Onshore CO_2 Transport and Storage Technoeconomic Models

Presented by:
David Morgan, Physical Scientist, SSAE
Alana Sheriff, Subsurface Engineer, SSAE

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Background

- Objectives
  - Develop screening-level models in Excel that estimate the revenues, costs and financial performance for a pipeline transporting liquid CO_2 and a CO_2 saline storage project
  - Models must be able to handle a wide range of inputs such as varying CO_2 mass flow rates, operational time periods and financial variables
- Project history
  - Initial versions were internal to NETL
  - First public releases were in 2014
  - FECM/NETL CO_2 Transport Cost Model (CO2_T_COM) had a major upgrade in 2023 and will have another release soon (August 2024)
  - FE/NETL CO_2 Saline Storage Cost Model had a major upgrade in 2017
    - Major release planned for September 2024
- Relevance
  - CO_2 pipeline transport and CO_2 saline storage are critical elements in the CCS value chain
  - FECM and NETL need to understand the costs of transporting CO_2 by pipeline, storing CO_2 in saline formations and the factors that drive these costs

CO2_T_COM Description

- Technoeconomic model for a single pipeline transporting CO_2 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 CO_2 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
- Financial model:
  - Given a price for CO_2, model calculates cash flows for revenues
  - Model depreciates capital costs and calculates taxes
  - Model calculates earnings (in nominal dollars) as revenues minus the sum of capital cots, O&M costs and taxes
  - Model uses the weighted average cost of capital (WACC) to discount earnings to present value dollars
  - Sums the earnings in present dollars to generate the net present value (NPV) for project
- Calculates break-even price for transporting CO_2 (NPV is zero)
- Finds the combination of the number of booster pumps and standard pipe diameter that gives the lowest break-even CO_2 price

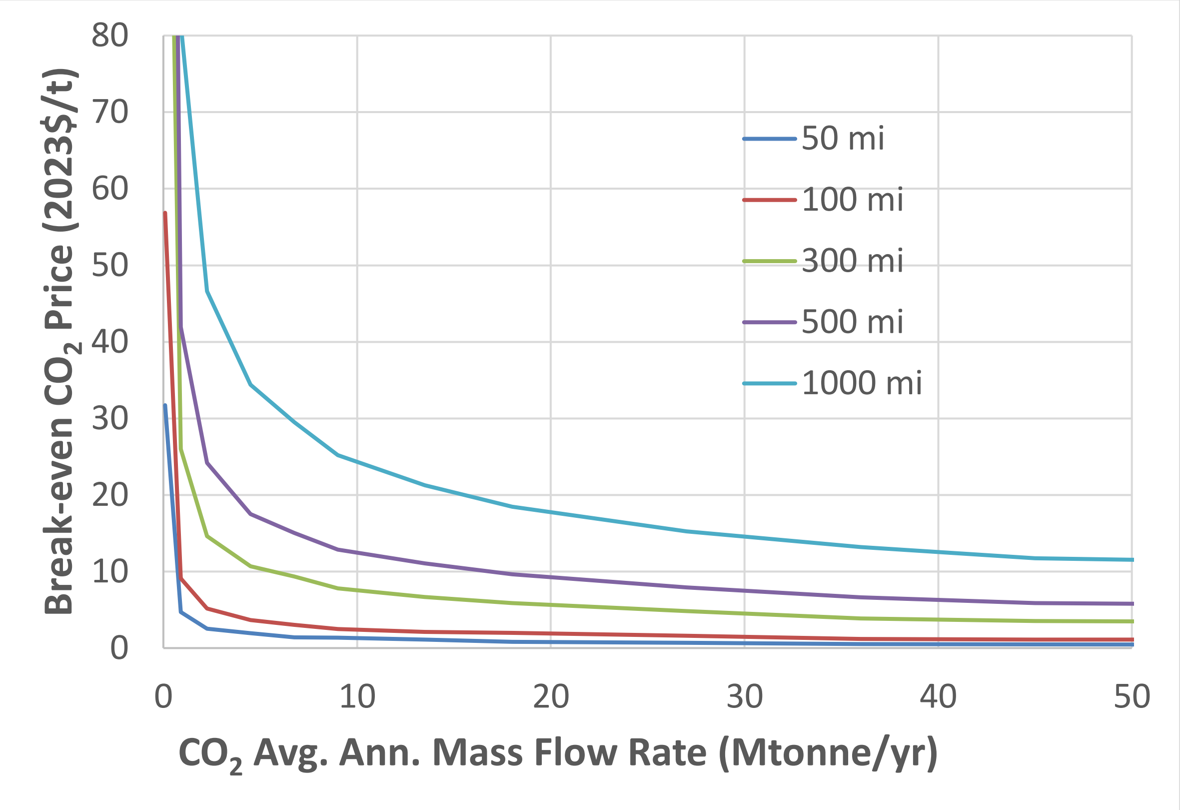
Key Inputs

- Pipeline length
- Average annual and maximum CO_2 mass flow rates
- Elevation change along pipeline
- Duration of operations

CO2_T_COM Example Results

- Break-even CO_2 prices provided for:
  - Different average annual CO_2 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 CO_2 price:
  - Decreases with increasing CO_2 mass flow rate
  - Increases with increasing pipeline length

