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# The Affordable Clean Energy Rule and the Impact of Emissions Rebound on Carbon Dioxide and Criteria Air Pollutant Emissions

Amelia T. Keyes, Kathleen F. Lambert, Dallas Burtraw, Jonathan J. Buonocore, Jonathan I. Levy, and Charles T. Driscoll

## Abstract

The Affordable Clean Energy (ACE) rule, the U.S. Environmental Protection Agency's (EPA) proposed replacement of the Clean Power Plan (CPP), targets heat rate improvements at individual coal plants in the U.S. Due to greater plant efficiency, such heat rate improvements could lead to increased generation and emissions, known as an emissions rebound effect. The EPA Regulatory Impact Analysis (RIA) for ACE and other analyses to date have not quantified the magnitude and extent of an emissions rebound. We analyze the estimated emissions rebound of carbon dioxide ($CO_2$) and criteria pollutants sulfur dioxide ($SO_2$) and nitrogen oxides ($NO_X$), using results from the EPA's power sector model, under the ACE in 2030 at model coal plants and at the state and national levels compared to both no policy and the CPP. We decompose emissions changes under a central illustrative ACE scenario and find evidence of a state-level rebound effect. Although the ACE reduces the emissions intensity of coal plants, it is expected to increase the number of operating coal plants and amount of coal-fired electricity generation, with 28 percent of model plants showing higher $CO_2$ emissions in 2030 compared to no policy. As a result, the ACE only modestly reduces national power sector $CO_2$ emissions and increases $CO_2$ emissions by up to 8.7 percent in eighteen states plus the District of Columbia in 2030 compared to no policy. We also find that the ACE increases $SO_2$ and $NO_X$ emissions in nineteen states and twenty states plus DC, respectively, in 2030 compared to no policy, with implications for air quality and public health. We compare our findings to other model years, additional EPA ACE scenarios, and other modeling results for similar policies, finding similar outcomes. Our results demonstrate the importance of considering the emissions rebound effect and its effect on sub-national emissions outcomes in evaluating the ACE and similar policies targeting heat rate improvements.

## 1. Introduction

The United States Environmental Protection Agency (EPA) in August 2018 released its proposed Affordable Clean Energy (ACE) rule. The ACE is the proposed replacement to the existing EPA Clean Power Plan (CPP), the carbon dioxide ($CO_2$) emissions standard for existing power plants. EPA has a legal obligation to regulate greenhouse gas emissions from existing power plants, which was affirmed by the Supreme Court's 2007 decision in *Massachusetts v Environmental Protection Agency* and triggered by the EPA's formal finding in 2009 that greenhouse gas emissions endanger public health and welfare (Mass v EPA 2007, EPA 2009).

The CPP was finalized in 2015 and established state-based $CO_2$ emissions goals for affected fossil fuel-fired power plants. The CPP identifies a number of flexible compliance options as part of the "best system of emissions reductions" (BSER) that the EPA is charged with identifying under section 111(d) of the Clean Air Act. It allows emissions reductions to come from carbon intensity reductions at individual plants—including heat rate improvements or fuel cofiring at the source—or from the substitution of generation towards less carbon-intensive and zero-carbon energy sources (EPA 2015a). Averaging across electricity generating units (EGUs) and intra- and inter-state trading among units are also allowed. Given the flexible compliance structure, the CPP can be termed a "systems-based" standard. At the time it was finalized, it was estimated that the CPP would decrease $CO_2$ emissions by 415 million tons, or 19 percent, below a business as usual base case level, or 32 percent below 2005 levels, by 2030 (EPA 2015b).

