Economics of CO_2 Capture and Storage (CCS)*

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Abstract

Any scenario on emissions reduction invariably includes CO_2 capture and storage (CCS) in coal-fired plants. There are about 50 CCS projects globally that can store 200,000 tons of CO_2 per day; however, only a dozen are operational, storing about 20,000 tons. About 100 projects are in various stages of planning. One recent study estimated potential emission reductions from CCS at 23 GtCO_2 by 2030, roughly half of emissions worldwide in 2004. But CCS projects are expensive. Estimates for early projects are \$100-\$300 per ton of CO_2 avoided (existing projects reportedly cost \$400 per ton). The most expensive is capture equipment. A recent NETL report estimated capture costs for retrofitted coal plants at \$17-145 per ton. Operational costs are also large. The "energy penalty" could reduce efficiency of power plants by as much as 40%. Pipeline transportation and storage costs are typically much less than the capture costs but dependent on distances and topography between sources and sinks, and geology of the sinks. Overall, operational costs of CCS projects could be as much as \$15 per ton. Offshore CCS projects cost 30-50% more than comparable onshore projects.

These high costs can be mitigated by some revenue streams. First, pure CO_2 and byproducts of the capture process could be marketed. Second, CO_2 can be used in enhanced oil recovery (EOR) projects. The U.S. oil industry has injected over 600 million tons of CO_2, and currently produces about 250,000 barrels of oil per day via EOR. In general, CO_2-EOR projects onshore are considered to break even at \$60-80/barrel for \$100-200 per ton of CO2. A recent study by BEG researchers mostly confirmed these figures for the Texas Gulf Coast. Offshore projects require 20-30% higher prices. Third, avoidance of carbon taxes or the sale of emission permits, if such regulation exists, will add value. Still, CCS projects will likely require public funds to be viable. In the proposed budget of the U.S. for 2011 about \$500 million is dedicated to advanced coal climate change technologies, including CCS. If CCS is part of a mandate, a major unknown is cost of measurement, monitoring and verification. Also, public opposition can hamper CCS projects. Uncertainty over subsurface ownership rights and liability in case of escaping emissions influence this opposition. Our treatment of the myriad issues and analysis is set within the context of CO_2 "road-mapping" and potential value chain considerations for full cycle development.

CEE CENTER FOR ENERGY ECONOMICS

Bureau of Economic Geology,
The University of Texas at Austin

Economics of CCS

AAPG 2011 Annual Convention & Exhibition

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CCS Projects

- ~50 CCS projects globally that can store 200,000 tons of CO_2 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 $GtCO_2$ by 2030, roughly half of emissions worldwide in 2004.

Costly Endeavor

- Estimates for early projects were \$100-\$300 per ton of CO_2 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_2 would add up to 1 ¢/kWh to the cost.