Impact of pipeline length and average annual CO_2 mass flow rate on break-even CO_2 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 CO_2
- Calculates cash flows for revenues, capital costs, O&M costs, taxes and cost of implementing financial instruments for financial responsibility
- Calculates earnings in nominal and discounted (present value) dollars
- Sums present value earnings to generate the net present value (NPV) for project
- Calculates break-even price for storing CO_2 (NPV is zero)
- Can cycle through all storage formations to calculate revenues, costs, and break-even CO_2 price for each formation

Key Inputs

- Average annual and maximum CO_2 mass flow rates
- Durations of injection and PISC
- Monitoring technologies
- Financial instrument for financial responsibility

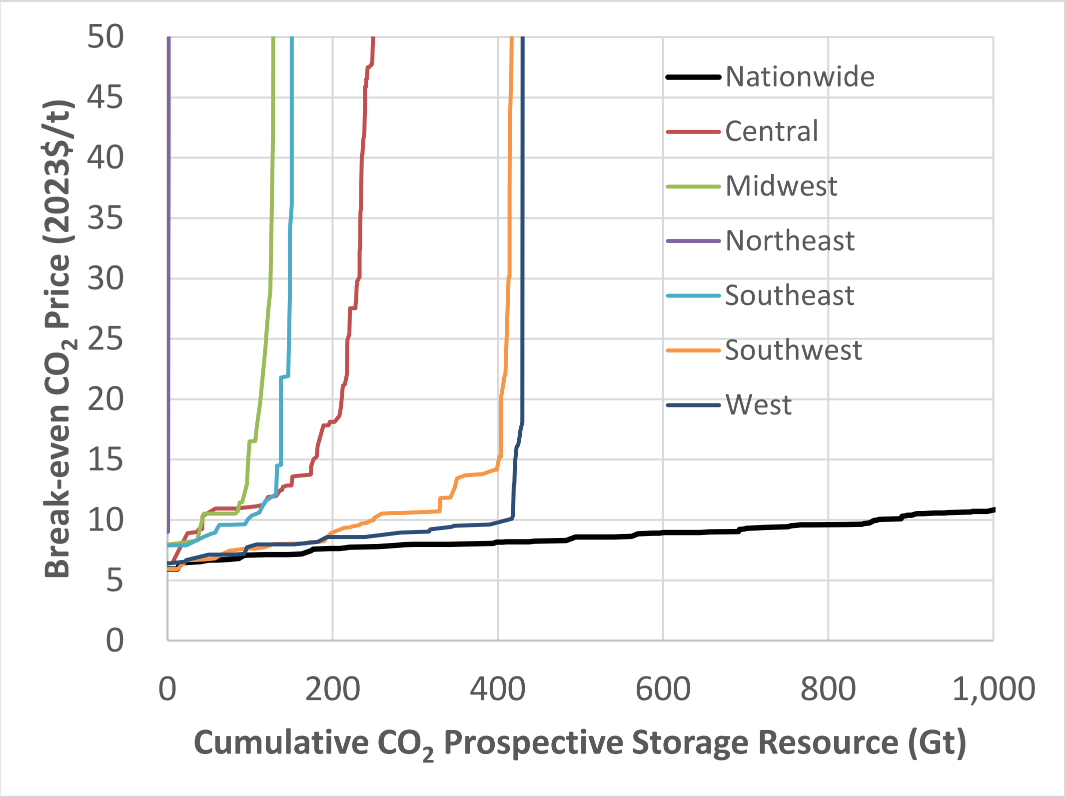
CO2_S_COM New Features

- Expanded geologic database (228 vs. 314 saline storage formations)
- Factor that reduces CO_2 prospective storage resource for storage formation due to possible pressure interference from multiple storage projects injecting CO_2 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 CO_2 prices in 2023 dollars
  - Revenues and costs based on injection of 4.3 million tonnes (Mt) of CO_2 annually for 30 years, 50 years of PISC and trust fund for financial responsibility
  - CO_2 prospective storage resource includes factor to account for pressure interference
- Observations:
  - Nationwide the CO_2 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 CO_2 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 CO_2 injected
  - Grouped costs were normalized by either the number of active injection wells or the mass of CO_2 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 NRAP and SMART projects
  - Python code that was discussed in a talk on Tuesday as part of the SMART program

Availability of Models or Tools

- CO2_T_COM: 2023 version available on NETL website. A new version should be released soon
  https://netl.doe.gov/energy-analysis/search?search=CO2TransportCostModel
- CO2_S_COM: 2017 version available on NETL website (called FE/NETL CO_2 Saline Storage Cost Model). Targeting the release of a new version in fall 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 NETL 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 soon
  - If interested in downloading the alpha version contact David Morgan (david.morgan@netl.doe.gov) or Chung Yan Shih (Chungyan.shih@netl.doe.gov)

Contributors

- Currently (in alphabetical order):
  - Kolawole Bello
  - David Morgan
  - Alana Sheriff
  - Chung Yan Shih
  - Derek Vikara
  - Travis Warner
- Past (in alphabetical order):
  - Elizabeth Basista
  - Laura Demetrion
  - Nizar Diab
  - Timothy Grant
  - Allison Guinan
  - Shangmin Lin
  - Andrea Poe
  - James Simpson
  - Taylor Vactor
  - Jason Valenstein

THANK YOU!

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CONTACT:

David Morgan
Strategic Systems Analysis & Engineering (SSAE)
412-386-7405
david.morgan@netl.doe.gov