PROJECT facts

U.S. DEPARTMENT OF ENERGY
OFFICE OF FOSSIL ENERGY
NATIONAL ENERGY TECHNOLOGY LABORATORY

Sequestration

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GEOLOGIC SCREENING CRITERIA FOR SEQUESTRATION OF CO_2 IN COAL: QUANTIFYING POTENTIAL OF THE BLACK WARRIOR COALBED METHANE FAIRWAY, ALABAMA

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Background

The amount of carbon dioxide (CO_2) in the Earth's atmosphere has risen substantially since the start of the industrial age. This increase is attributed widely to the burning of fossil fuels, and if current trends in resource utilization continue, anthropogenic CO_2 emissions will triple during the 21st century. Among the principal ways CO_2 emissions from power plants can be addressed is to sequester this greenhouse gas in geologic formations. Within the number of geologic formations that can potentially store CO_2 are unminable coalbeds. Coalbeds are an especially attractive target because coal can store large quantities of gas. In this process of being adsorbed, the CO_2 displaces adsorbed methane. Thus, the sequestered CO_2 serves as a sweep gas to enhance recovery of coalbed methane.

The coalbed methane fairway of the Black Warrior basin is a logical location to develop screening criteria and procedures from numerous standpoints. According to the U.S. Environmental Protection Agency, Alabama ranks 9^{th} nationally in CO_2 emission from power plants and two coal-fired power plants are within the coalbed methane fairway. More than 34 billion cubic meters of coalbed methane have been produced from the Black Warrior basin, which ranks second globally in coalbed methane production. Production is now leveling off, and enhanced coalbed methane recovery has the potential to offset impending decline and extend the life and geographic extent of the fairway far beyond current projections.

The Geological Survey of Alabama and its partners conducted research to determine the amount of CO_2 that can be stored in the Black Warrior coalbed methane region of Alabama.

Primary Project Goal

The primary goal of this project was to develop a screening model that is widely applicable, quantify CO_2 sequestration potential in Black Warrior CBM fairway, and apply screening modeling to identify favorable demonstration sites for CO_2 sequestration.

Objectives

- Develop a geologic screening model for CO_2 sequestration sites that is widely applicable.
- Quantify the CO_2 sequestration potential of coals in the Black Warrior coalbed methane fairway, where two coal-fired power plants operate adjacent to a thriving coalbed methane industry.
- Apply the screening model to identify sites favorable for demonstration of enhanced coalbed methane recovery and mass sequestration of CO_2 emitted from coal-fired power plants in this basin of Alabama.

Conclusion

Coalbed methane formations in the upper Pottsville Formation of the Black Warrior basin are extremely heterogeneous, and this heterogeneity must be considered to screen areas for the application of CO_2 sequestration and enhanced coalbed methane recovery technology. Major screening factors include stratigraphy, geologic structure, geothermics, hydrogeology, coal quality, sorption capacity, technology, and infrastructure. Applying the screening model to the Black Warrior basin indicates that geologic structure, water chemistry, and the distribution of coal mines and reserves are the principal determinants of where CO_2 can be sequestered. By comparison, coal thickness, temperature-pressure conditions, and coal quality are the key determinants of sequestration capacity and the quantity of coalbed methane that can be accessed through enhanced recovery operations.

Upper Pottsville coal beds are preserved in a series of flooding-surface-bounded depositional cycles of fluvial-deltaic origin that span 1,500 to more than 4,000 feet of section. More than 20 coal beds have been completed in some wells. Coal beds as thin as 1 foot are commonly completed, and net completable coal thickness ranges from about 10 to more than 70 feet.

Because coal and coalbed methane resources are dispersed widely through a thick section, multiple zone technology will need to be developed and applied to realize the potential of upper Pottsville strata for CO_2 sequestration and enhanced coalbed methane recovery.

