



## Economics of CCS

AAPG 2011 Annual Convention & Exhibition

April 12, 2011

Gürcan Gülen, Ph.D., Senior Energy Economist

## CCS Projects

- ~50 CCS projects globally that can store 200,000 tons of CO<sub>2</sub> per day (e.g., Sleipner, Weyburn).
- Only a dozen are operational, storing about 20,000 tons.
- ~100 projects are in various stages of planning.
- One recent study estimated potential emission reductions from CCS at 23 GtCO<sub>2</sub> by 2030, roughly half of emissions worldwide in 2004.

## Costly Endeavor

- Estimates for early projects were \$100-\$300 per ton of CO<sub>2</sub> avoided; current estimates \$40-60.
- A recent NETL report: \$17-145 per ton capture costs at retrofitted coal plants.
- The most expensive is capture equipment.
- Operational costs are also large (up to \$15 per ton).

## Other Cost Considerations

- The “energy penalty” could reduce plant efficiency by as much as 40%.
- Pipeline costs are small but dependent on distances & path between sources & sinks.
- Storage costs are much lower than capture but depend on geology of the sinks.
- Offshore CCS projects cost 30-50% more than comparable onshore projects.

## Impact on Electricity Price

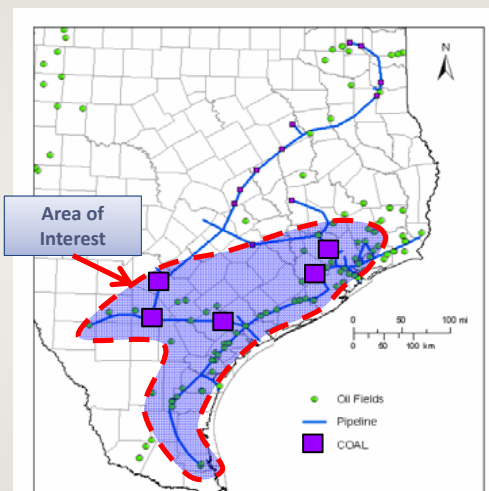
- Capture would add ~1.8-3.4 ¢/kWh to cost of electricity from a pulverized coal plant (0.9-2.2 ¢/kWh from an IGCC plant).
- The transport and storage of CO<sub>2</sub> would add up to 1 ¢/kWh to the cost.

## CO<sub>2</sub>-EOR

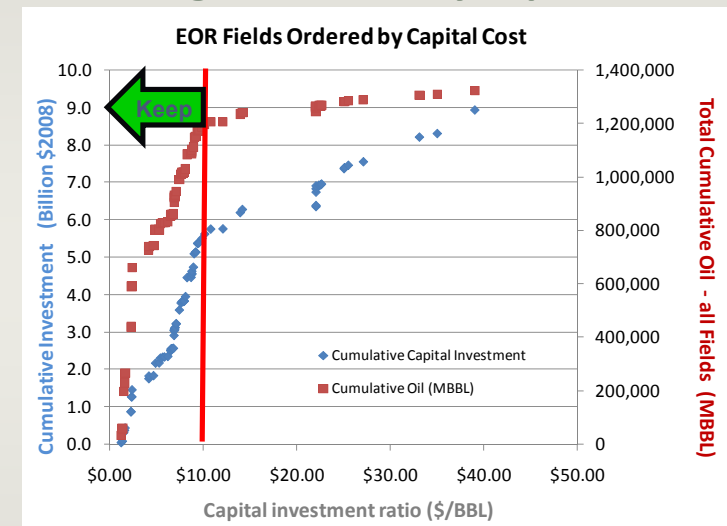
- The U.S. oil industry has injected over 600 million tons of CO<sub>2</sub> for EOR
  - currently producing ~250,000 bbl/d.
- CO<sub>2</sub>-EOR projects onshore break even at \$60-80/barrel for \$100-200 per ton of CO<sub>2</sub>.
- Offshore projects require 20-30% higher prices.
- Breakeven+20-30% return is necessary.

