

Modeling the Cost of Onshore CO₂ Pipeline Transport and Onshore CO₂ Saline Storage

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Background

- CCS is an essential technology for reducing carbon emissions for fossil fuels and moving the U.S. economy toward Net Zero greenhouse gas emissions
- DOE's Office of Fossil Energy and Carbon Management (FECM) and the National Energy Technology Laboratory (NETL) must understand the cost of CO₂ capture, transport and storage
- NETL has developed two Excel-based technoeconomic models
 - FECM/NETL CO₂ Transport Cost Model (CO₂_T_COM) for CO₂ pipeline transport
 - FECM/NETL CO₂ Saline Storage Cost Model (CO₂_S_COM)
- These two models are the focus of this talk
- Two additional tools will be briefly described as well
 - Reduced order costs for CO₂ saline storage for use in energy market models
 - NRAP/SMART Technoeconomic and Liability Evaluation for Storage (TALES) model

CO₂_T_COM: Description

- Technoeconomic model for a single pipeline transporting CO₂ as a liquid
- Pipeline capital costs based on natural gas pipeline capital costs
 - Provides regression equations for natural gas pipeline capital costs from four different researchers
 - Equations depend on length and standard diameter of pipe
 - Factor provided to adjust costs since CO₂ pipelines operate at higher pressures than natural gas pipelines and require thicker pipe walls
- Costs provided for pumps placed along the pipeline to boost the pressure
- Assumes pipeline operator charges capture or storage facility for using pipeline
- Includes cash flows for revenues, capital costs, O&M costs and taxes
- Weighted average cost of capital (WACC) used to discount net earnings and calculate net present value (NPV) for project
- Calculates break-even price for transporting CO₂ (NPV is zero)
- Finds the combination of the number of booster pumps and standard pipe diameter that gives the lowest break-even CO₂ price

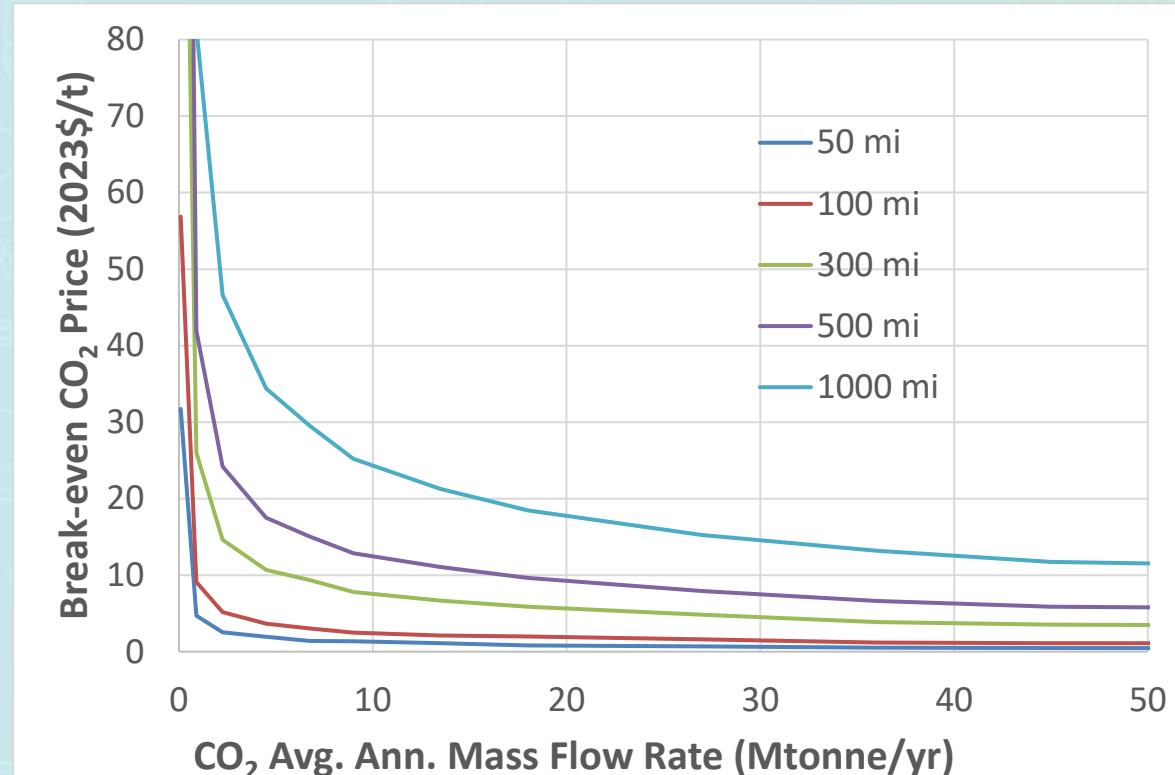
Key Inputs

- Pipeline length
- Average annual and maximum CO₂ mass flow rates
- Elevation change along pipeline
- Duration of operations

