Carbon Capture Retrofit Database – v.2019.1

primary project goals

The U.S. Department of Energy's (DOE) National Energy Technology Laboratory (NETL) has developed three carbon capture retrofit database (CCRD) tools that provide high-level analysis on the incremental cost for retrofitting point sources with carbon dioxide (CO_2) capture and/or compression systems. The tools also provide options to include the cost of implementing other plant emissions reduction technology improvements that may be required to comply with various regulations (e.g., Mercury and Air Toxic Standards [MATS][1] and New Source Performance Standards [NSPS][2]) when installing CO_2 scrubbing technology, or aid in maximizing the efficiency of the installed CO_2 removal technology.

technical goals

- Provide a tool that allows for the quick approximation of the cost to retrofit an existing power or industrial plant with CO_2 capture equipment, grounded in sound techno-economic analysis (TEA) fundamentals and methodology approaches.
- Provide sufficient technology options for selection, upstream of the capture system, to maximize the applicability of the tool.
    - For example, if a candidate plant for retrofit does not remove sulfur from the flue gas at adequate levels to meet the inlet flue gas specifications of the capture system to be added, the tool provides additional technology options for selection and inclusion to frame all requirements for the addition of CO_2 capture.

technical content

Techno-economic evaluation of the impacts that post-combustion CO_2 capture systems impart on power and industrial plants is key to determination of technology viability. Performing a TEA of an individual technology can provide insights into the key process parameters for a given capture system and identify areas for improvement that offer the most return by way of performance improvement and cost reduction. Practitioners of TEAs generally operate using their preferred set of assumptions, modeling and cost estimating methodologies, and sensitivity analysis approaches, and these standards may vary across organizations. In addition, there may be limitations regarding data availability and approaches for filling these gaps may vary widely. These factors can contribute to assessments that may or may not be developed on equivalent bases, and thus may not be comparable without sufficient definition of all assumptions and methodologies.

At NETL, systems analysis of power and power-related technologies, particularly post-combustion carbon capture, has been a focus for many years, and a key output of that work has been publicly available guidelines for conducting a TEA

technology maturity:
Systems Engineering and Analysis

project focus:
Carbon Capture Retrofit Database Tools

participant:
National Energy Technology Laboratory – Research and Innovation Center

project number:
FWP-1022402

predecessor projects:
N/A

NETL technical portfolio lead:
Alexander Zoelle
alexander.zoelle@netl.doe.gov

NETL principal investigator:
Timothy Fout
timothy.fout@netl.doe.gov

partners:
N/A

start date:
July 2016

percent complete:
100%

that are normalized, consistent, and transparent. However, even with the detailed guidance available for technology developers seeking to assess their systems, differences can still arise that lead to incompatible studies and results. To alleviate this issue, NETL has developed numerous tools for public use that build on the extensive systems analysis guidelines developed by NETL and simplify the process of systems analysis to allow for a broader range of engineers and scientists to take advantage of techno-economic evaluations.

NETL has developed three separate CCRD tools:

- Two power-related tools:
  - One assessing coal-fired pulverized coal (PC) and atmospheric fluidized bed (AFB) units (the PC CCRD) and another assessing natural gas units (the natural gas combined cycle [NGCC] CCRD).
- A third focused on industrial source (IND) sectors.

The IND CCRD contains data on facilities from the ammonia, cement, ethanol, hydrogen, and natural gas processing industries. The tools allow for a user to quickly screen, at a high level, the impact of adding carbon capture to a plant by calculating the incremental cost for retrofitting point sources with CO_2 capture and/or compression systems.

The reference costs for all CCRDs are predicated on baseload operation, so no cost or performance considerations are rendered for turn-down capability. In addition, the reference cost data sourced from NETL reports, and applied in the CCRDs, has been developed for a target plant size; therefore, scaling cost and performance data to units of significantly differing sizes, compared to the reference data, will introduce inaccuracies due to the nature of process design. Calculation of cost results follows NETL's guidance[3] and utilizes capital charge factors that will be contingent on a number of financial parameter assumptions, including interest rate, return on equity, economic life of the plant, debt and equity split, debt term, and others.

Similar to reference costs, the performance basis for the reference systems considered in the CCRD were developed for International Organization for Standardization (ISO) ambient conditions[4][5], and no cost or performance adjustments are made in the CCRD to account for the operating ambient conditions.

