Overview of the FECM/NETL CO_2 Transport Cost Model (CO2_T_COM)

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Background

- **Objectives**
  - Develop a screening-level model in Excel that estimates the revenues, costs and financial performance for a pipeline transporting liquid CO_2
  - Model must be able to handle a wide range of inputs such as varying CO_2 mass flow rates, pipeline lengths, operational time periods and financial variables
- **Project history**
  - Initial version was internal to NETL
  - First public release was in 2014
  - Last major upgrade in 2023
    - Minor upgrade in 2024
- **Relevance**
  - CO_2 pipeline transport is a critical element in the CCS value chain
  - FECM and NETL need to understand the costs of transporting CO_2 by pipeline and the factors that drive these costs

CO2_T_COM Assumptions

- **CO_2 is transported as a liquid**
- **Costs are calculated for a point-to-point pipeline**
- **Pipeline can have pumps spaced at equal distances along the pipeline to boost the pressure**
- **Pipeline capital costs are based on capital costs for natural gas pipelines from data collected by FERC**
  - Regression equations for these costs as a function of pipeline length and diameter are provided from the analysis of four researchers: Parker (2004), McCoy and Rubin (2008), Rui et al. (2011) and Brown et al. (2022)
  - Algorithm developed by ICF International (2009) is used to calculate a factor that converts natural gas pipeline capital costs to CO_2 pipeline capital costs
- **Pump costs are based on technoeconomic model developed by McCollum and Ogden (2006)**
- **CO_2 density and compressibility calculated using algorithm from Duan et al. (1992) and viscosity calculated using algorithm from Fenghour et al. (1998)**

CO2_T_COM Calculations

- **Inputs**
  - User specifies key technical inputs such as CO_2 mass flow-rate (max. and annual avg.), pipeline length, number of pump, elevation change across pipeline and pressure drop between pumps
  - User specifies key financial parameters such as fraction debt (remainder is equity), escalation rates, interest rate on debt and minimum desired return on equity
  - User specifies duration of construction, duration of pipeline operation and price for transporting CO_2
- **Technical calculations**
  - Model assumes pipeline is divided into equal length segments with a pump at start of each segment except the first segment
  - Model calculates smallest standard pipe diameter that can sustain the maximum CO_2 mass flow rate given the pressure drop and elevation change across the segment
- **Costs**
  - Model calculates capital costs for pipeline and pumps
  - Model calculates annual operations and maintenance (O&M) costs for pipeline and pumps

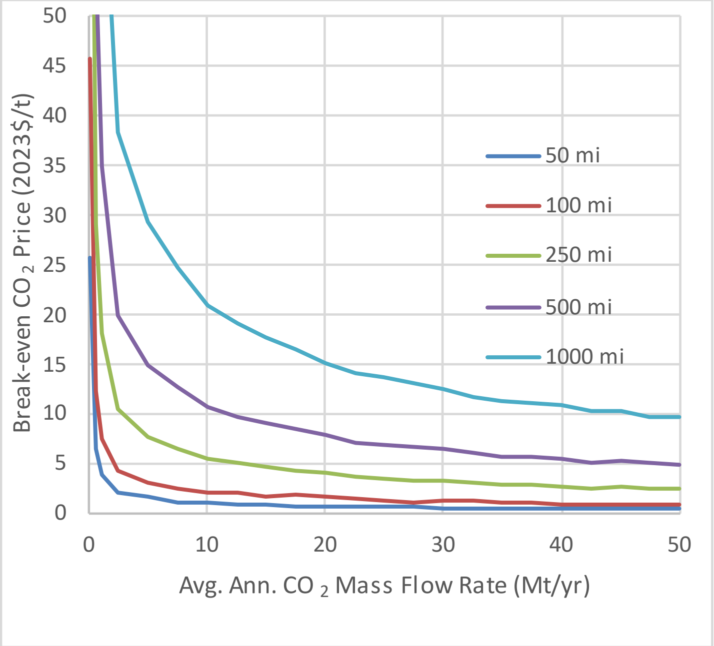
CO2_T_COM Calculations (cont'd)

