***Clean Power Plan Insights for Pennsylvania***

Jeffrey Anderson, Carnegie Mellon University, (503) 956-4667, jja1@andrew.cmu.edu

Paul S. Fischbeck, Carnegie Mellon University, (412) 268-3240, pf12@andrew.cmu.edu

Haibo Zhai, Carnegie Mellon University, (412) 268-1088, hbzhai@cmu.edu

David C. Rode, Quadrilateral Energy Group, (412) 268-3240, rode@andrew.cmu.edu

## Overview

The Environmental Protection Agency (EPA) issued the Clean Power Plan (CPP) for existing power generation sources in part to limit the emission of carbon dioxide (CO2) that is associated with climate change. The intent of the plan is to decrease the national annual CO2 emission intensity of fossil-fuel generating sources in 2030 by an average of thirty-two percent from the 2005 level. To achieve this reduction, the EPA identified certain permitted approaches and guidelines, as well as state-specific emission targets. However, it is up to the policymakers in each state to determine which of these approaches should be taken and which guidelines should be followed to achieve a cost-effective, compliant solution for existing and future state power generation capacity. Therefore the main objective of this research is to gain insight into the cost-effectiveness of the CPP approaches and the ramifications of the guidelines through examination of a state-specific implementation of the CPP. In particular, this presentation examines the endogenous implementation of the CPP in Pennsylvania—a state rich in fossil-fuel energy, but limited in renewable energy potential.

## Methods

This methodology uses simulations of the performance and cost profiles of existing and new coal-fired and natural gas combined cycle (NGCC) capacity from the Integrated Environmental Control Model (IECM), a tool developed by Carnegie Mellon University, in an optimization model to determine cost-effective compliance strategies under multiple constraint sets. Rather than use the individual characteristics and performance parameters found in the EPA 2012 NEEDS and eGRID databases to create models in the IECM for the CPP-affected coal-fired electric generating units (EGUs) and NGCC plants, the generation-weighted average attributes for these generation sources classes were calculated and input into the IECM. This created unique source models with which CO2 mitigation technologies and CPP protocols were simulated. Similarly, the generation-weighted average attributes for state-specific oil and gas steam turbine (OGST), hydropower, nuclear, wind, and utility solar power source classes were calculated from these databases to estimate the unsubsidized levelized cost of electricity (LCOE), based upon published values. For illustrative purposes, the attributes for the Pennsylvania CPP affected and excluded source classes are shown in the Table.

Table. Generation-weighted attributes and cost estimates for existing generation source classes in 2012 and 2030.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Source | Nameplate Capacity (MW) | Capacity Factor (%) | LCOE ($/MWh) | CO2 Emission Intensity (lbs/MWh) | 2030 Capacity Factor (%) | 2030 LCOE($/MWh) |
| Pulverized Coal | 14,936 | 57 | 40.8 | 2,112 | 51 | 51.7 |
| NGCC | 11,398 | 61 | 35.0 | 883 | 64 | 50.1 |
| OGST | 3,005 | 7 | 129.0 | 1,493 | 7 | 126.0 |
| Nuclear | 10,015 | 86 | 25.4 | 0 | 90 | 24.2 |
| Wind | 1,385 | 18 | 123.0 | 0 | 28 | 72.6 |
| Hydropower  | 2,408 | 9 | 25.9 | 0 | 9 | 25.0 |
| Utility PV  | 44 | 5 | 380.0 | 0 | 18 | 222.0 |

These capacity factors, CO2 emission intensities, and modeled cost parameters for the source classes (Table) were inputs to an optimization model. The objective function of this model is to maximize the cost-effectiveness of the state generation fleet by varying the existing and future capacities for the source classes, subject to meeting generation demand and various regulatory and resource constraints on these capacities. Source capacity requirements for new zero-carbon and low-carbon generation in this model to be compliant with the CPP were determined in part with calculations pertaining to the emission reduction credits (ERCs) and mass allowances (MAs) outlined in the CPP.

## Results

In 2012, affected sources (as identified by the CPP) generated 92% of the total state generation. The results of the optimization model for a least-cost compliant solution (here taken as the lowest fleet LCOE) indicate that in 2030 these affected sources can meet the affected 2012 generation demand level and be over-compliant with the CPP mass-based approach, both with and without restrictions on new fossil-fuel generation sources. This over-compliance was achieved without the introduction of new renewable energy sources and required increasing the capacity factor for the nuclear source class by four percent, and using two of the building blocks described in the regulation: (1) improving the heat rate of the coal-fired EGUs, and (2) re-dispatching the electrical generation from the coal-fired EGUs to the NGCC plants. These steps were not adequate however, when the eight percent of generation sources that are excluded by the CPP were retired and the overall demand was increased. As more generation was required, the optimal fleet LCOE increased, and the optimal reductions in CO2 mass emitted decreased until the CPP limits for each restriction were reached, Figure 1. For the mass-based approach with restrictions on the addition of new fossil-fuel sources, capacity limitations on new renewable energy sources resulted in the need to retrofit carbon capture and storage subsystems (CCS) at 90% capture to some of the NGCC capacity before 104% of the 2012-generation demand was required (Figure 2). The introduction of CCS was not required for the mass-based approach without restrictions even when 106% of the 2012-generation demand was required.



Figure 1. Simulating increased generation demand resulted in increased fleet CO2 emissions and increased fleet LCOE for the mass-based approach with and without restrictions on new fossil-fuel generation sources, when the fleet capacity was optimized for lowest LCOE. 2012 fleet LCOE was estimated to be $35.6/MWh. The corresponding fleet emission level was 102 million short tons.



Figure 2. Generation mix required to achieve lowest LCOE while maintaining compliance with the restricted mass-based approach. Compliance for CPP affected sources is achieved in 2030 without existing or new wind generation.

## Conclusions

This research provides a methodology with which policymakers can gain insights into the implementation of the CPP approaches and guidelines for affected source compliance. Preliminary results of the application of the methodology to Pennsylvania for implementation of the mass-based approaches with and without restrictions on new fossil-fuel generation sources indicated that compliance in each case could be achieved in 2030 without the need for new renewable energy capacity. However, the unrestricted approach was on the cost-effective frontier, until the emitted CO2 reached the lower mass limit for the restricted case. After this point, the policymaker must make a tradeoff between seeking lower emissions or lower fleet LCOE. Furthermore, the restricted case required retrofitting CCS to some NGCC capacity to meet demand and compliance requirements.