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CO_2 Earth Storage: Enhanced Geothermal Energy and Water Recovery and Energy Storage

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Abstract

Mitigating climate change requires a range of measures, including increased use of renewable and low-carbon energy and reducing the CO_2 intensity of fossil energy use. We present an approach designed to address the major deployment barriers to CO_2 capture, utilization, and storage (CCUS) and utility-scale energy storage needed to maximize use of variable renewable energy and low-carbon baseload power. We use the huge fluid and thermal storage capacity of the earth, together with overpressure driven by CO_2 storage, to harvest, store, and dispatch energy from subsurface (geothermal) and surface (solar, fossil, nuclear) thermal resources, as well as excess energy from electric grids. Permanent storage of CO_2 enables the earth to function as a low-carbon energy-system *hub*. Stored CO_2 plays three key roles: (1) as a supplemental fluid that creates pressure needed to efficiently recirculate working fluids that store and recover energy, (2) as a working fluid for efficient, low-water-intensity electricity conversion, and (3) as a shock absorber that allows diurnal and seasonal recharge/discharge cycles with minimal pressure oscillations, thereby providing enormous pressure-storage capacity, with reduced risk of induced seismicity or leakage of stored CO_2. To assure safe storage pressures, a portion of the brine produced from the CO_2 storage reservoir can be diverted to generate water.

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Keywords: Geologic CO_2 storage; energy storage; low-carbon energy; capacity factor; reservoir pressure management; enhanced water recovery

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1. Introduction

Meeting the Paris Climate Agreement goal of limiting the increase in the global average temperature to below 1.5°C, compared to pre-industrial levels, requires large-scale implementation of a range of measures, including increased use

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of renewable and other low-carbon energy and reducing the CO_2 intensity of fossil energy use. But each of these measures faces major technical and economic deployment barriers. Variability of the predominant renewables (wind and solar) requires major advances in utility-scale energy storage. Renewable energy and other low-carbon energy, such as nuclear and fossil-energy power plants integrated with CO_2 capture, utilization, and storage (CCUS), have high up-front capital cost and low operating cost, which economically favors high capacity factors [1]. Fossil-energy power plants integrated with CCUS will have difficulty co-existing on electric grids and maintaining high capacity factors with an increasing presence of variable renewables. Deployment barriers for CCUS in saline reservoirs include: (1) the lack of a business case to incentivize deployment; (2) water intensity of CO_2 capture, and (3) overpressure, which is fluid pressure that exceeds the original reservoir pressure due to CO_2 injection, because it drives key storage risks: induced seismicity, caprock fracture, and CO_2 leakage [2,3,4,5,6]. With the exception of compressed air energy storage (CAES), all existing energy-storage technologies are deployed above ground with high fabrication costs, and all existing technologies are limited in capacity to diurnal storage. To date, the energy-storage technology with the greatest capacity is pumped hydroelectric energy storage (PHES). However, PHES has topographic requirements that greatly limit its geographic deployment potential. In regions such as California, solar power will dominate renewable energy growth [7], which will result in large seasonal mismatches between energy supply and demand. No existing energy-storage technology has the capacity to fill this need. In this paper, we present preliminary reservoir and techno-economic analyses of an approach that uses industrial-scale CCUS to enable utility-scale diurnal and seasonal energy storage.

2. CO_2 Earth Battery

The Earth Battery [8,9,10] is a CCUS technology designed to address the major deployment barriers to CCUS and utility-scale diurnal and seasonal energy storage. By taking advantage of the huge fluid and thermal storage capacity of the earth and overpressure from CO_2 storage, it may be possible to harvest, store, and dispatch energy from subsurface (geothermal) and surface (solar, nuclear, fossil) thermal resources, and excess energy from electric grids. Stored CO_2 plays three key roles: (1) as a supplemental fluid that creates pressure needed to recirculate working fluids that store and recover energy, (2) as a working fluid for efficient, low-water-intensity, electricity conversion in Brayton Cycle turbines, and (3) as a shock absorber to allow recharge/discharge cycles to occur with reduced pressure oscillations. Large quantities of stored CO_2 create enormous pressure-storage capacity, enabling utility-scale energy storage.

The Earth Battery takes CO_2 captured from fossil-energy systems and injects it into a saline reservoir to store pressure, generate artesian flow of brine, and provide a supplemental working fluid to efficiently harvest geothermal heat and to store heat from above-ground sources (Fig. 1) for dispatchable power. Concentric rings of horizontal injection and production wells create a

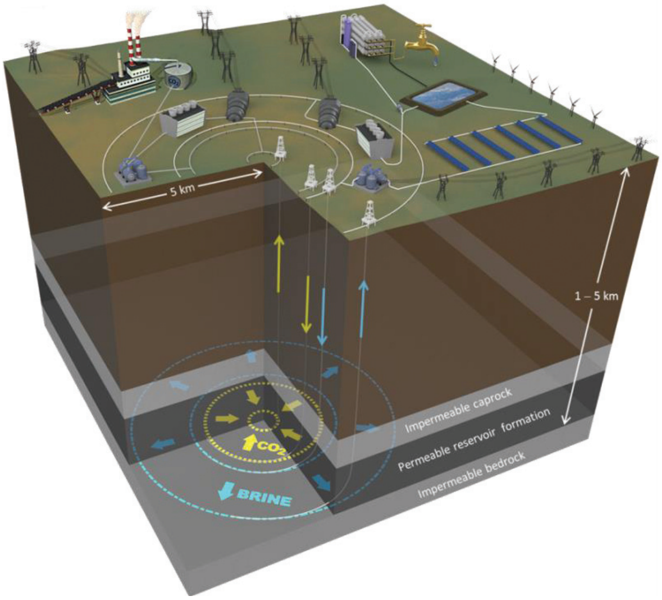

Fig. 1. A CO_2 Earth Battery system is shown with four concentric rings of horizontal injection and production wells in a permeable reservoir overlain by an impermeable caprock. This well arrangement is designed to confine the pressurized CO_2 and brine beneath the caprock. Supercritical CO_2 from a fossil fuel power plant is pressurized for injection in the second ring of wells, which displaces brine produced at the inner ring. Produced brine is heated, using heat from an above-ground source, (e.g., solar thermal farm) pressurized, and injected in the third well ring, using excess power from the grid. Gradually, the inner ring produces CO_2, which is sent through a Brayton Cycle turbine, prior to being pressurized for injection in the second ring. Hot brine produced at the outer well ring is used to heat produced CO_2, prior to being stored in a staging pond. When waste/excess heat is available, brine from the pond is heated and pressurized for injection in the third well ring, using excess power from the grid. To manage reservoir pressure, some of the produced brine is diverted for consumptive use, such as in a reverse osmosis plant.