Compressional folds and extensional faults are abundant in the Black Warrior basin, and these structures have a significant effect on the production performance of coalbed methane wells. Normal faults are major reservoir discontinuities, and trans-stratal fracture systems associated with these faults pose potential leakage risks. Therefore, CO_2 sequestration and enhanced recovery operations should avoid fault zones. Strata-bound joint and cleat systems are developed between the fault zones, and these fracture systems tend to favor the development of reservoir compartments around individual coal zones that favor bed-parallel flow over crossformational flow.

Permeability, water chemistry, and temperature-pressure conditions are the key hydrologic and geothermal variables to be considered when screening coalbed methane formations. Permeability-depth relationships in the Pottsville Formation favor sequestration and enhanced recovery efforts in coal shallower than 2,000 feet. Water chemistry is a fundamental control on where sequestration technology can be applied because of UIC regulations. Fresh-water plumes along the southeast margin of the Black Warrior basin contain water with TDS content less than 3,000 mg/L, and current UIC regulations prohibit underground injection into water that fresh. Most of the coalbed methane fields contain water with 3,000 to 10,000 mg/L TDS, and an aquifer exception can be obtained to facilitate enhanced hydrocarbon recovery programs (Class II UIC). Water with TDS content higher than 10,000 mg/L is common in some of the southwestern coalbed methane fields, and in these areas, CO_2 can be injected into coal without enhanced hydrocarbon recovery (Class I UIC).

Coalbed methane formations in the Black Warrior basin are normally pressured to underpressured, and geothermal gradients are generally between 8 and 15°F per 1,000 feet. Temperature correlates negatively and significantly with the sorption capacity of coal and must therefore be considered in regional estimates of sequestration capacity. Reservoir pressure has been depleted by prolonged dewatering associated with coalbed methane production. Beyond a depth of 2,480 feet, CO_2 will become a supercritical fluid if the reservoir returns to a normal hydrostatic pressure gradient. Supercritical CO_2 can weaken and react with coal, and rapid volumetric changes at the critical point raise some concerns about reservoir integrity and wellbore integrity. However, coal has stored supercritical CO_2 under natural conditions over geologic time.

The most important coal quality parameters determining how much gas can be stored in coal are ash content and rank. Ash content correlates negatively with sorption capacity, but the utility of ash content for regional assessment of sequestration and enhanced recovery potential is limited because ash data are too variable to predict between data points. Coal rank correlates highly with gas sorption capacity and is a regionalized variable that can be projected between data points with confidence. For these reasons, rank and reservoir temperature are key variables required to quantify the sequestration potential of coalbed methane formations in the Black Warrior basin.

The sorption capacity per unit weight of coal in the Black Warrior coalbed methane fairway is influenced strongly by rank and reservoir temperature, whereas the sorption capacity per unit area of coal in the upper Pottsville Formation is influenced strongly by coal thickness. At 100 to 350 psi, upper Pottsville coal can adsorb between 250 and 700 scf/t and between 5 to 80 MMcf/ac of CO_2 on an as-received basis. Estimated at a modest pressure of 50 psi, unswept coalbed methane resources range from 40 to 100 scf/t and 1 to 7 MMcf/ac.

Numerous technological and infrastructural variables must be examined to screen areas for CO_2 sequestration and enhanced coalbed methane recovery. Critical variables for the Black Warrior coalbed methane fairway include proximity to coal-fired power plants, the design and maturity of coalbed methane fields, and pipeline infrastructure. Identifying the locations of underground coal mines, coal reserves, unplugged core holes, and communities are also important components of a screening strategy. Two coal-fired power plants are at the northern margin of the coalbed methane fairway, and a new plant is planned for the central part of the fairway. Most of the fairway is reaching maturity, although infill drilling and recompletion programs in some fields limit where demonstration and enhanced recovery programs should be sited. Coal mines and coal reserves are scattered through the northern part of the coalbed methane fairway and should be protected from sequestration activities.