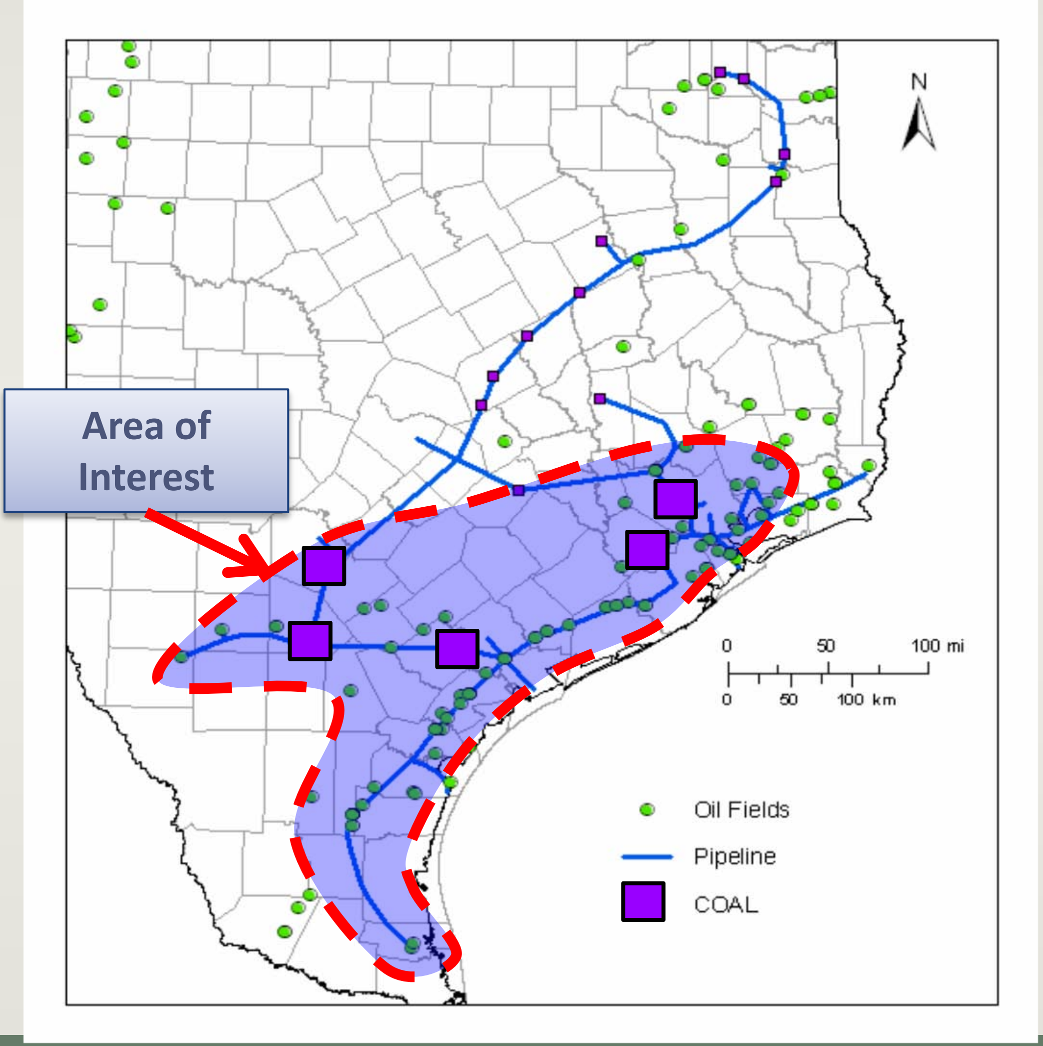
Source: International Panel on Climate Change report 2007, p.343

CO2-EOR

- The U.S. oil industry has injected over 600 million tons of CO_2 for EOR
  - currently producing ~250,000 bbl/d.
- CO_2-EOR projects onshore break even at \$60-80/barrel for \$100-200 per ton of CO_2.
- Offshore projects require 20-30% higher prices.
- Breakeven+20-30% return is necessary.

BEG Research

- 5 coal power plants
- 31 oil reservoirs for CO_2 EOR
- Connected via a pipeline network
- Up to 20 $MtCO_2$/yr CO_2 needed for 20 yrs



King, C., Gülen, G., Essandoh-Yeddu, J. and Hovorka, S. "Economic Analysis of an Integrated Anthropogenic Carbon Dioxide Network for Capture and Enhanced Oil Recovery along the Texas Gulf Coast," Paper ES2009-90415, *Proceedings of the ASME 3rd International Conference on Energy Sustainability*, San Francisco, CA, July 19-23, 2009.