CO₂_T_COM: Example Results

- Break-even CO₂ prices provided for:
 - Different average annual CO₂ mass flow rates
 - Pipeline lengths
 - Uses natural gas pipeline capital cost equations from Brown et al. (2022)
 - Capacity factor set to 90%
 - Prices presented in 2023 dollars
- Break-even CO₂ price:
 - Decreases with increasing CO₂ mass flow rate
 - Increases with increasing pipeline length

Impact of pipeline length and average annual CO₂ mass flow rate on break-even CO₂ price.



CO2_S_COM: Description

- Technoeconomic model for a CO₂ saline storage project from the perspective of a storage project operator
- Includes geologic database for 314 potential storage formations in U.S.
- Includes costs for all aspects of a CO₂ saline storage project such as:
 - Costs associated with site characterization and obtaining a Class VI permit
 - Costs for drilling and operating injection wells
 - Costs for roughly 50 different monitoring technologies
 - Costs associated with post-injection site care and site closure
 - Costs for implementing financial instruments to meet the financial responsibility requirements of the Class VI regulations
- Assumes storage operator charges capture facility for storing CO₂
- Calculates cash flows for revenues, capital costs, O&M costs, taxes and cost of implementing financial instruments for financial responsibility
- Calculates net earnings in nominal and discounted (present value) dollars
- Sums present values net earnings to generate the net present value (NPV) for project
- Calculates break-even price for storing CO₂ (NPV is zero)
- Can cycle through all storage formations to calculate revenues, costs, and break-even CO₂ price for each formation

Key Inputs

- Average annual and maximum CO₂ mass flow rates
- Durations of injection and PISC
- Monitoring technologies
- Financial instrument for financial responsibility