The proposed ACE instead employs a narrow "source-based" regulation, which defines and limits the legally relevant BSER as heat rate improvement opportunities at individual coal plants (EPA 2018a). Heat rate is the amount of fuel input (Btu) used to produce a kWh of electricity; a lower heat rate indicates a more efficient unit, which emits less $CO_2$ per kWh. As a general rule of thumb, a reduction of 10 million Btu equals roughly a one-ton reduction in $CO_2$ for coal EGUs. There is considerable heterogeneity in the heat rate of U.S. coal plants and substantial opportunity to make coal plants more efficient (Linn et al. 2014, Sargent & Lundy 2009, Staudt & Macedonia 2014, DiPietro & Krulla 2010, DOE/NETL 2009, MIT 2009, SFA 2009, Campbell 2013). ACE sets standards for emissions rate improvements at facilities, but because these standards are based solely on estimated potential for heat rate improvements, we refer to this type of source-based option as a heat rate improvement standard. ACE does not include fuel cofiring among its described emission reduction options. States would be required to submit plans to EPA to implement the rule, taking into account criteria such as remaining useful life, and it is possible states would propose to allow co-firing to achieve comparable emissions reductions. The ACE also allows for the possibility that states determine that no emissions reduction options are feasible.

With the issuance of the proposed replacement regulation, the EPA released a regulatory impact analysis (RIA) that models emissions under the ACE compared to a reference scenario with the CPP and a scenario with no power plant carbon standard (EPA 2018b). The RIA includes projections of national power section emissions outcomes, but does not examine or quantify the role that a potential emissions rebound effect may play in driving the emissions outcomes. The rebound effect is a phenomenon in which facilities with high baseline emissions rates are made more efficient through investments to reduce their heat rates, and consequently operate more frequently and remain in operation for a longer period. This phenomenon is well documented in the environmental economics literature, though the majority of evidence focuses on energy efficiency (Greening et al. 2000, Sorrell et al. 2009). Previous studies have found evidence that an emissions rebound effect can diminish emissions reductions or even lead to emissions increases following heat rate improvements at high-emissions facilities (Linn et al. 2014, Keyes et al. 2018), but no other studies have specifically examined the role of an emissions rebound in the ACE.

We analyze the model-plant level results published by EPA to better understand the predicted impact of ACE on $CO_2$ emissions from coal plants and the potential impact on total $CO_2$ emissions at national and state levels (EPA 2018b). We also analyze the changes in emissions of co-pollutants including sulfur dioxide ($SO_2$) and nitrogen oxides ($NO_X$), which affect local air quality and human health.

We conduct a formal decomposition analysis of the estimated national changes in generation and $CO_2$ emissions between the ACE and a no-policy scenario to examine the underlying drivers of the emissions changes and to estimate the contribution of a potential emissions rebound effect. We provide decomposition results for states that are estimated to experience emissions increases under the source-based ACE rule.

Our analysis largely evaluates the impacts of ACE based on 2030 projections for a central case we selected from EPA's three illustrative ACE modeling scenarios. In addition, we compare these results to emissions results for 2021–2050 and for the EPA's two other illustrative ACE cases.

This analysis builds upon a study by the same authors that independently models potential national and state level $CO_2$ emissions impacts in 2030 for a source-based scenario compared to a scenario with no power plant carbon standard and to a flexible systems-based scenario similar to the CPP (Keyes et al. 2018). Our findings on the emissions rebound effect are compared to the results of Keyes et al. (2018).

## 2. Methods

### 2.1. Data

We conduct our analysis using results from the EPA's policy scenario modeling for the ACE RIA. EPA used the Integrated Planning Model (IPM) to estimate power sector outcomes from 2021–2050. IPM is a dynamic linear programming engineering-economic model of the US power sector. It maps almost 13,000 existing and planned EGUs into about 1,700 model plants. The model differentiates power sector outcomes into demand and supply regions and accounts for interstate electricity trade. IPM is solved with fixed electricity demand. EPA uses IPM to project emissions of $CO_2$ and co-pollutants and a number of other outcomes under various policy scenarios.[1]

Five scenarios were modeled using IPM: a scenario with no power plant carbon standard, an illustrative scenario with the CPP, and three illustrative ACE scenarios that represent potential state determinations of performance standards and compliance with those standards (EPA 2018b). The CPP scenario assumes a rate-based implementation applied only to existing fossil-fired EGUs, one of multiple options available to states. Each ACE scenario assumes uniform heat rate improvement (HRI) potential at all coal plants and uniform cost per kW of HRI investment. The ACE scenarios differ in their assumptions about the status of the New Source Review (NSR) provision of the U.S. Clean Air Act. NSR currently requires permitting for major generation sources that make major modifications. ACE introduces a change in NSR to allow major sources to avoid triggering NSR if modifications do not affect their hourly rate of emissions. The first ACE scenario, 2 percent HRI at $50/kW at coal plants, assumes that the EPA's proposed revisions to the NSR requirements are not implemented and therefore identifies relatively modest opportunities for heat rate improvements; the second scenario, 4.5 percent HRI at $50/kW, assumes NSR revisions are implemented and identifies greater opportunities for heat rate improvements; and the third scenario, 4.5 percent HRI at $100/kW, also assumes NSR revisions are implemented but assumes heat rate improvements have a higher cost, which is more appropriate for plants with relatively low capacity or limited remaining useful life.