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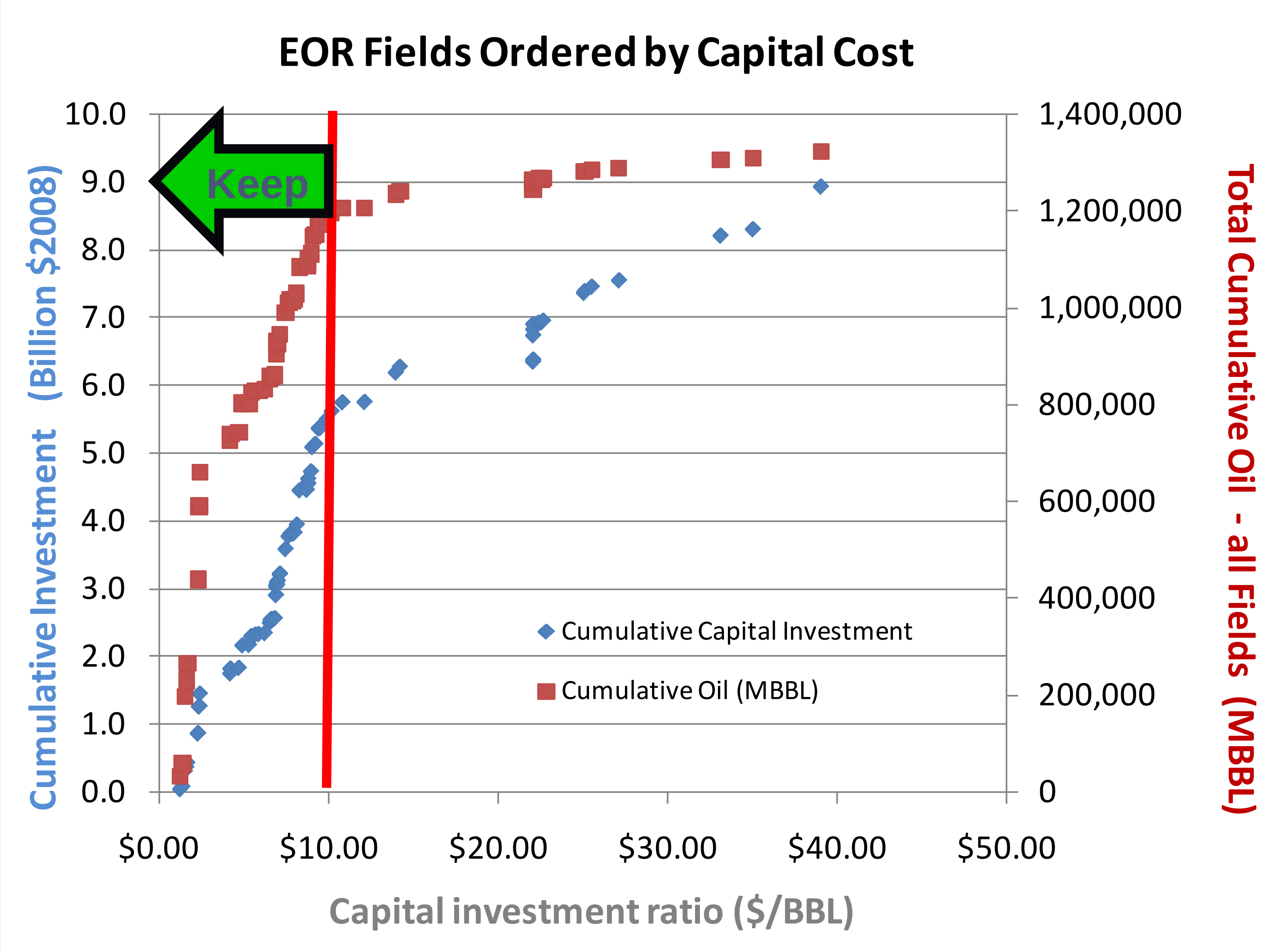
Screening EOR fields by capital cost



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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_2 ; \$56/BBL ; \$0.065/tCO_2**
- Catch? EOR operators won't pay that much for CO_2
  - Historically: $$\frac{\$/tCO_2}{\$/BBL} < 0.3$$
    - At \$56/BBL → 20 \$/tCO2 → 34% IRR for reference case
  - EISA 2007 already provides \$10/tCO_2 for EOR
  - Texas has tax credits for anthropogenic CO_2-EOR

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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_2 but reduces available capacity to 360 MW

King, C., Coleman, S., Cohen, S., Gülen, G. "The economics of an integrated CO_2 capture and sequestration system: Texas Gulf Coast case study." *Proceedings of the 10th International Conference on Greenhouse Gas Technologies*, Amsterdam, The Netherlands, September 19-23, 2010.