- **Given the price for CO_2, the model:**
  - Calculates cash flows for revenues, capital costs and O&M costs in constant and nominal dollars
  - Depreciates capital costs and calculates taxes
  - Calculates earnings in nominal dollars
  - Discounts earnings using weighted average cost of capital to provide present value earnings
  - Sums the present value earnings to give net present value (NPV) for project
    - If **NPV exceeds zero**, the **project is viable** at the specified CO_2 price
- **Alternatively, model can find the CO_2 price that makes NPV for the project equal to zero**
  - This is the **break-even price** for CO_2 (also called **levelized price** for transporting CO_2)
  - This is the lowest price the pipeline owner can charge and cover all costs
  - Project is viable at this price but just barely
- **Finally, rather than specifying the number pumps, the model can:**
  - Determine the **combination of number of pumps and pipe diameter** that gives the **lowest break-even CO_2 price**
  - As the number of pumps increases (which increases costs), the diameter will decrease of the smallest viable pipe (the pipe cost will also decrease) so there is a trade-off between pipe diameter and number of pumps

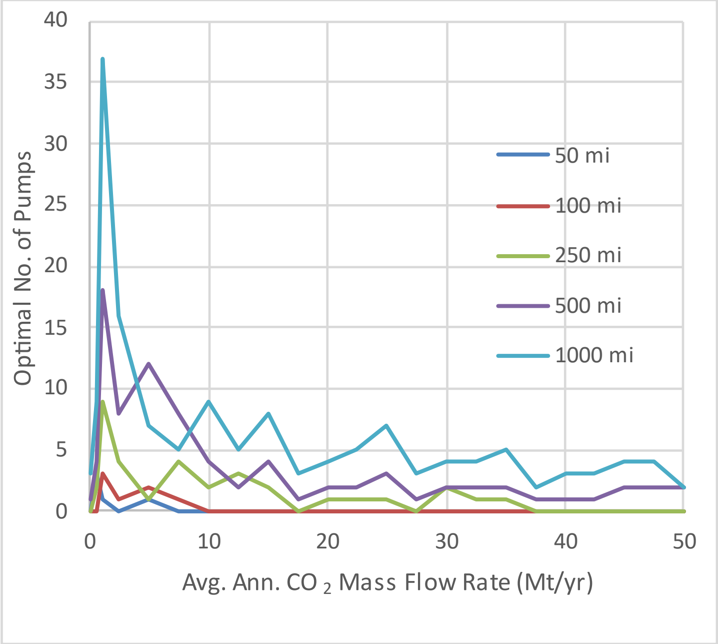
CO2_T_COM: Example Results

- **Inputs and outputs:**
  - Natural gas pipeline capital cost equations from Brown et al. (2022)
  - Capacity factor set to 90%
  - Prices presented in 2023 dollars

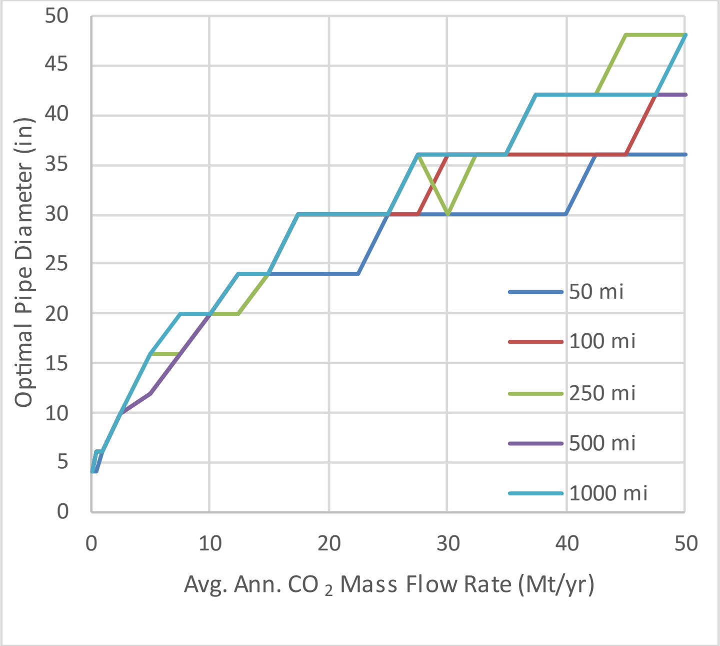
Break-even CO_2 prices vs. avg. annual CO_2 mass flow rate



Optimal no. pumps vs. avg. annual CO_2 mass flow rate



Optimal pipe diameter vs. avg. annual CO_2 mass flow rate



Conclusions

- **Where CO2_T_COM has been used**
  - Utilized in numerous internal national and regional analyses of CCS for NETL and FECM
  - Used in Princeton's Net-zero America study
  - Used to generate reduced order costs that have been used in EIA's NEMS, LANL's SimCCS, NREL's ReEDS
  - One of the most widely downloaded of SSAE's technoeconomic models
- **Next steps**
  - Minor update in 2024