Our analysis uses the published output from EPA's IPM model runs. We use the IPM State Emissions datasets to examine total emissions of $CO_2$ and co-pollutants $SO_2$ and $NO_X$ at the state and national level. Additionally, we use the IPM RPE datasets, which provide projections of fuel generation and emissions ($CO_2$, $SO_2$ and $NO_X$) for each model plant to evaluate outcomes. Our analysis focuses on emissions outcomes in 2030 for the 4.5 percent HRI at $50/kW scenario compared to the CPP and no-policy scenarios. We choose this scenario as our ACE central case because it incorporates the implementation of EPA's proposed NSR reform and a lower cost of HRI investment. We also compare these results with the other two ACE scenarios and to results for 2021–2050.

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[1] See EPA (2018b) for a detailed description of modeling assumptions and inputs.

### 2.2. Decomposition Analysis

To analyze estimated changes in EGU generation and associated emissions, we use a logarithmic mean decomposition index (LMDI) approach, based on Ang (2015). We implement Model 1 in Table 1 of Ang (2015) and substitute $CO_2$ emissions for energy consumption (E) and electricity generation for industrial output (Q). This method follows from that used in Palmer et al. (2018) to decompose modeled emissions changes under a carbon tax. We estimate the contribution of three factors to the change in emissions under the ACE compared to the no-policy scenario: activity, structure, and intensity. The activity factor is emissions changes associated with changes in total electricity generation; the structure factor is emissions changes associated with shifts in generation among fuel types; and the intensity factor is emissions changes associated with changes in emission intensity within fuel types.

The emission intensity of fuel types (the intensity factor) is the factor targeted by a heat rate improvement standard and it can change when a policy causes various fossil fuel plants to improve their efficiency. Under a heat rate improvement standard, the intensity factor contributes to emissions reductions if the standard successfully reduces the emission intensity of coal plants.

The rebound effect is embodied in changes in the generation mix (the structure factor), which changes when a policy affects the relative competitiveness of generation sources. This can occur under a heat rate improvement standard if the standard improves the efficiency of coal plants and thus causes substitution towards coal away from other, lower-emitting generation sources. Our estimate of the rebound effect is likely conservative because the EPA's model holds total demand constant. If demand were allowed to change, the rebound effect would include both the structure factor and the activity factor. Change in demand can occur if the increased efficiency of coal lowers the cost of electricity generation and thus increases total electricity demand, as would be expected in organized wholesale power markets. In regulated markets, these investments could increase or decrease total costs, depending on the reason such investments are previously unrealized. Reasons could include inconsistent pass-through clauses, avoidance of triggering NSR, access to capital, and uncertainty about greenhouse gas regulations (Richardson et al. 2011, Campbell 2013, Linn et al. 2014). However, under constant demand, at the national level the activity factor in our analysis is not directly associated with the rebound effect. At the state level, a change in the activity factor can be associated with the rebound effect because changes in trade flows across states can lead to a net change in generation in some states. This effect is absorbed into the structure factor at the national level. Although electricity demand is held constant, total electricity generation (the activity factor) can still differ on the national level across model scenarios for several reasons: policies may cause changes in trade flows between the U.S. and Canada, or changes in state or regional generation within the U.S. These changes may affect the total amount of electricity transferred between regions, thus affecting total losses and generation.

