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Global Climate & Energy Project

STANFORD UNIVERSITY

Coal Energy Conversion with Aquifer-Based Carbon Sequestration

Investigator

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Objective

This research aims to investigate a novel coal-based electrical power generation process that involves CO_2 capture in inherently stable forms by conducting supercritical oxidation of coal in aquifer-derived and aquifer-sequestered water. The process converts the chemical energy in coal to thermal energy and electricity with permanent storage of conversion products in saline aquifers. If successful, it may provide a sequestration option that is more acceptable to the public because it does not require intensive monitoring.

Background

The sequestration of CO_2 emissions from coal power plants into deep saline aquifers has been identified as a suitable route for mitigating CO_2 released to the atmosphere. However, the permanency of storage is a concern. When compressed CO_2 is injected into aquifers, it is not in chemical equilibrium with the subsurface environment; it is buoyant, and therefore has the potential to migrate back to the surface through fissures in formation cap rock or along well bores.

The proposed process (see figure below) converts coal under supercritical conditions using aquifer brine as a solvent. The only process effluents are CO_2-laden water and fly ash/saline solid residues. Processing occurs at a near-constant pressure above the critical point of water (pumps not shown) so as to achieve compact, high-efficiency extraction of hydrocarbons from the coal, followed by complete oxidation to carbon dioxide and water. A heat engine is used to extract

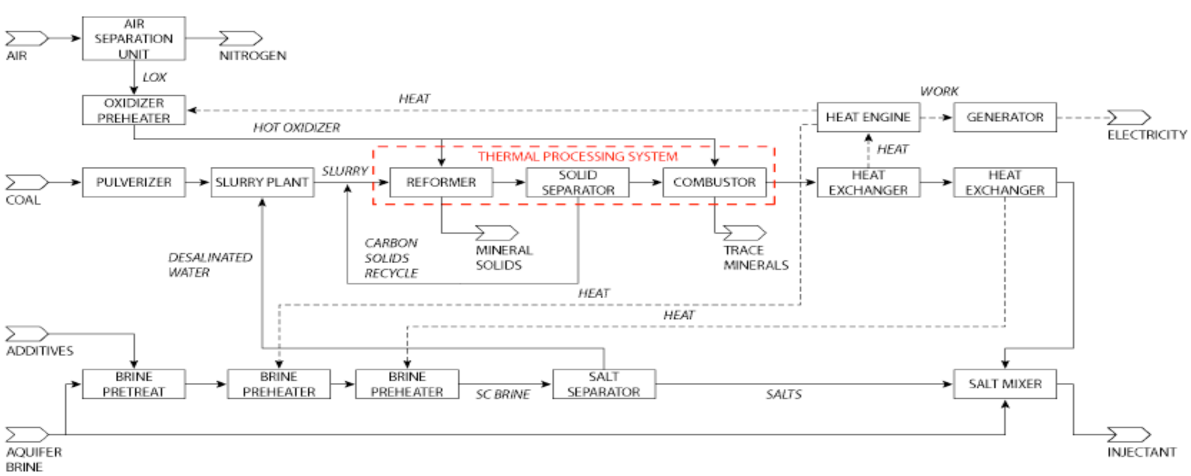

Figure 1: Flow diagram of coal-to-energy conversion process with no matter released to the atmosphere and in which all fluid combustion products, particularly carbon dioxide, are pre-equilibrated in aquifer water before injection into the subsurface.

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energy from the product gases and begin the cooling process toward aquifer conditions. After further heat exchange with the incoming brine, the product stream is mixed with excess brine to yield a homogeneous, subcritical (in temperature) CO_2-saturated brine for injection back into the aquifer.

Approach

The research proposed is divided into six tasks. An overriding goal is to establish a common basis of understanding between the researchers versed in coal science, energy processing, aquifer flow, and geochemistry.

Life Cycle and Economic Analyses: Determine the efficiencies and approximate costs associated with each of several possible configurations of the proposed energy conversion process. These analyses will be used to determine the design choices made in investigating component requirements. This work requires completing process, energy, and mass models for several process configurations. All systems will be subject to heat integration, particularly the preheating and desalination processes. Lesser consideration will be given to modifications that yield only slight increases in efficiency but have high capital costs.

Development of the Supercritical Coal Conversion Reactor: Characterize the coal conversion process under supercritical water (SCW) conditions and develop a supercritical coal reformer that will transform the coal into a mineral-free, aqueous fuel solution. The rates and mechanisms of coal conversion (extraction, devolatilization, gasification, and oxidation) under SCW conditions will be predicted quantitatively. Additionally, the thermodynamic and transport properties of select species at supercritical water conditions will be characterized. The fates of S, N and other impurities during coal conversion in SCW environments will also be determined by studying the inorganic reactions that take place.

Supercritical Combustor Development: Develop a combustor that is capable of fully reacting the supercritical fluid fuel stream supplied to it by the coal processing reformer and delivering it in a state suitable for energy extraction by a heat engine. The combustor will include the elements required to understand the interface between the hot products and the energy extraction stage (heat engine).

Materials: Investigate issues associated with the materials used to construct the SCW reactor. Materials represent one of the most critical issues in developing the proposed process, as container integrity is one of the greatest problems in all commercial-scale supercritical water oxidation (SCWO) reactors. The deliverables from this task include data from materials tests and mathematical submodels suitable for stand-alone evaluations, and incorporation into computational fluid dynamics (CFD) codes that describe the fate of impurities as functions of pressure, fluid composition, and temperature.

Aquifer Interfacing and Geochemical Compatibility: Determine the potential effects of this energy conversion scheme on the geochemical conditions of the aquifer in general, and specifically on the phases of As, Hg, and Pb introduced by use of coal as fuel. In order to determine the chemical state of contaminants within the brine, a combination of equilibrium-based reaction simulations and spectroscopic/microscopic examinations of energy system products will be used. Using a measured composition of the energy system derived from brine chemistry, the computationally-based equilibrium speciation program, Geochemist's Workbench (GWB), will be employed to determine the expected products of Hg, As, and Pb (or any other heavy metal or metalloid present in the source coal).

Reactor Analysis: Analyze reactor design, process configuration and integration issues. Tools will be developed that are useful for studying the chemistry and fluid mechanics relevant to the proposed aquifer-based coal conversion process, with an emphasis on the coal thermal processing system. Many of the materials and process complications of this process may be addressed through creative reactor design.