Update of CO2_T_COM and CO2_S_COM Models (CO_2 Transport and Storage Costs)

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Agenda

- Project overview
- CO2_T_COM (FECM/NETL CO_2 Transport Cost Model)
- CO2_S_COM (FECM/NETL CO_2 Saline Storage Cost Model)
- Where the models have been used
- Where to find the models

Project Overview

- Funding supplied by FECM FWP-1022464
- Project performed by the Energy Systems Analysis Team in the Strategic Systems Analysis and Engineering Directorate within NETL's Research and Innovation Center
  - Federal personnel: David Morgan (lead) and Timothy Grant
  - Site support contractors: Allison Guinan, Alana Sheriff, Nizar Diab and Chung Shih
- Project objectives: Improve capabilities and performance characteristics of two models:
  - FECM/NETL CO_2 Transport Cost Model (CO2_T_COM), a CO_2 pipeline transport techno-economic model
  - FECM/NETL CO_2 Saline Storage Cost Model (CO2_S_COM), a CO_2 saline storage techno-economic model

CO2_T_COM: Features

- Excel-based techno-economic point-to-point CO_2 pipeline transport model
- Assumes CO_2 is transported as a liquid
- Key inputs:
  - Pipeline length
  - Elevation increase or decrease along pipeline
  - Maximum daily CO_2 mass flow rate and average annual CO_2 mass flow rate
  - Duration of operations
  - Number of booster pumps*
  - Price for transporting CO_2*
- Technical aspects:
  - Model has dataset of nominal or standard pipe diameters or sizes
  - Model divides pipeline into equal length segments with booster pump at end of each segment except last segment
  - Model determines smallest standard diameter pipe that can sustain the maximum daily CO_2 mass flow rate given the segment length and pressure drop across the segment

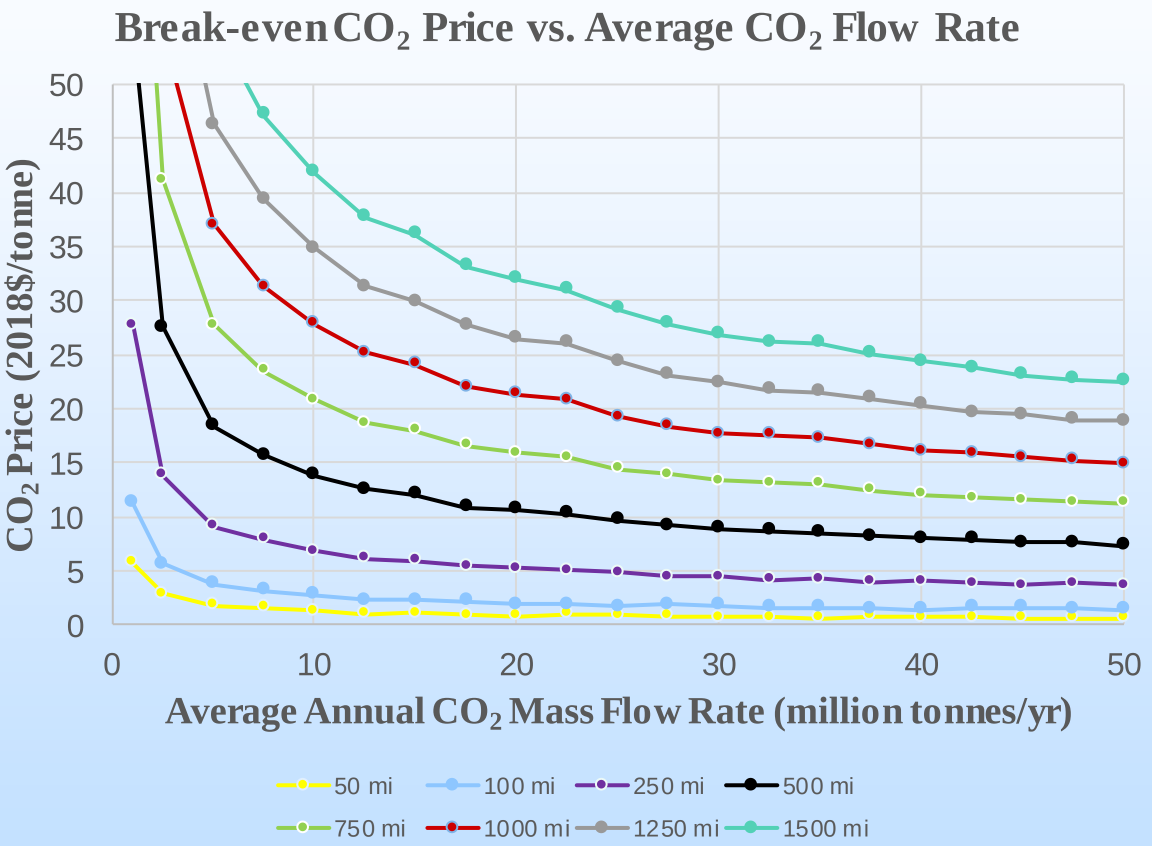
CO2_T_COM: Features (cont'd)

