Environmental Science & Technology

Policy Analysis

pubs.acs.org/est

Opportunities for Decarbonizing Existing U.S. Coal-Fired Power Plants via CO_2 Capture, Utilization and Storage

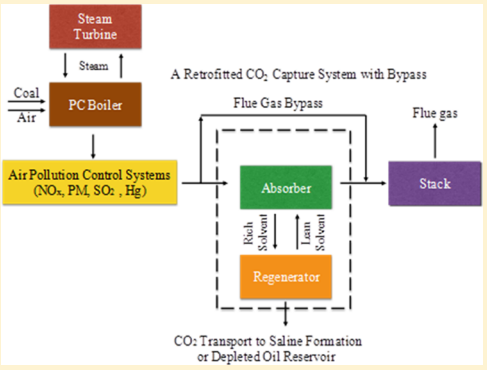
Haibo Zhai,*[,†] Yang Ou,[§] and Edward S. Rubin[†,§]

[†]Department of Engineering and Public Policy, Carnegie Mellon University, Pittsburgh, Pennsylvania 15213, United States

[§]Department of Mechanical Engineering, Carnegie Mellon University, Pittsburgh, Pennsylvania 15213, United States

Supporting Information

ABSTRACT: This study employs a power plant modeling tool to explore the feasibility of reducing unit-level emission rates of CO_2 by 30% by retrofitting carbon capture, utilization, and storage (CCUS) to existing U.S. coal-fired electric generating units (EGUs). Our goal is to identify feasible EGUs and their key attributes. The results indicate that for about 60 gigawatts of the existing coal-fired capacity, the implementation of partial CO_2 capture appears feasible, though its cost is highly dependent on the unit characteristics and fuel prices. Auxiliary gas-fired boilers can be employed to power a carbon capture process without significant increases in the cost of electricity generation. A complementary CO_2 emission trading program can provide additional economic incentives for the deployment of CCS with 90% CO_2 capture. Selling and utilizing the captured CO_2 product for enhanced oil recovery can further accelerate CCUS deployment and also help reinforce a CO_2 emission trading market. These efforts would allow existing coal-fired EGUs to continue to provide a significant share of the U.S. electricity demand.



INTRODUCTION AND OBJECTIVES

In June 2014, the U.S. Environmental Protection Agency (EPA) proposed a Clean Power Plan that establishes state-specific rate-based goals for carbon dioxide (CO_2) emissions from existing electric generating units (EGUs). The proposal is to reduce nationwide carbon pollution by an average of 30% below 2005 levels in 2030.[1] To formulate a consistent national basis, the EPA established four "building blocks" for emission reductions. However, each state has the flexibility of choosing mitigation measures to meet the overall emission goal, including measures that are not mentioned in any of the four building blocks. Carbon capture and storage (CCS) is not included in the building blocks, mainly because of concerns about substantially increased costs and space limitations. However, the EPA also recognizes the potential viability of partial CCS at some plants.[1]

Compared to new plants, existing coal-fired EGUs often have lower unit efficiency and higher marginal operating costs.[2] Multiple EGUs within a single plant might have different attributes. Given the large cost and high energy penalty associated with amine-based CCS systems,[3,4] previous studies indicate that retrofitting amine-based CCS to existing coal-fired plants would lead to substantial increases in the cost of electricity generation (COE).[5,6] The lifetime of the CO_2 capture facilities can be limited by the remaining life of existing plants. These factors are often viewed as critical barriers to CCS deployment.[6] However, for existing coal-fired EGUs that have been fully or substantially amortized, the COE of an EGU retrofitted with CCS can be comparable to or lower than that of a new plant.[6] Relatively large, young, high-efficiency coal-fired EGUs equipped with flue-gas desulfurization (FGD) and selective catalytic reduction (SCR) systems are potentially suitable for CCS retrofit applications.[7,8] Auxiliary power systems can be used to maintain the electricity output of retrofitted plants.[4,9,10] Thus, the feasibility of a CCS retrofit should be evaluated on a site-specific basis because the retrofit cost varies significantly with unit characteristics.[5,11] As a revenue-enhancing opportunity, selling the captured CO_2 product for enhanced oil recovery can lower the added cost for CCS.[10]

It remains unclear with the prospect for CCS retrofits of U.S. coal-fired generating capacity (totaling 318 gigawatts)[12] to help comply with the EPA's newly proposed regulations. Thus, the EPA seeks comments on the extent to which EGUs could be retrofitted with CCS. The major objectives of this study, therefore, are to (1) investigate the feasibility of retrofitting CO_2 capture, utilization, and storage (CCUS) to existing U.S. pulverized-coal-fired EGUs to achieve a 30% reduction in unit-level CO_2 emission rates; (2) identify which EGUs are feasible for partial CO_2 capture by examining how unit characteristics would impact retrofit cost and feasibility; and (3) explore other mechanisms that can improve the retrofit viability for feasible EGUs. This paper thus presents the first comprehensive

Received: March 4, 2015
Revised: May 12, 2015
Accepted: May 29, 2015
Published: May 29, 2015

DOI: 10.1021/acs.est.5b01120
Environ. Sci. Technol. 2015, 49, 7571−7579