Geophysical Research Abstracts
Vol. 17, EGU2015-7539, 2015
EGU General Assembly 2015

Hybrid Geo-Energy Systems for Energy Storage and Dispatchable Renewable and Low-Carbon Electricity

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Three primary challenges for energy systems are to (1) reduce the amount of carbon dioxide (CO_2) being emitted to the atmosphere, (2) increase the penetration of renewable energy technologies, and (3) reduce the water intensity of energy production. Integrating variable renewable energy sources (wind, sunlight) into electric grids requires advances in energy storage approaches, which are currently expensive, and tend to have limited capacity and/or geographic deployment potential. Our approach uses CO_2, that would otherwise be emitted to the atmosphere, to generate electricity from geothermal resources, to store excess energy from variable (wind, solar photovoltaic) and thermal (nuclear, fossil, concentrated solar power) sources, and to thus enable increased penetration of renewable energy technologies.

We take advantage of the enormous fluid and thermal storage capacity of the subsurface to harvest, store, and dispatch energy. Our approach uses permeable geologic formations that are vertically bounded by impermeable layers to constrain pressure and the migration of buoyant CO_2 and heated brine. Supercritical CO_2 captured from fossil power plants is injected into these formations as a cushion gas to store pressure (bulk energy), provide an heat efficient extraction fluid for efficient power conversion in Brayton Cycle turbines, and generate artesian flow of brine—which can be used to cool power plants and/or pre-heated (thermal storage) prior to re-injection. Concentric rings of injection and production wells create a hydraulic divide to store pressure, CO_2, and thermal energy. The system is pressurized and/or heated when power supply exceeds demand and depressurized when demand exceeds supply. Time-shifting the parasitic loads from pressurizing and injecting brine and CO_2 provides bulk energy storage over days to months, whereas time-shifting thermal-energy supply provides dispatchable power and addresses seasonal mismatches between supply and demand. These conditions enable efficient fluid recirculation, heat extraction, power conversion, and add operational flexibility to dispatch electricity. Overall, the system can (a) levelize concentrating solar power, (b) mitigate variability of wind and solar power, (c) reduce water and carbon intensity of energy systems, (d) avoid wasting or curtailing high-capital cost, low-carbon energy resources and (e) allow low-carbon, base-load power to operate at full capacity.

This work was performed under the auspices of the U.S. DOE by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344, and has been funded by the U.S. National Science Foundation Sustainable Energy Pathways Program (1230691) and the U.S. Department of Energy Geothermal Technologies Office (DE-FOA-0000336).