Greenhouse Gas Mitigation Measures

Carbon Capture and Storage for Combustion Turbines

Technical Support Document

New Source Performance Standards for Greenhouse Gas Emissions from New, Modified, and Reconstructed Fossil Fuel-Fired Electric Generating Units; Emission Guidelines for Greenhouse Gas Emissions from Existing Fossil Fuel-Fired Electric Generating Units; and Repeal of the Affordable Clean Energy Rule Proposal

Docket ID No. EPA-HQ-OAR-2023-0072

U.S. Environmental Protection Agency
Office of Air and Radiation
May 23, 2023

Table of Contents

Introduction

This document describes the EPA's approach to estimating the costs of carbon dioxide (CO_2) capture and storage (CCS) on combined cycle combustion turbine EGUs. The primary source of this information for CCS installation on new plants is the U.S. Department of Energy's (DOE) National Energy Technology Laboratory (NETL) baseline report. The EPA extrapolated the NETL Baseline report's partial CO_2 capture data to estimate the costs for CCS projects of different sizes. The EPA used the NETL CCS retrofit report to estimate the costs of CCS for existing combined cycle EGUs.

CCS involves the separation and capture of CO_2 from a gas, the pressurization and transportation via pipeline of the captured CO_2 (if necessary), and utilization or long-term geologic storage (also referred to as geologic sequestration). Equipping an EGU with CCS prevents emissions but also requires energy and decreases the efficiency of the EGU.

A separate TSD[1] discusses four categories of post-combustion carbon capture: absorption, adsorption, membranes, and cryogenic. Absorption is the uptake of CO_2 into the bulk phase that forms a chemical or physical bond to a solvent or other carrier material. Adsorption is a physical or chemical binding to a solid sorbent surface. Membranes separate CO_2 from the bulk gas using variations in molecular permeation rates through porous material based on the different molecular structure of CO_2. Cryogenic separation processes use the difference in boiling points of gasses to separate them via condensation. All four categories are equally applicable to natural gas- and coal-fired flue gas and other industrial sources of emissions. Current post-combustion CO_2 capture projects have primarily used amine solvent adsorption capture systems. This document describes carbon capture technologies, combustion turbine-specific applications, planned projects, feed studies, and the EPA's methodology to estimate the costs of CCS for combustion turbines. The separate *Greenhouse Gas Mitigation Measures for Steam Generating Units* TSD should be consulted for additional discussion of CCS, including technology development, incentives, deployment, and transportation and storage of captured CO_2.

[1] See the *Greenhouse Gas Mitigation Measures for Steam Generating Units* TSD in Docket ID No. EPA-HQ-OAR-2023-0072.

CCS Costing Approaches for New Natural Gas-fired Combined Cycle EGUs

For the 40 CFR part 60, subpart TTTTa BSER analysis, the EPA estimated the costs of CCS using the NETL report titled, *Cost and Performance Baseline for Fossil Energy Plants Volume 1: Bituminous Coal and Natural Gas to Electricity* (DOE/NETL - 2023/4320, October 14, 2022). This report provides detailed costing for 90 percent and 95 percent carbon capture rates for large natural gas-fired combined cycle combustion turbines and large subcritical and supercritical pulverized bituminous coal-fired steam generating EGUs. While this report provides detailed costing information for full capture for large EGUs, it does not provide information on the costs of partial CCS or the costs for smaller EGUs.

Estimating CCS Costs for Various Sizes of New Natural Gas-fired Combined Cycle EGUs

To estimate the costs of partial CCS and the costs for smaller EGUs, the EPA assumed that the CCS costs for combustion turbine EGUs follow the same general economies of scale/trends as for coal-fired EGUs and used the NETL report titled, *Cost and Performance Baseline for Fossil Energy Plants Supplement: Sensitivity to CO_2 Capture Rate in Coal-Fired Power Plants* (DOE/NETL-2019, December 23, 2020). The 2020 report includes detailed costing information for various percentages of partial CCS for large supercritical pulverized bituminous coal-fired steam generating EGUs. Using the information in the partial capture case, the EPA developed trend lines (*i.e.*, curve fits) for the capital, fixed, and variable operating costs based on the design capture rate (in tonnes of CO_2 captured per hour) of the carbon capture equipment. The EPA then used the derived equation to determine the capital, fixed, and variable operating costs of carbon capture equipment for various sizes of carbon capture equipment. These costs are specific to 90 percent capture of the CO_2 in the flue gas from a bituminous pulverized coal-fired steam generating EGU.

