Update of CO2_T_COM and CO2_S_COM Models (CO₂ Transport and Storage Costs)

FWP-1022464
August 18, 2022

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U.S. Department of Energy
National Energy Technology Laboratory
Carbon Management Project Review Meeting
August 15 - 19, 2022
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/NELT CO₂ Transport Cost Model (CO2_T_COM), a CO₂ pipeline transport techno-economic model
  • FECM/NELT CO₂ Saline Storage Cost Model (CO2_S_COM), a CO₂ saline storage techno-economic model
CO2_T_COM: Features

• Excel-based techno-economic point-to-point CO₂ pipeline transport model
• Assumes CO₂ is transported as a liquid
• Key inputs:
  • Pipeline length
  • Elevation increase or decrease along pipeline
  • Maximum daily CO₂ mass flow rate and average annual CO₂ mass flow rate
  • Duration of operations
  • Number of booster pumps*
  • Price for transporting CO₂*
• 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 CO₂ 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 CO₂, 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 CO₂ price is high enough to cover all costs including financing costs

• Model can calculate the break-even price for transporting CO₂
  • CO₂ price where NPV for the project is zero
  • Lowest price the CO₂ 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 CO₂
  • 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 CO₂ mass flow rate increases, the break-even CO₂ price decreases
- As pipeline length increases, the break-even CO₂ price increases
CO2_S_COM: Features

- Excel-based techno-economic model for onshore CO₂ 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 CO₂ mass flow rates
  - Duration of injection
  - Price for storing CO₂
- 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 CO₂ price
  - Lowest price storage operator can charge for storing CO₂ 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 CO₂ 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 CO₂ 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

### Break-even CO₂ Price for Different Cases

<table>
<thead>
<tr>
<th>CO₂ Price (2018$/tonne)</th>
<th>Mount Simon3</th>
<th>Rose Run3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Case 1</td>
<td>Case 2</td>
</tr>
</tbody>
</table>

### Key take away: Geology is important!

<table>
<thead>
<tr>
<th>Case</th>
<th>Monitoring Intensity</th>
<th>Duration of PISC (years)</th>
<th>Financial Instrument for PISC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Case 1</td>
<td>High</td>
<td>50</td>
<td>Trust Fund</td>
</tr>
<tr>
<td>Case 2</td>
<td>Moderate</td>
<td>50</td>
<td>Trust Fund</td>
</tr>
<tr>
<td>Case 3</td>
<td>Moderate</td>
<td>15</td>
<td>Trust Fund</td>
</tr>
<tr>
<td>Case 4</td>
<td>Moderate</td>
<td>15</td>
<td>Self-insurance</td>
</tr>
</tbody>
</table>
**CO2_S_COM: Cost-Supply Analysis**

- **Cumulative CO\(_2\) stored versus break-even CO\(_2\) price** (results shown for Case 2)

  ![Cumulative CO\(_2\) Stored vs. CO\(_2\) Price-National](image)

  ![Cumulative CO\(_2\) Stored vs. CO\(_2\) Price-Regional](image)

- **US emits ~3.5 Gtonnes CO\(_2\)eq/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 CO₂ pipeline transport and saline storage cost equations within EIA’s National Energy Modeling System (NEMS)
  - Provided capital and O&M CO₂ pipeline costs and break-even CO₂ storage costs for NREL’s Regional Energy Deployment System (ReEDS) Model
  - Provided CO₂ 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/NELT CO₂ 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/NELT CO₂ 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
Disclaimer

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All images in this presentation were created by NETL, unless otherwise noted.
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