## BEG Research

- 5 coal power plants
- 31 oil reservoirs for CO<sub>2</sub> EOR
- Connected via a pipeline network
- Up to 20 MtCO<sub>2</sub>/yr CO<sub>2</sub> needed for 20 yrs



## Screening EOR fields by capital cost



## Results Consistent with Literature

- Reference case (3 coal plants, 22 fields) assumes 20% internal rate of return (IRR) for all three industries (capture, pipeline, EOR)
  - \$55/tCO<sub>2</sub> ; \$56/BBL ; \$0.065/tCO<sub>2</sub>
- Catch? EOR operators won't pay that much for CO<sub>2</sub>
  - Historically:  $\frac{\$/tCO_2}{\$/BBL} < 0.3$ 
    - At \$56/BBL → 20 \$/tCO<sub>2</sub> → 34% IRR for reference case
  - EISA 2007 already provides \$10/tCO<sub>2</sub> for EOR
  - Texas has tax credits for anthropogenic CO<sub>2</sub>-EOR

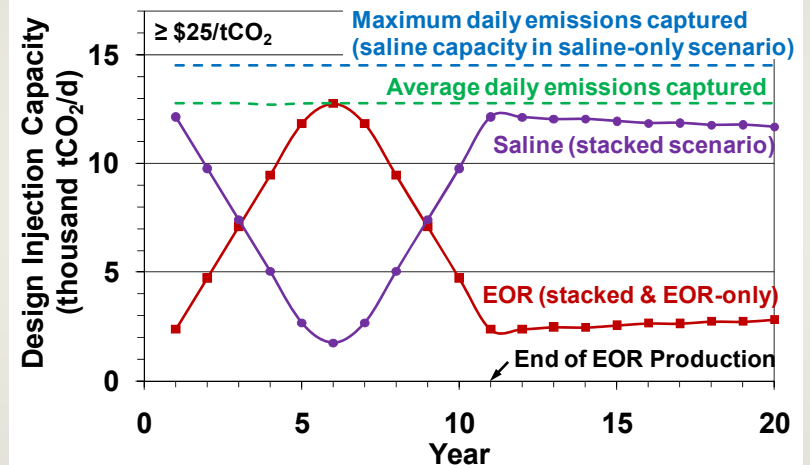
## More Recent BEG Research

- Single coal unit, pipeline, EOR field, and saline reservoir (1:1)
- Coal unit - 613 MW rated capacity (490 MW average available)
  - Amine scrubbing for capture removes 90% of CO<sub>2</sub> but reduces available capacity to 360 MW

## Assumptions

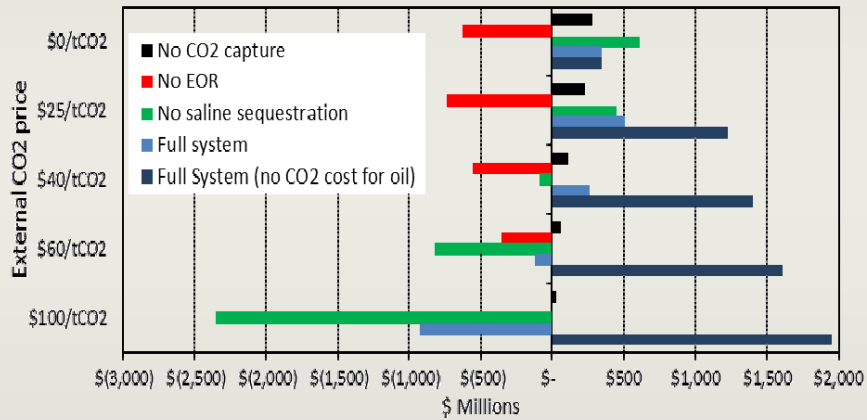
- 20-year net present value (NPV) of the system is calculated for several CO<sub>2</sub> prices
- Commodity prices
  - Fuel prices constant for all studies: \$70/BBL Oil, \$6.6/MMBTU NG, \$1.5/MMBTU coal
  - CO<sub>2</sub> price is constant in each 20-year analysis
  - Electricity price changes with CO<sub>2</sub> price according to merit order dispatch model

## Design Injection Capacity Depends on the CCS Scenario



## More Recent BEG Research

Net Present Value: 1 coal plant, pipeline, and Conroe as EOR+saline location



## Public Funding & Guarantees May Be Necessary

- In 2011 budget, \$500 million is dedicated to advanced coal climate change technologies, including CCS
- Cost of measurement, monitoring and verification?
- Public opposition?
- Subsurface ownership rights and liability in case of escaping emissions?