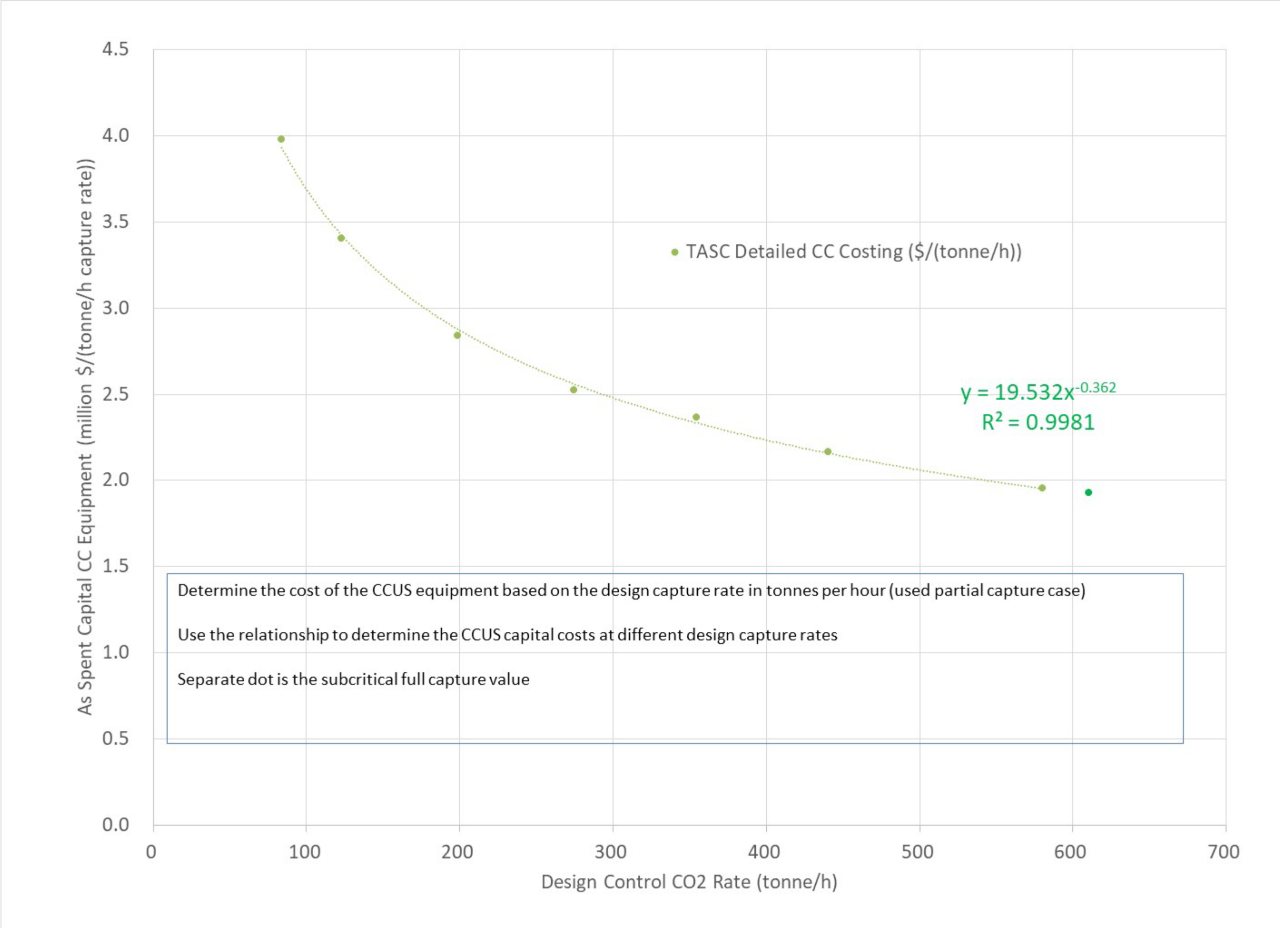
The EPA used the following approach to determine the capital costs of the carbon capture equipment:

- First, the EPA used the detailed equipment costs from the NETL full capture case and compared those detailed costs to the detailed costs for the supercritical bituminous coal-fired non-capture case. These costs could then be used to determine the reduction in costs of the boiler island itself due to economies of scale. The EPA then made a simplifying assumption that the boiler island economies of scale are linear. This allowed the EPA to estimate the boiler island costs for the various partial capture cases.[2]
- Next, the EPA compared the estimated carbon capture equipment costs in the detailed costing information to the carbon capture costs estimated from subtracting the boiler island costs from the total costs of the EGU. From this, the EPA used the ratio of costs to reduce the estimated costs of the carbon capture equipment.
- The EPA used these values in the partial capture report and divided those costs by the design capture rate in tonnes of CO_2 per hour. The EPA then plotted the 'as spent capital' costs against the capture rate to determine the economies of scale of capture equipment. Figure 1 shows the relationship between the 'as spent capital' and capture rate. Equation 1 shows the 'as spent capital' of the carbon capture equipment in millions of $ per tonne per hour CO_2 capture rate.

$$As\ Spent\ Capital = 19.532 * Design\ Capture\ Rate^{-0.362}$$

[2] Detailed costing information was not included in the partial capture cases. Since the NETL analysis assumes a constant net output, the boiler island itself is larger as the level of CCS is increased.

Figure 1: Capital Cost of CCS Equipment



Similarly, the EPA determined the annual fixed costs and variable operating costs at the different partial capture rates to determine the annual fixed costs and variable operating costs of the capture cases compared to the non-capture case. The EPA did not apply any adjustments for economies of scale to either of these values. Figures 2 and 3 show the relationship between fixed and variable costs and the design CO_2 control rate.