- Cash flow model:
  - With the standard pipe diameter and number of booster pumps, model calculates capital costs, and operations and maintenance (O&M) costs in each year
  - Given a price for transporting CO_2, model calculates revenues in each year
  - Model depreciates capital costs, calculates taxes, and determines earnings after taxes
  - Model uses weighted average cost of capital to discount earnings after taxes
  - Model sums the discounted earnings to give the net present value (NPV) for the project
    - Positive NPV indicates CO_2 price is high enough to cover all costs including financing costs
- Model can calculate the **break-even price for transporting CO_2**
  - CO_2 price where NPV for the project is zero
  - Lowest price the CO_2 pipeline operator can charge and still cover all costs including financial costs
  - Extremely useful metric
- Model can find the **combination of number of booster pumps and standard pipe diameter** that gives the **lowest break-even price for transporting CO_2**
  - Even more useful metric

CO2_T_COM: What's New

- Two escalation rates:
  - First escalation rate escalates revenues and costs from base year (2011) to first year of project
  - Second escalation rate escalates revenues and costs from first year of project onward
    - Can be set to 0%/yr for a real or constant dollar analysis
- Improved algorithm for determining the smallest standard pipe diameter needed for a specified number of booster pumps (which determines pipe segment length)
- New tab on the ribbon that is used to run different Visual Basic for Applications (VBA) macros in the model
- New macro-driven capability to evaluate multiple cases
  - Case consists of a pipeline length, fluid flow rates and elevation change
  - Model generates user-specified results for each case
- Fix for a few instances where user inputs or macro-driven inputs resulted in the model crashing
- Improved description of equations and algorithms in model in User's Manual
  - Discussion of basis for default financial assumptions used in model
  - Detailed description of the pipe fluid flow equations used in the model

CO2_T_COM: Example Results



- As average annual CO_2 mass flow rate increases, the break-even CO_2 price decreases
- As pipeline length increases, the break-even CO_2 price increases

CO2_S_COM: Features

- Excel-based techno-economic model for onshore CO_2 saline storage
- Calculates revenues and costs for a saline storage project from perspective of the operator of a single saline storage project
- Key inputs:
  - Maximum daily and average annual CO_2 mass flow rates
  - Duration of injection
  - Price for storing CO_2
- Includes database of geologic properties for 314 storage formations in lower 48 states
- Calculates key technical aspects of storage:
  - Plume sizes
  - Number of injection wells needed
  - Formation storage capacity (unconstrained and constrained by possible pressure interference)
- Includes costs for all stages of a storage project
  - Site screening, site selection, site characterization, and permitting
  - Operations
  - Post injection site care (PISC) and site closure

CO2_S_COM: Features (cont'd)

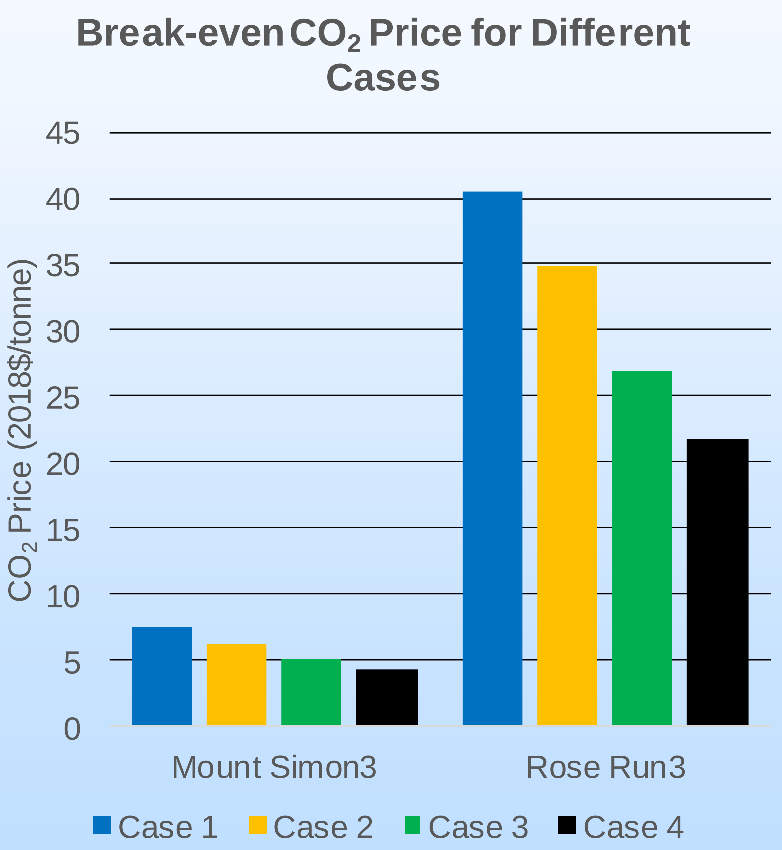
- Includes costs for large number of monitoring technologies
  - Deep monitoring wells
  - Geophysical technologies (seismic and others)
  - Groundwater wells, vadose zone monitoring, and air monitoring
- Calculates costs for all components of financial responsibility
  - Corrective action, injection well plugging, emergency and remedial response, and PISC and site closure
- Calculates costs for implementing financial instruments to comply with financial responsibility
  - Trust fund, escrow account, insurance, surety bonds, and self insurance
- Cash flow model that includes financing costs (debt and equity)
- Key output is break-even CO_2 price
  - Lowest price storage operator can charge for storing CO_2 and cover all costs including financing costs
- Model can generate results for a single geologic formation or for multiple formations
- Results from multiple formations can be used to generate cost-supply curves for CO_2 storage

