CO2 Pipeline Cost Analysis Utilizing a Modified FE/NETL CO2 Transport Cost Model Tool

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Abstract
Costs and specifications for multiple large-scale CO2 pipeline scenarios were derived using a modified FE/NETL CO2 Transport Cost Model (Grant and Morgan, 2016). Transportation analysis is a component of a Phase I CarbonSAFE project, integrated CCS for Kansas (Oklahoma), administered by the Kansas Geological Survey. One plan evaluated is gathering 10.9 million tonnes/yr (MT/yr) CO2 from 32 Midwest ethanol plants, combining it with 2.5 MT/yr CO2 from a Kansas coal-fired power plant, and transporting the CO2 to a saline aquifer site for CCS and to CO2 enhanced oil recovery markets in Kansas, Oklahoma and Texas. Economies of scale would reduce transportation costs for both, especially critical for the CCS project. For a single point to pipeline, the NETL Cost Model takes inputs, including length, CO2 capacity, pressure, project financing, and other parameters, and calculates capital and operating costs, and technical specifications such as pipeline diameter and pumping stations required. Calculations are by spreadsheet formulas and Excel VBA functions. The model was modified to evaluate multiple segments of a complex gathering and transportation system in one operation. Without changing or modifying the NETL spreadsheets or VBA code, a VBA macro was added that collects input parameters from a list of pipeline segments and calculates and records model outputs for each segment. Modifications of the FE/NETL CO2 Transport Cost Model are discussed and the analyses of several CO2 pipeline scenarios are presented. The modified tool provides efficient high-level analysis of complex infrastructure required for large-scale CO2 transportation from multiple sources.

Integrated CCS for Kansas

Goals & Objectives
1. Identify and address major technical and nontechnical challenges of implementing CO2 capture and transport and establishing secure geologic storage for CO2 in Kansas
2. Evaluate and develop a plan and strategy to address the challenges and opportunities for commercial-scale CCS in Kansas

Base Case Scenario
1. Capture 50 million tonnes CO2 from one of three Jeffrey Energy Center’s 800 MW plants over a 20 year period (2.5Mt/yr)
2. Compress CO2, and transport 300 miles to Pleasant Prairie Field in SW Kansas for storage in saline aquifer below oil zones
• Approximately 50 miles to Davis Ranch and John Creek Fields.
3. Evaluate transport cost savings through scaling by combining with transportation infrastructure for CO2 from ethanol in Upper Midwest

FE/NETL Transport Cost Model

Why use the FE/NETL Transport Cost Model?
• Needed an efficient tool to evaluate multiple pipeline scenarios in a high-level review of transportation options.
• The Morgan and Grant (2014) cost model is well-documented and thoughtfully applies publicly available costing data and equations from reliable, peer-reviewed sources.
• The Cost Model was easily adapted to our needs for evaluating capital and operating costs for multiple pipeline segments by creating additional Excel VBA macro functionality to interact with the NETL cost model.

FE/NETL Stated Objectives:
• Develop a mathematical model that estimates the costs of transporting liquid CO2 using a pipeline – Point to point pipeline (Engineering model).
• Model calculates break-even first year CO2 price for transporting CO2 (Financial Model)

FE/NETL Transport Cost Model Tool

Engineering model
• User specifies length, CO2 volume/yr, pipeline capacity factor, input and output pressure, and change in elevation. User can specify the number of booster stations.
• Outputs: minimum and nominal pipeline diameter, capital costs by category (materials, labor, misc., surge tanks, control systems, booster pumps), and operating costs (pipe, O&M, equipment and pumps O&M, and electrical costs).

Financial model (financial model not used in study)
• User specifies: start year (2011), length of construction period (3 years) and length of operations (30 years)
• User specifies financial parameters: net/equity rate (%), rate of debt (5%/yr), desired rate of return on equity (12%/yr), escalation rate (3%/yr), tax rate (36%), project contingency (15%) depreciation method.
• Output: Model generates cash flow of revenues and calculates break-even first year CO2 price

Pipe line cost estimates by diameter in 2011$/m. Parker (2004), used in Cost Model give highest pipeline capital costs followed by McCoy and Rubin (2008) and Rui et al. (2011).