    Link: https://netl.doe.gov/energy-analysis/search?search=CO2TransportCostModel

    Note: 2024 version may not be posted by meeting, currently undergoing external review.
  - Some potential future improvements:
    - Factor converting natural gas pipeline capital costs to CO_2 pipeline capital costs could be re-examined
    - Pump costs could be updated
    - Converting model to Python would make it more accessible to other applications, such as web-based tools developed elsewhere by NETL researchers

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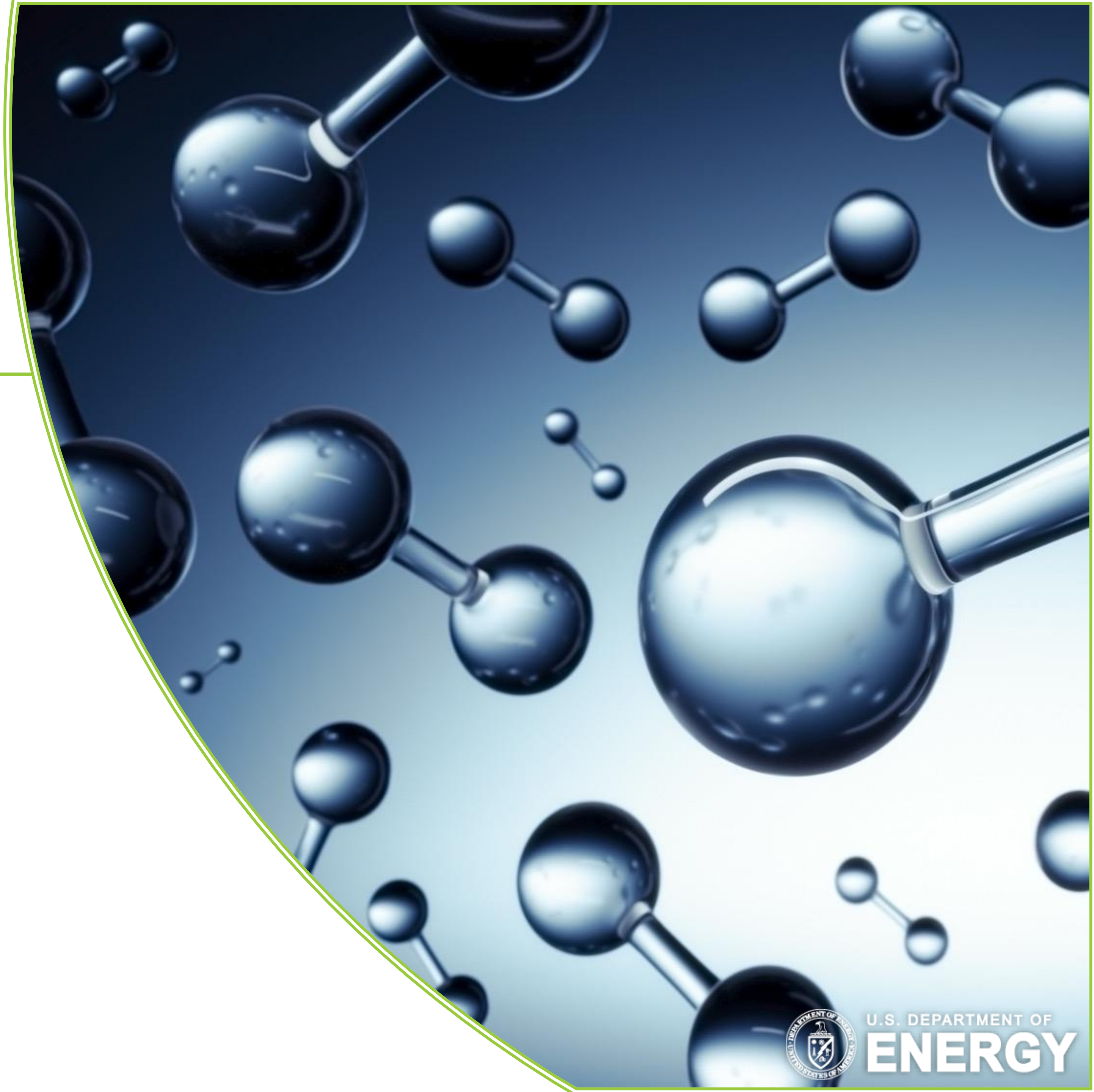

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