In order to reflect the expected but undefined costs associated with the retrofit of existing plants, a retrofit cost factor is applied to all sites with no consideration given to the amount of retrofit equipment required, the available space, or other site-specific conditions. As the plant configuration will have a significant impact on the actual installation costs and design (and therefore equipment costs) of each system, the site-specific retrofit factor would be expected to deviate significantly from the average value applied in the CCRDs.

The PC and NGCC CCRDs do not provide a library of existing U.S. fleet power plants for which calculations may be applied to. If this type of analysis is desired, the individual user must obtain and import this data into the CCRD. The CCRD does come pre-populated with cases that derive from legacy NETL systems analysis studies of representative coal and natural gas power plants. These cases can be used without further adjustment if appropriate for the analysis desired.

In the case of a user importing U.S. fleet plant data, the CCRD offers several options to allow the user to bring the plant into compliance with air emissions regulations, such that the plant is suitable for the addition of post-combustion capture equipment. For example, if an existing unit does not meet the nitrogen oxides (NO_X) environmental regulatory limit, a selective catalytic reducer (SCR) can be included in the retrofit configuration, and the cost of adding the SCR unit is calculated by the CCRD based on the CO_2 capture rate. There are cost result accuracy considerations given the approach employed by the CCRD to include addition of the SCR. The scaling approach of CO_2 flow rate provides a short-cut method reasonable for a screening-level assessment to approximate costs, but does not take into account site-specific considerations of the existing plant, such as boiler type, coal type, removal efficiency requirements, and other factors, and thus could result in an over- or under-sized SCR. Similar to NO_X, if an existing unit does not meet the sulfur dioxide (SO_2) regulatory limit, wet flue gas desulfurization (FGD) can be included in the retrofit configuration, and the cost of FGD is calculated by the CCRD based on the CO_2 capture rate. The same cost result accuracy considerations listed for addition of SCR apply to the addition of FGD.

While scaling the CO_2 removal system on the rate of CO_2 captured is significantly more accurate than for either FGD or SCR (discussed above) for similarly designed plants, regardless of coal type, considerable deviations can occur due to various process design choices, such as excess air to the boiler, infiltration air, air leakage, efficiency of existing gas cleanup systems, and operating temperature and pressure. Using solvent-based CO_2 removal systems as an example, additional air in the flue gas will not only increase the volumetric flow rate, but will also have a diluting effect on the CO_2 concentration of the flue gas. These factors will affect the sizing of both the pre-scrubber and absorption columns (impacting capital costs), as well as the solvent circulation rate (impacting the operating and maintenance [O&M] costs, capital cost, and auxiliary load). The same cost result accuracy considerations listed for addition of SCR and FGD apply to the retrofit of the CO_2 removal system, and the user should take these considerations into account when interpreting the results.

The reference CO_2 compression system considered in the CCRD is an integrally geared centrifugal type, designed for baseload operation[4], which may not be suitable for all unit sizes. For small units, reciprocating compressors may be more appropriate, but the current CCRD does not offer this technology selection option.

In instances where the user provides U.S. plant fleet data, the CCRD charting tools allow for generation of an array of scenario results plots. In Figure 1, the fleet-of-entries level view is presented for the breakeven CO_2 sales price. In this scenario, which is based on a particular user-defined set of assumptions, the plot shows that 80% of the total plant capacity input into the CCRD tool and retrofitted could return a cost of $125/tonne or less. Figure 2 presents a different scenario, where the nameplate capacity of the unit retrofitted, based on the user-defined fleet data, is plotted against the calculated breakeven CO_2 sales price. The trend shows that as the unit size increases, the breakeven CO_2 sales price decreases.

