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Coupling carbon dioxide sequestration with geothermal energy capture in naturally permeable, porous geologic formations: Implications for CO_2 sequestration

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Abstract

Carbon dioxide (CO_2) sequestration in deep saline aquifers and exhausted oil and natural gas fields has been widely considered as a means for reducing CO_2 emissions to the atmosphere as a counter-measure to global warming. However, rather than treating CO_2 merely as a waste fluid in need of permanent disposal, we propose that it could also be used as a working fluid in geothermal energy capture, as its thermodynamic and fluid mechanical properties suggest it transfers geothermal heat more efficiently than water. Energy production and sales in conjunction with sequestration would improve the economic viability of CO_2 sequestration, a critical challenge for large-scale implementation of the technology. In addition, using CO_2 as the working fluid in geothermal power systems may permit utilization of lower temperature geologic formations than those that are currently deemed economically viable, leading to more widespread utilization of geothermal energy. Here, we present the results of early-stage calculations demonstrating the geothermal energy capture potential of CO_2-based geothermal systems and implications of such energy capture for the economic viability of geologic CO_2 sequestration.

Keywords: Geothermal energy; CPG; CO_2 sequestration

1. Introduction and Background

Geologic CO_2 sequestration is often considered the primary approach with soon-to-be available technology by which anthropogenic CO_2 emissions to the atmosphere could be significantly reduced [1]. However, a challenge for large-scale implementation of sequestration is cost; CO_2 capture and storage (CCS) could add 20%, or more, to the cost of fossil-fuel-based electricity generation, assuming CCS costs of 0.02 $U.S.A. per kWh [2]. Advances in CCS technology and experience, together with legislation such as carbon cap and trade, will improve the economic feasibility of CCS, however, these advances may not be sufficient to encourage large-scale CCS implementation.

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Coupling CCS with renewable energy capture, electricity production, and/or district heating would further improve the economic viability of CCS, among numerous other advantages, as outlined in this contribution.

Geothermal energy offers clean, consistent, reliable electric power with no need for grid-scale energy storage, unlike most renewable power alternatives. However, geothermal energy is often underrepresented in renewable energy discussions and has considerable room for growth (e.g., [3], [4]). New technology and methods will be critical for future investment, and rapid implementation of new techniques will be important to ensure geothermal energy plays a significant role in the future energy landscape worldwide.

CO_2 is of interest as a geothermal working fluid because, among numerous other benefits, its thermodynamic and fluid mechanical properties suggest it transfers geothermal heat more efficiently than water [5], [6]. Previous literature, however, has proposed geothermal energy recovery by CO_2 in the subsurface only in the context of engineered geothermal systems (EGS) [5], [7], [8], [9], [10], [11]. EGS are typically generated by hydrofracturing so-called hot-dry rock, a process that may induce seismicity because the critical fracture stresses of geologic formations are intentionally exceeded. As such, EGS has encountered considerable socio-political resistance, exemplified by the termination of several EGS projects during the year 2009 (e.g., Basel in Switzerland [12]). In contrast, the method described here does not rely on hydrofracturing or similar permeability-enhancing technologies, but rather utilizes existing, high-permeability and high-porosity geologic reservoirs that are overlain by a low-permeability caprock. The sizes of such natural reservoirs are typically much larger than those of hydrofractured reservoirs [13]. Consequently, the CO_2 sequestration potential of the system described here is expected to be significantly greater than that of EGS. Therefore, we distinguish our approach from EGS and refer to it as a CO_2-plume geothermal (CPG) system.

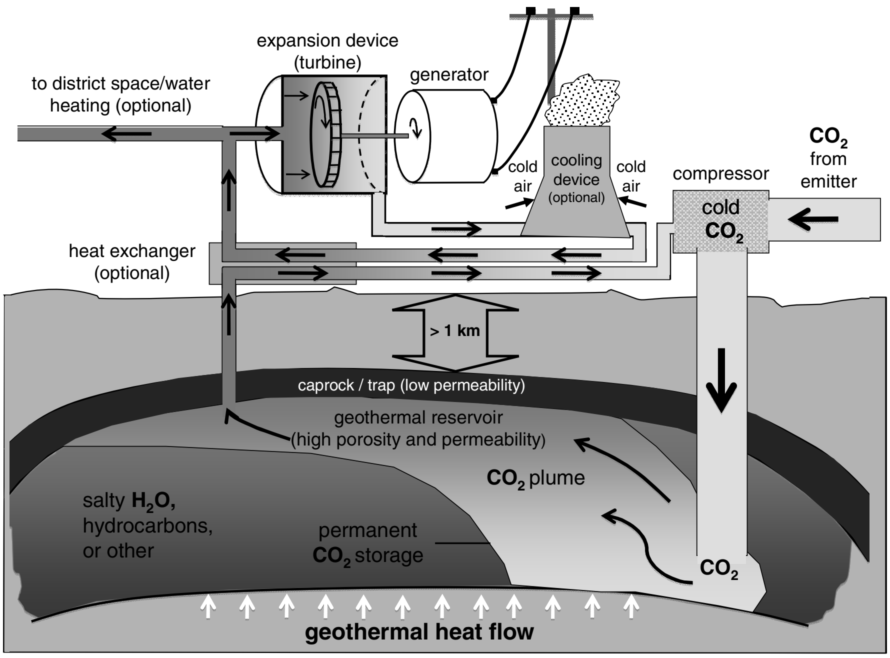

Figure 1 Simplified schematic of one possible implementation of a CO_2-plume geothermal (CPG) system, established in a deep saline aquifer or as a component of enhanced oil/hydrocarbon recovery (EOR) operations. Some components of the system are generalized or absent. As in traditional geothermal approaches, energy recovered from CPG systems could be used both for electricity generation and for space/water heating. Moreover, a wide range of realizations can be envisioned including direct and binary cycles, bottom cycles, and multiple secondary working fluids. Note that only one production well is shown here, while actual implementations would likely include multiple production, and possibly several injection, wells (see also Figure 2 for a typical 5-spot well pattern).