Notes by Presenter:

- as an initial study, we just considered a single CCS value train in our system
- also looked at various scenarios
  - No CCS means no capture at the generating unit, so no trans/storage
  - stacked storage means that there is geology suitable for EOR and saline injection at different depths at the same site. Generally, EOR uses a fraction of the captured CO2 and the remaining CO2 is injected into saline. This config is desirable because it provides flexibility to handle variable CO2 flows from the power plant at injection site
  - saline only assumes no EOR available (details later)
  - EOR only assumes no saline available (details later)

Assumptions

- 20-year net present value (NPV) of the *system* is calculated for several CO_2 prices
- Commodity prices
  - Fuel prices constant for all studies: $70/BBL Oil, $6.6/MMBTU NG, $1.5/MMBTU coal
  - CO_2 price is constant in each 20-year analysis
  - Electricity price changes with CO_2 price according to merit order dispatch model

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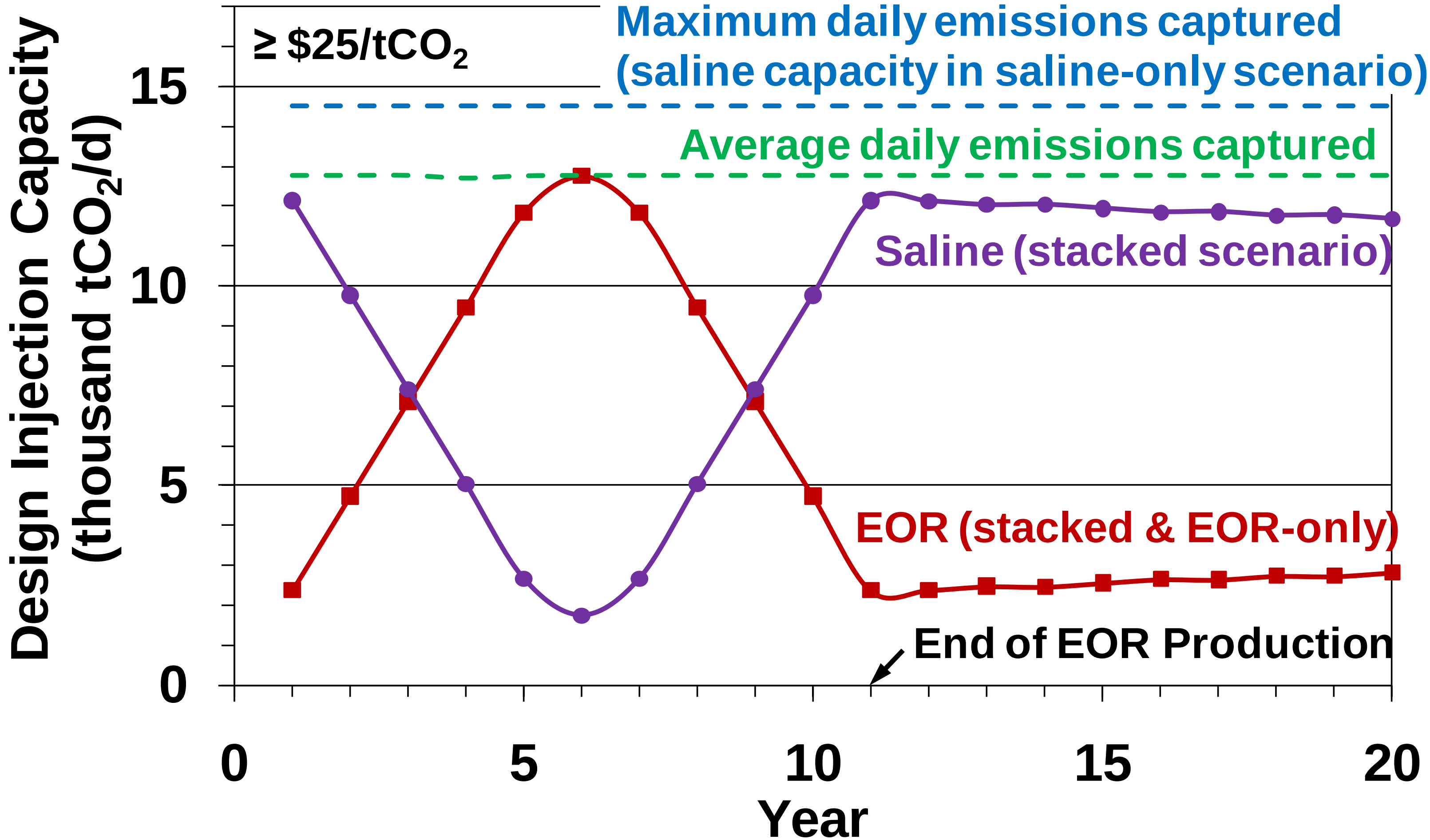
Design Injection Capacity Depends on the CCS Scenario