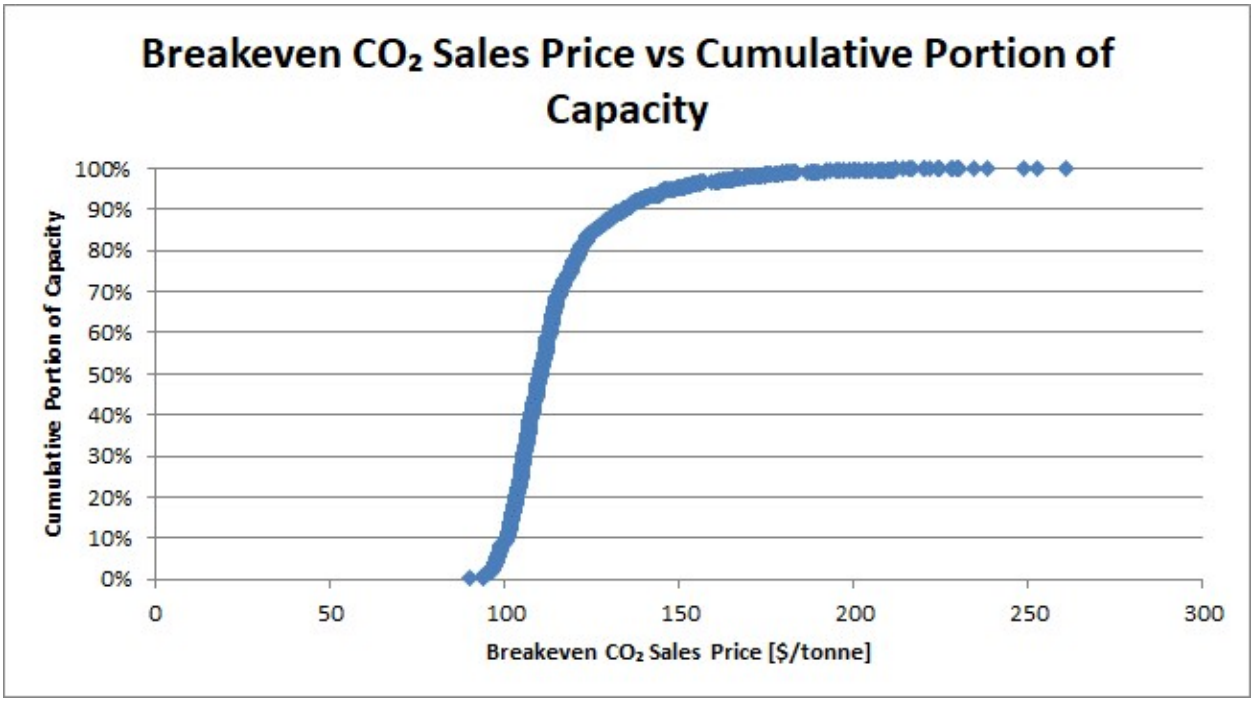

Figure 1: Breakeven CO_2 sales price versus cumulative portion of capacity retrofitted.