CO2_S_COM: What's New

- Two escalation rates:
  - First escalation rate escalates revenues and costs from base year (2008) to first year of project
  - Second escalation rate escalates revenues and costs from first year of project onward
    - Can be set to 0%/yr for a real or constant dollar analysis
- Expanded number of geologic formations in model's geologic database
- Includes factor that reduces storage capacity for a formation due to possible pressure interference from multiple storage projects injecting CO_2 simultaneously
- More transparent presentation of the financial instruments for complying with financial responsibility requirements
- New tab on the ribbon that provides alternative way to run different VBA macros in the model
- New macro-driven sensitivity analysis capability
  - User specifies input variables to modify and output variables to track
  - Sensitivity analysis can be done on one storage formation or several storage formations

CO2_S_COM: Sensitivity Analysis

- Results for two storage formations for different cases

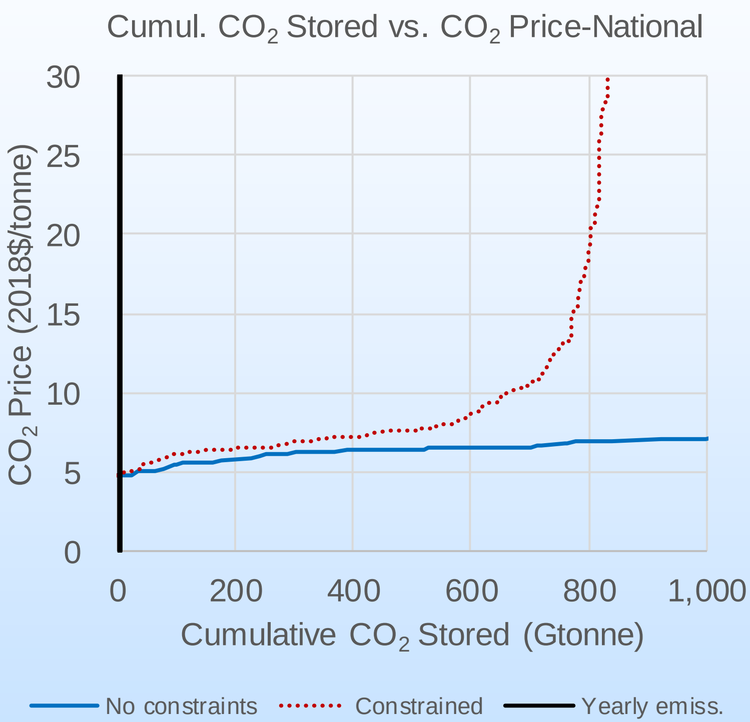


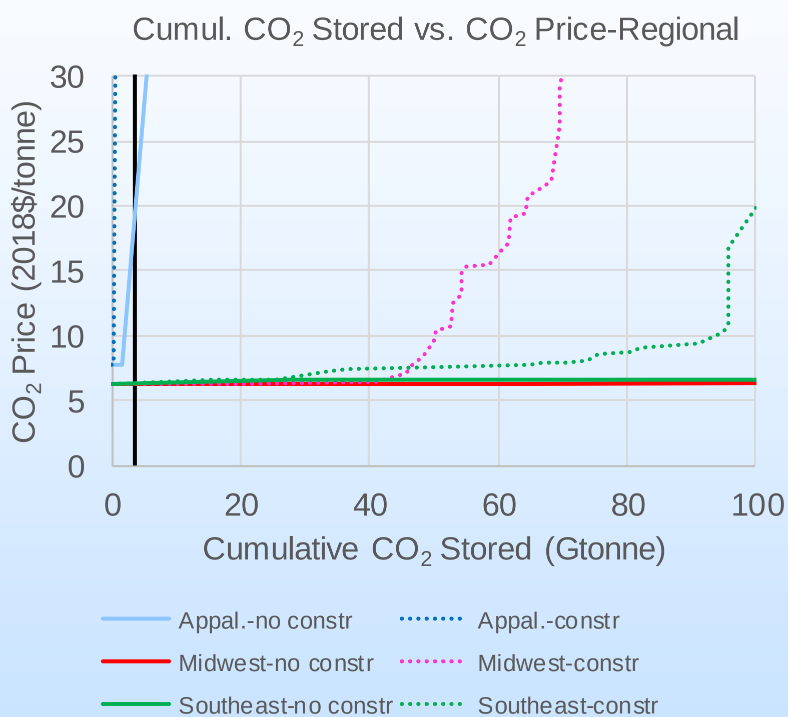
Case	Monitor-ing Intensity	Duration of PISC (years)	Financial Instrument for PISC
Case 1	High	50	Trust Fund
Case 2	Moderate	50	Trust Fund
Case 3	Moderate	15	Trust Fund
Case 4	Moderate	15	Self-insurance

Key take away: Geology is important!

CO2_S_COM: Cost-Supply Analysis

- Cumulative CO_2 stored versus break-even CO_2 price (results shown for Case 2)





- US emits ~3.5 Gtonnes CO_{2eq}/yr from electricity generation and industrial production
- Ample low-cost CO_2 saline storage options nationally, but there could be lack of such options on a regional basis

Where Models Have Been Used

- Both CO2_T_COM and CO2_S_COM
  - Used for many internal NETL analyses
  - Provided basis for reduced order CO_2 pipeline transport and saline storage cost equations within EIA's National Energy Modeling System (NEMS)
  - Provided capital and O&M CO_2 pipeline costs and break-even CO_2 storage costs for NREL's Regional Energy Deployment System (ReEDS) Model
  - Provided CO_2 pipeline transport and saline storage costs for the Hydrogen Energy Earthshot Initiative
- CO2_T_COM