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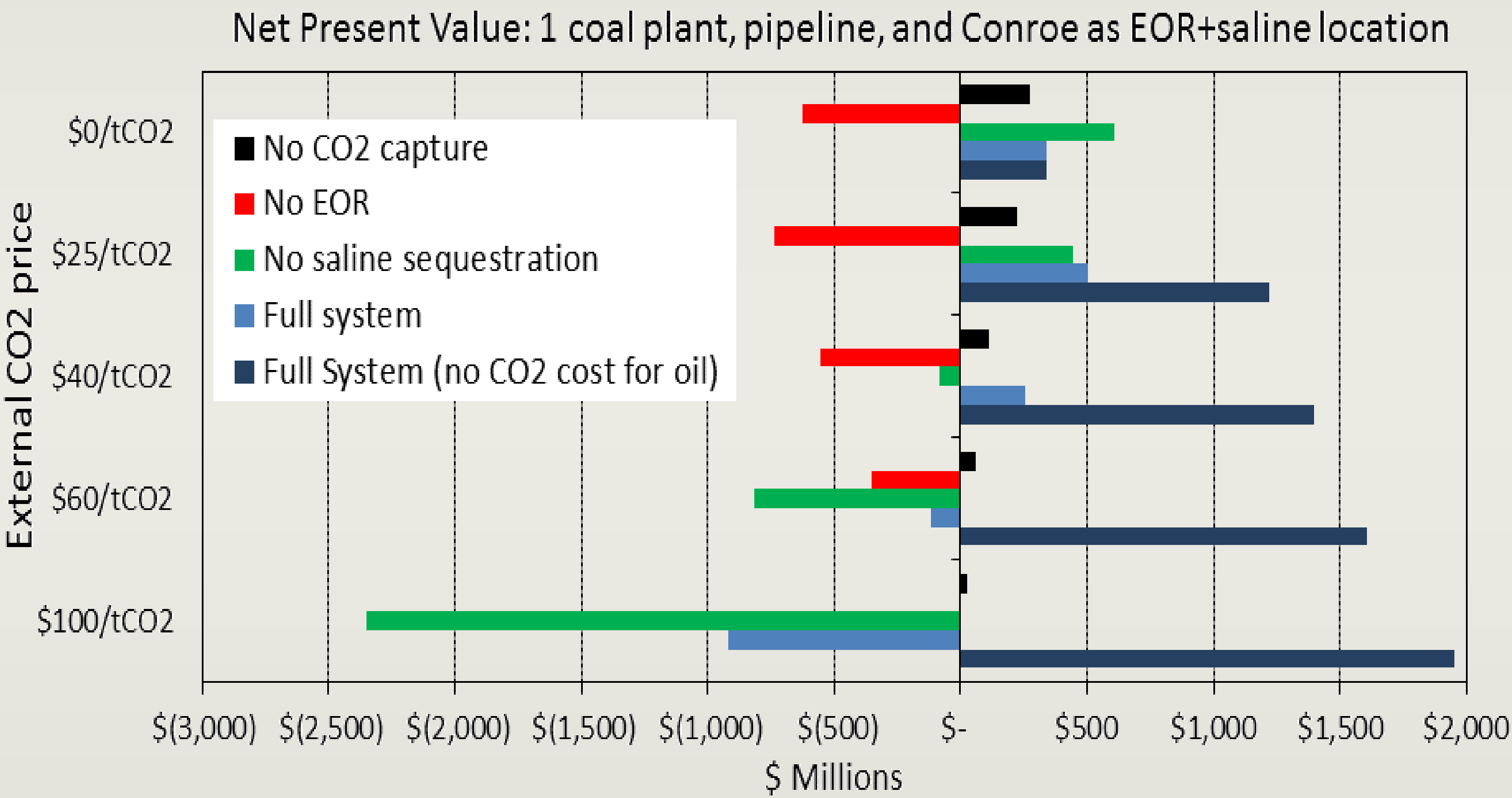

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Public Funding & Guarantees May Be Necessary

- 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?