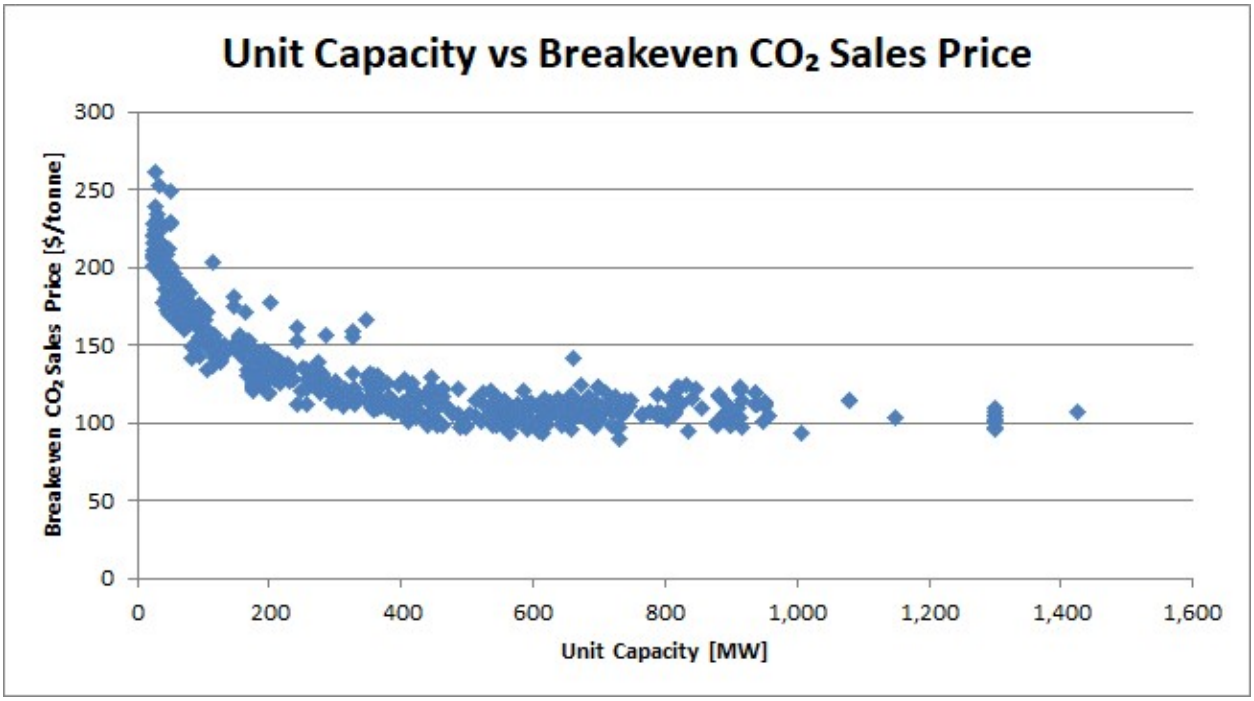

Figure 2: Unit capacity retrofitted versus breakeven CO_2 sales price.

technology advantages

- The tool allows for a first-cut screening of the potential impact of technology options, ranging from developing to commercially available CO_2 capture technologies, on the existing fleet of coal and gas power plants (when fleet data is provided by the user), as well as industrial sources.

R&D challenges

- Lack of detailed energy and mass balance diagrams for each plant in the U.S. fleet reduces absolute accuracy of single point results.
- Lack of comprehensive publicly available U.S. fleet plant data for pre-population of the tool database.
- The user must provide their own plant data or use the pre-populated cases that derive from legacy NETL systems analysis studies of representative coal and natural gas power plants.
- The individual plant level accuracy of results is subject to the underlying performance and cost approximation methodologies and plant data. While the underlying methodologies are sound, an individual plant-level model and capital cost estimate is not developed for each case. Thus, the most useful application of the tool results is to compare case outputs based on varying user inputs (e.g., power plant inputs, capture technology inputs, etc.) rather than assessing an individual case's absolute result.

status

NETL has developed three CCRD tools that allow for a quick approximation of the cost to retrofit an existing power or industrial plant with CO_2 capture equipment.

available reports/technical papers/presentations

Kuehn, Norma. "Natural Gas Combined Cycle Carbon Capture Retrofit Database." April 2, 2019. *https://netl.doe.gov/energy-analysis/details?id=2950*.

Kuehn, Norma. "Industrial Sources Carbon Capture Retrofit Database." April 2, 2019. *https://netl.doe.gov/energy-analysis/details?id=2951*.

Kuehn, Norma. "Pulverized Coal Carbon Capture Retrofit Database." April 2, 2019. *https://netl.doe.gov/energy-analysis/details?id=2949*.

references

[1] Environmental Protection Agency, "40 CFR Part 63: National Emission Standards for Hazardous Air Pollutants for Source Categories," [Online]. Available: http://www.ecfr.gov/cgi-bin/text-idx?tpl=/ecfrbrowse/Title40/40cfr63_main_02.tpl. [Accessed 5 January 2016].

[2] Environmental Protection Agency, "40 CFR Part 60: Standards of Performance for New Stationary Sources," [Online]. Available: http://www.ecfr.gov/cgi-bin/textidx?tpl=/ecfrbrowse/Title40/40cfr60_main_02.tpl. [Accessed 5 January 2016].

[3] National Energy Technology Laboratory, "Cost Estimation Methodology for NETL Assessments of Power Plant Performance," Department of Energy, Pittsburgh, PA, 2011.

[4] National Energy Technology Laboratory, "Cost and Performance Baseline for Fossil Energy Plants, Volume 1a: Bituminous Coal (PC) and Natural Gas to Electricity," Department of Energy, Pittsburgh, 2015.

[5] National Energy Technology Laboratory, "Cost of Capturing CO_2 from Industrial Sources – Revision 2," Department of Energy, Pittsburgh, PA, 2014.