  - Provided basis for reduced order pipeline cost equations that are used in Los Alamos National Laboratory's SimCCS model
  - Used in Princeton's 2021 Net Zero America study
- CO2_S_COM
  - Used in National Petroleum Council's 2019 report on CCUS (Meeting the Dual Challenge)
- Both models have many users outside NETL

Where to Find the Models

- FECM/NETL CO_2 Transport Cost Model (CO2_T_COM)
  - New version posted to NETL's website in Spring 2022
    - Excel spreadsheet model
    - User's manual
    - PowerPoint presentation summarizing model's features
  - https://netl.doe.gov/energy-analysis/search?search=CO2TransportCostModel
- FECM/NETL CO_2 Saline Storage Cost Model (CO2_S_COM)
  - New version will be posted to NETL's website in Fall 2022
    - Excel spreadsheet model
    - User's manual
    - Other documentation
  - Current 2017 version is at:
    - https://netl.doe.gov/energy-analysis/search?search=CO2SalineCostModel

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Questions?

Thank you!

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Appendix

– These slides will not be discussed during the presentation but are mandatory.

Participants

- Models have been developed by NETL federal workers and site support contractors
- Current participants
  - Federal personnel: David Morgan and Timothy Grant
  - Site support contractors: Allison Guinan, Alana Sheriff, Nizar Diab, Chung Shih
- Past participants
  - Federal personnel: Donald Remson
  - Site support contractors: Andrea Poe, Jason Valenstein, James Simpson, Shangmin Lin, Laura Demetrion, Elizabeth Basista

History

- Model development began in 2011 and both CO2_T_COM and CO2_S_COM were used for internal analyses until 2014
- In 2014, first versions of CO2_T_COM and CO2_S_COM were publicly released to NETL website
- In 2017, a new version of CO2_S_COM was released to NETL website
- In 2018, a new version of CO2_T_COM was released to NETL website
- In spring 2022, the latest version of CO2_T_COM was released to NETL website
- In fall 2022, the latest version of CO2_S_COM is scheduled for release to NETL website
- Future model development is intended to incorporate insights from projects, such as CarbonSAFE, that are moving toward commercial-scale implementation