, for the heat-transfer environment of the binary power plant, is two-fifths that of water, while the viscosity for SCCO2 is one-third that of water under comparable reservoir conditions. That is, for the same reservoir flow impedance and surface injection pressure, the lower viscosity of SCCO2 would result in three times the production mass flow rate but at only two-fifths the rate of heat transport per unit mass. For an SCCO2-HDR system, moreover, the potentially negligible pumping power requirements would boost the net power output when compared to a water-based HDR system, increasing even more this apparent performance advantage of SCCO2 as a geofluid.

However, this new SCCO2-based HDR system could be made about an order of magnitude more productive -- approaching 50 MW(th) -- than the deeper two-well HDR reservoir that was extensively flow tested at Fenton Hill between 1992 and 1995. This could be done by first using a three-well flow geometry (two production wells and one injection well), and then by employing currently available methods of reservoir productivity enhancement such as drilling multilateral production wells or using newly developed methods of near-production-well flow impedance reduction.

The commercial development of this new heat-mining concept, given the ubiquitous worldwide distribution of the HDR geothermal resource, could be a significant contributor to solving two of the most pressing problems for this new century:

- The increasing need for indigenous supplies of clean energy, particularly for many of the emerging nations of Africa, Asia, and those bordering the Pacific Rim.
- Global warming resulting from ever increasing amounts of atmospheric CO2 derived from the combustion of fossil fuels.

For the later problem, an SCCO2-based HDR power plant would provide an important ancillary benefit: a means of sequestering significant amounts of CO2 deep in the earth, when SCCO2 is used for both the fracturing fluid and the heat transport fluid for deep-earth heat-mining systems. Further, replacing fossil fuel combustion with heat derived from HDR geothermal resources would have a greater long-term mitigating effect on global warming than CO2 sequestration alone. This is because, to a first order, such an HDR power plant would have the capability of continuously sequestering, by diffusion into the surrounding rock mass, about as much CO2 as that produced by a typical coal-fired power plant, each on a per MW-electric generation basis [24 tons of CO2 per day per MW(e)].