CO_2 Sequestration in Thin and Shallow Coal Beds: Eastern Kansas

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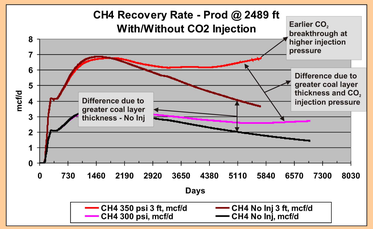
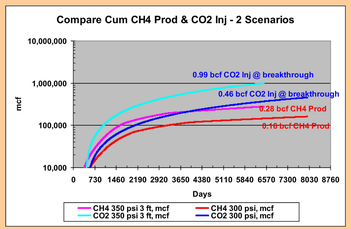
Effect of Thicker Coal Beds & Higher CO_2 Injection Pressure
1 Injector & 4 Distant Producers (640 acres)
Coal bed thickness 3 ft, CO_2 Injection @ 350 psi

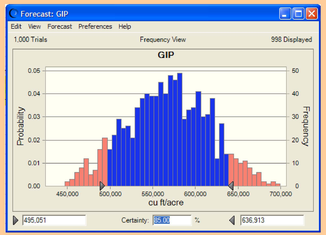




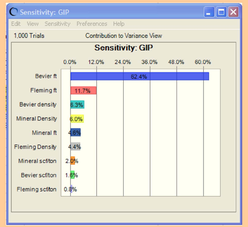
In this vicinity of eastern Kansas, coal beds greater than 3 ft have rarely been mapped. Thus, the maximum expected thickness of the three coal beds was assumed to be 3 ft.

For a distant producer (2489 ft away from injector), CH_4 production rate is higher when no CO_2 is injected. When injection pressure increases, CO_2 breakthrough occurs earlier at the producing wells resulting in sooner shut-in. However, more CO_2 is sequestered in the 640 acres and more CH_4 gets produced over a shorter time interval when beds are thicker and injection pressures are higher.

MONTE CARLO SIMULATION



Given known variations in thickness, scf/ton, and coal density, the GIP (gas in place) in 3 major coal beds (Bevier, Fleming, and Mineral) is approximated (with 85% confidence) to be between 0.5 to 0.64 mmcf/acre in the area around the Johnson County Landfill.



A Tornado chart reveals that the thickness of the Bevier coal plays a dominant role in determining total GIP of underlying coal beds.

Based on 4 Producers & 1 Injector (640 acres, 350 psi)
CH_4 RF = 28.1 %
CO_2 sequestered = 4.3 times

Around Johnson County Landfill area, based on the performance of 1 central Injector and 4 far-off Producers (2489 ft) located on 640 acres, it is estimated that

A) between 0.14 to 0.18 mmcf of ECBM can be recovered per acre, while

B) sequestering between 0.6 to 0.77 mmcf of CO_2 per acre.

CONCLUSIONS

1. Thin (≈5 ft) unmineable coal beds in eastern Kansas can sequester around 0.39 bcf of CO_2 in 640 acres over 20-years. Over the same period, sequestration results in CH_4 production varying between 0.09 and 0.13 bcf.

2. When the distance between injector and producer well is small (≈ 1200 ft), CO_2 injection results in immediate enhancement of CH_4 production rate followed by CO_2 breakthrough resulting in shutting down of the producer.

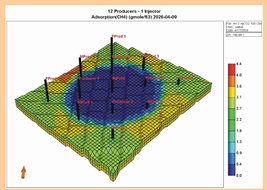
3. When the distance between injector and producer well is large (≈ 2500 ft), the enhancement in CH_4 production rate is delayed and so is the CO_2 breakthrough resulting in sequestration of significant volumes of CO_2.

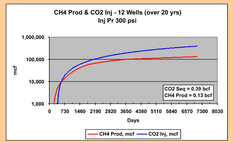
4. CH_4 recovery is maximized in absence of CO_2 injection because producing wells do not need to be shut down due to CO_2 breakthrough.

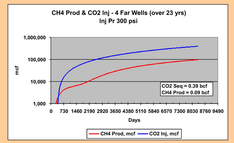
5. For effective CO_2 sequestration, production wells are critical to mobilizing desorbed CH_4 from the coal resulting in adsorption of CO_2 and preventing in the increase of cleat (fracture) pressure.

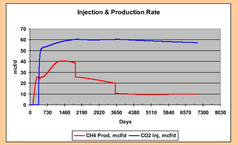
6. Initial estimates show that thin coal beds modeled in this study have the potential to sequester between 0.6 to 0.77 mmcf of CO_2 per acre while resulting in the production of 0.14 to 0.18 mmcf of CH_4.

CO_2 Sequestration Potential - 4 Distant Producers vs. 12 Producers at Varying Distances (in 640 acres)
CO_2 Injection Pressure = 300 psi, Wells shut-in when 3% CO_2









SEQUESTRATION POTENTIAL OF THIN UNMINEABLE COAL BEDS
- over 20 years

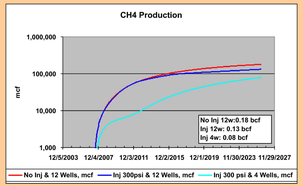
Volume of CO_2 sequestered - 0.39 bcf
- Independent of whether there are 4 or 12 producers
- Less expensive to drill 12 wells as compared to 4

However, CH_4 recovery maximized when there are 12 producing wells
- 12 wells - 0.13 bcf CH_4 produced in less than 20 years
  - before 3% CO_2 breakthrough
- 4 wells - 0.09 bcf CH_4 produced in around 23 years
  - before 3% CO_2 breakthrough

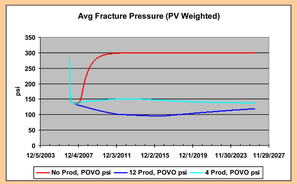
Uncertainties related to sequestration and ECBM potential.

Each evaluation is case specific because simulation results are significantly influenced by the following:
- Cleat Permeability, Porosity, Spacing
- Fracture pressure of coals (depth)
- Coal thicknesses and Adsorption Isotherms
- Palmer and Mansoori Parameters
  - data often unavailable
- Permeability asymmetry

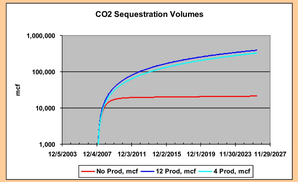
OTHER ASPECTS RELATED TO CO_2 SEQUESTRATION IN COALS



In thin coal seams, the maximum amount of CH_4 recovery takes place when there is no CO_2 injection and there are 12 producers. The CH_4 recovery is less when CO_2 is injected because producing wells have to be shut-in when CO_2 percentage in the gas exceeds 3% (or some other % limit set by the pipeline companies). Effects of CO_2 injection on enhanced CH_4 production from distant producers is obviously delayed.



When CO_2 is injected in a coal beds that are contained in a bounded no-flow volume (inside the simulator), the fracture pressure in the coals increase over time if there are no producing wells located away from the injector. This pressure increase is expected to happen in the field where there are no physical no-flow boundaries because the mobility of the injected CO_2 is limited by the cleat permeability and the hydrostatic pressure in the cleat system prevalent all around the injector.



Increases in cleat (fracture) pressure due to CO_2 injection reduces the injectivity of the CO_2. CO_2 injection is enhanced if it can displace (dislodge) the CH_4 adsorbed in the coal beds, and CH_4 will be mobilized only when it is able to desorb from the coal bed as a result of lowering of cleat pressure by dewatering surrounding producing wells. Thus, surrounding CH_4 production wells are needed for successful CO_2 sequestration in coal beds.

ACKNOWLEDGEMENTS

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