Modifications to Cost Model

For calculating multiple pipeline network segment costs in one operation, created additional Excel VBA macro functionality to interact with the NETL cost model without modifications to the NETL spreadsheets or VBA code.
• Added a new worksheet to the Cost Model workbook (see Poster Panel 2) with user input parameters and cost model output.
• Created a VBA macro that collects inputs from a list of pipeline segments copied into the new worksheet.
• Changed binning on pipe diameters so minimum nominal size 4".
• New macro inputs the parameters for each segment to the Cost Model.
• Records model outputs for each segment individually in the new worksheet.

Additional Work

Changes to improve the model:
• Update to current dollars.
The Cost Model reports in 2011 dollars.
• Surge tank cost and application needs to better understood and possible modifications applied. In the current model, a single surge tank at a set cost is applied for each pipeline segment.
• The control system cost is a single flat rate per pipeline segment, and is rather low. This needs to be modified.
• Need to add an additional booster pump at the end of each segment that joins another segment. Current model is a point-to-point pipeline with the downstream ending at an injection well rather than needing to be boosted to pipeline pressure.
• Comparison with detailed costs from "real-life" examples could guide further improvements.

References


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CO2 Volumes and Network Design

Large-scale gathering and transportation system connecting 32 ethanol plants and delivering CO2 to Kansas, Oklahoma and Texas. Bubbles are sized according to CO2 volume. Ethanol plants are yellow (in the evaluated scenario) and brown (not in the scenario). Gray circles are ICKan industry partners, one of which is shown to be connected under this scenario. Pleasant Prairie is one of the storage sites considered in the project. Black line segments are existing CO2 pipeline infrastructure.

Work Flow
1. Ethanol production data for Midwest facilities from US Dept. of Energy, EIA, 2017
2. The volume of CO2 calculated at a rate of 6.624 lbs/CO2/gallon ethanol (Dubois et al., 2002).
3. Import Ethanol plant data to ArcGIS. Choose ethanol plants to tine into system.
4. Selection criterion: Larger ethanol plants and Jeffrey Energy Center in a large scale pipeline system. Abbreviations include mi – mile, MT/yr – million tonnes/year, dec. – decimal, psig – pounds per square inch gauge, ft – feet, in – inch. Costs are in thousands of dollars.

Model input and output data by pipeline segment for case 1, connecting 32 ethanol plants and Jeffrey Energy Center in a large scale pipeline system. Abbreviations include mi – mile, MT/yr – million tonnes/year, dec – decimal, psig – pounds per square inch gauge, ft – feet, in – inch. Costs are in thousands of dollars.

Results and Discussion

Multiple Cases:
1. Ethanol gathering system + Jeffrey Energy Center - large-scale system depicted in the Midcontinent map
2. Ethanol gathering only – same as above but without Jeffrey EC
3. Jeffrey EC to Midcontinent Trunk line – feed to the Ethanol gathering system
4. Jeffrey EC + CHS to Pleasant Prairie storage site – illustrated in Kansas map
5. Generic large source point-to-point – mimic a very large natural CO2 source to market
6. Generic small source point-to-point – mimic a very large ethanol plant to oil field
7. CVR to Thrall-Aagard oil field – proposed pipeline in Integrated Mid-Continent CCS and EOR project, DE0-0001942 (McPherson et al., 2010)

Discussion:
1. Sensitivity to distance and pipeline size is very evident
2. Jeffrey EC to the trunk line costs are about half what the direct route to the Pleasant Prairie storage site
3. The generic large source, mimics a large natural source, illustrating tough price competition with a disparate small source gathering system
4. Cost for the 80-mile CVR to Thrall-Aagard were estimated by Rooney Engineering at $82.64 in 2010, 35% higher than the cost-model estimate.

More comparisons with actual cost data, especially for small volume, short pipeline segments is needed

FE/NETL model cost results compare favorably with two Denbury pipelines carrying 11.2 and 12.6 Mt/yr CO2, 232 and 314 miles respectively. (Morgan and Grant, 2014)

FE/NETL model are similar to a 2008 proprietary engineering study for a similar but smaller project than Ethanol CO2 system in this paper.

FE/NETL model cost are 35% lower than 2010 engineering study for 80-mile pipeline in Kansas reported in FE0001942 final report.