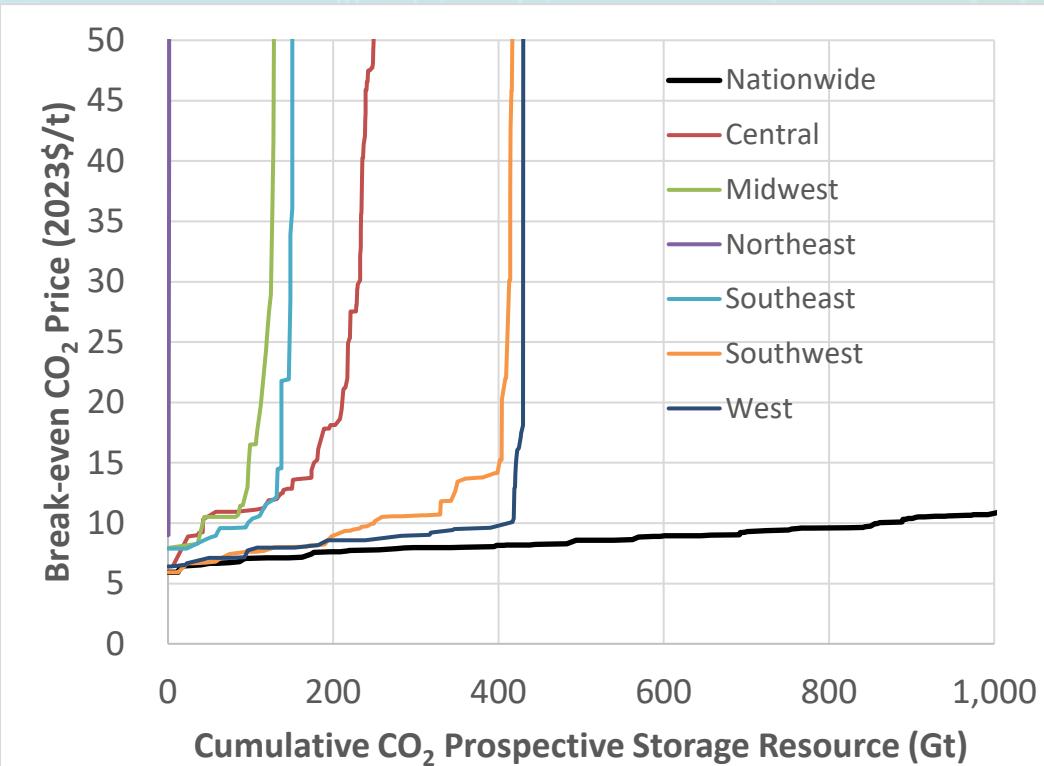
CO2_S_COM: New Features

- Expanded geologic database (228 vs. 314 saline storage formations)
- Factor that reduces CO₂ prospective storage resource for storage formation due to possible pressure interference from multiple storage projects injecting CO₂ simultaneously
- More transparent presentation of financial instruments for complying with financial responsibility requirements
- Two escalation rates with one providing the ability for real dollar analysis
- Macro-driven sensitivity analysis capability
- Custom ribbon tab to run different VBA macros
- More intuitive presentation of key input variables and key results
- Major re-factoring of spreadsheet to make calculation chain from inputs to results easier to follow and easier to validate

CO₂_S_COM: Example Results

- Cost-supply curves provided for:
 - All storage formations in US
 - Storage formations in different regions
 - Break-even CO₂ prices in 2023 dollars
 - Revenues and costs based on injection of 4.3 million tonnes (Mt) of CO₂ annually for 30 years, 50 years of PISC and trust fund for financial responsibility
 - CO₂ prospective storage resource includes factor to account for pressure interference
- Observations
 - Nationwide the CO₂ prospective storage resource is sufficient for a least a century of storage at a price of \$10/tonne
 - Some regions have limited to virtually no low-cost storage formations

Nationwide and regional cost-supply curves



Two Additional Tools

- Reduced order costs for CO₂ saline storage for use in energy market models
 - Outcome of a collaborative project between personnel from FECM HQ, Los Alamos National Laboratory (LANL) and NETL
 - Project involved comparisons between CO₂_S_COM and LANL's SCO₂T model with modifications to both models to make the calculations comparable but not the same
 - For each storage formation, costs were grouped based on when the costs are incurred, type (capital, fixed O&M, variable O&M), depreciation category and whether the costs depended on the mass of CO₂ injected
 - Grouped costs were normalized by either the number of active injection wells or the mass of CO₂ injected to generate reduced order costs
 - Reduced order costs are provided for all 314 storage formations in a spreadsheet for use in energy market models
- NRAP/SMART Technoeconomic and Liability Evaluation for Storage (TALES) model
 - TALES is being developed under the National Risk Assessment Partnership (NRAP) and the Science-informed Machine Learning to Accelerate Real Time (SMART) Decisions in Subsurface Applications
 - TALES is being developed as a collaborative effort between NETL, LANL, Pacific Northwest National Laboratory, Lawrence Livermore National Laboratory and Lawrence Berkley National Laboratory
 - Python code that will have a GUI interface within the SMART Visualization and Decision Support Platform
 - Cash flows and financial model similar to CO₂_S_COM, but TALES allows user to completely customize cost components while CO₂_S_COM has pre-defined cost components
 - TALES will utilize output from NRAP and SMART tools and provide costs to tools when needed
 - TALES will estimate the cost of remedial responses to adverse events

Availability of Models or Tools

- CO2_T_COM: 2023 version available on NREL website. Targeting the release of a new version in March 2024
<https://netl.doe.gov/energy-analysis/search?search=CO2TransportCostModel>
- CO2_S_COM: 2017 version available on NREL website (called FE/NREL CO₂ Saline Storage Cost Model). Targeting the release of a new version in spring or summer 2024
<https://netl.doe.gov/energy-analysis/search?search=CO2SalineCostModel>
- Reduced order costs for use in energy market models: Report and companion spreadsheet (2024 version) available on NREL website
<https://netl.doe.gov/energy-analysis/search?search=ReducedOrderCosts>
- NRAP/SMART Technoeconomic and Liability Evaluation for Storage (TALES) model is under development with a target date for alpha version at end of April 2024 (most likely on NRAP Gitlab site)

Disclaimer

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Questions?

Thank you.

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