Coal-fired power plants serving the Black Warrior basin in Alabama emit approximately 31 MMst (2.4 Tcf) of CO_2 annually. The total sequestration capacity of the Black Warrior coalbed methane fairway at 350 psi is about 189 MMst (14.9 Tcf), which is equivalent to 6.1 years of greenhouse gas emissions from the coal-fired power plants. Applying the geologic screening model indicates that significant parts of the coalbed methane fairway are not accessible because of fault zones, coal mines, coal reserves, and formation water with TDS content less than 3,000 mg/L. Excluding these areas leaves a sequestration potential of 60 MMst (4.7 Tcf), which is equivalent to 1.9 years of emissions. Therefore, if about 10 percent of the flue gas stream from nearby power plants is dedicated to enhanced coalbed methane recovery, a meaningful reduction of CO_2 emissions can be realized for nearly two decades. If the fresh-water restriction were removed for the purposes of CO_2 sequestration, an additional 10 MMst (0.9 Tcf) of CO_2 could feasibly be sequestered. The amount of unswept coalbed methane in the fairway is estimated to be 1.49 Tcf at a pressure of 50 psi. Applying the screening model results in an accessible unswept gas resource of 0.44 Tcf. Removal of the fresh-water restriction would elevate this number to 0.57 Tcf. If a recovery factor of 80 percent can be realized, then enhanced recovery activities can result in an 18 percent expansion of coalbed methane reserves in the Black Warrior basin.

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COST

Total Project Value
$1,398,068

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$ 789,565 / $ 608,503

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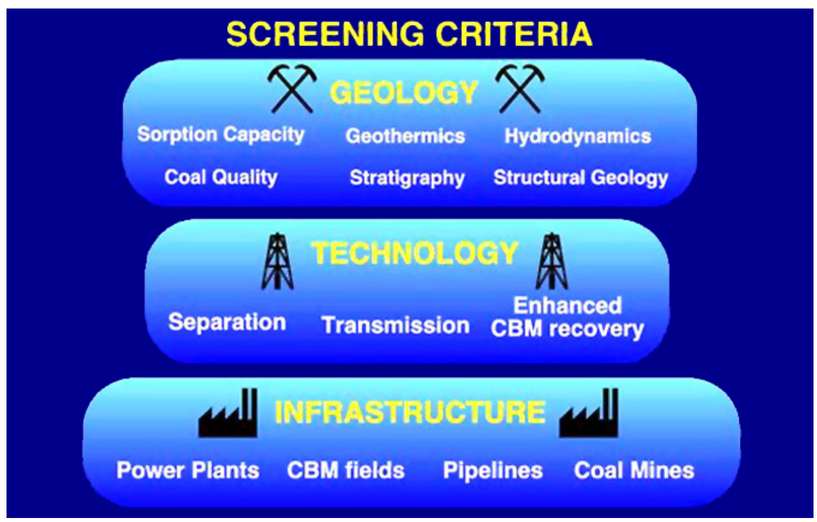
Results of this investigation indicate that the potential for CO_2 sequestration and enhanced coalbed methane recovery in the Black Warrior basin is substantial and can result in significant reduction of greenhouse gas emissions while increasing natural gas reserves. Application of the geologic screening model to the Black Warrior coalbed methane fairway indicates that sequestration and enhanced recovery operations are possible in nearly all coalbed methane fields, and the only areas that appear to be technically infeasible within those fields are areas with coal reserves and fault systems. Future work should focus on the development and implementation of demonstration programs that focus on determination of optimal CO_2 injection rates, quantification of sequestration and enhanced gas recovery efficiency, and monitoring and verification of sequestration activities.

Benefits

The developed screening model will provide a widely applicable tool for evaluating potential geological sites for sequestration of CO_2. Ultimately, this project will result in sequestration of CO_2 and enhanced methane recovery from unmineable coalbeds. The technology results of the project will be transferred to the public, academia, and industry for application toward ultimate commercialization of sequestration technologies.



Variables that will be used to develop the screening model.