## 3. Results

### 3.1. National and State Level $CO_2$ Emissions Changes

National $CO_2$ emissions are projected to be slightly lower under the ACE compared to no policy, and higher compared to the CPP, in all modeled years but 2050 (Table 1). In 2050, two of the three ACE scenarios have higher $CO_2$ emissions compared to no policy. Cumulative $CO_2$ emissions from 2021–2050 are slightly lower under all three ACE scenarios compared to no policy and slightly higher compared to the CPP. In 2030, compared to no policy, $CO_2$ emissions are projected to be 0.8 percent lower under the

4.5 percent HRI at $50/kW scenario, 0.7 percent lower under the 2 percent at $50/kW scenario, and 1.5 percent lower under the 4.5 percent at $100/kW scenario.

There is substantial variation in state-level outcomes under the ACE. For the 4.5 percent HRI at $50/kW scenario, eighteen states plus the District of Columbia are projected to experience at least small increases in $CO_2$ emissions in 2030 compared to no policy (Figure 1). The numbers are similar for the other two ACE scenarios: 16 states plus Washington, DC for the 2 percent at $50/kW scenario and 14 states plus Washington, DC for the 4.5 percent at $100/kW scenario. Compared to the CPP, 22 states and Washington, DC are projected to have emissions increases under the 4.5 percent HRI at $50/kW ACE scenario (Figure 2).[2]

## 3.2. Coal-Fired Power Plant $CO_2$ Emissions Changes

We examine the impact of the ACE on model coal-fired power plants to illustrate the main drivers of emissions changes by focusing on 2030 emissions for the 4.5 percent HRI at $50/kW scenario, which is our ACE central case. IPM's model coal plants are aggregated representations of constituent coal plants within states, 381 of which were operating in the U.S. in 2016 (EIA 2017a). Under EPA's projections of ACE, $CO_2$ emissions from coal plants are projected to be only slightly lower (0.6 percent) in 2030 compared to no policy (Table 2). While the emissions intensity of coal plants declines by 4.5 percent, the number of coal plants in operation and total coal-powered electricity generation increase. This shift offsets the benefits of emissions intensity improvements and causes the total emissions reduction to be small compared to the emissions intensity improvements.

Under the EPA's interpretation of section 111(d) of the Clean Air Act as constraining regulations to measures that can be taken at a source (power plant), total $CO_2$ emissions are actually projected to increase at a number of the affected plants. Of the 333 model coal plants that would be in operation in 2030 under no policy, 93 of those (or 28 percent) are projected to have higher total $CO_2$ emissions under the ACE. Additionally, under the ACE five additional model coal plants are projected to be operating in 2030 that would have been idled or retired under no policy.

## 3.3. Decomposition of $CO_2$ Emissions Changes

The decomposition shows the extent to which the rebound effect is projected to offset emissions reductions under the ACE. Total national emissions under the ACE are estimated to decrease by 14.3 million short tons (0.8 percent) compared to the no-policy scenario in 2030. Our decomposition analysis breaks down the three primary factors driving that change in emissions (Figure 3a). We find that reductions in emissions intensity within fuel types reduce emissions by 47.4 million tons, mainly due to the lower emissions intensity of coal generation. However, the rebound effect associated primarily with greater utilization of coal plants increases emissions by 32.4 million tons, partially offsetting the reductions from improvements in emissions intensity and resulting in smaller estimated total reductions. Note that the rebound effect is greater on a fleet basis, due to substitution to more efficient units, than researchers have estimated for an individual facility (e.g. Linn et al. 2014). A slight increase in total electricity generation drives emissions up by an additional 0.6 million tons.

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[2] Conversely, 25 states are projected to have lower emissions under the the 4.5 percent at $100/kW scenario compared to the CPP. This is because the CPP creates performance standards for fossil generation sources, and emissions at EGUs can increase under the CPP if their level of generation increases. The CPP is a flexible standard aimed at achieving system-wide emissions reductions.

For the eighteen states plus DC projected to experience higher $CO_2$ emissions in 2030 under the ACE compared to no policy (Figure 1), total $CO_2$ emissions are expected to increase by 8.5 million tons. Decomposition reveals that emissions intensity improvements drive down emissions by 14.3 million tons, but these reductions are more than offset by generation mix shifts that drive up emissions by 21.4 million tons and greater total generation that drives up emissions by 1.4 million tons (Figure 3b). This rebound effect is caused mostly by shifts towards increased coal generation. Of the eighteen states that experience total increases in $CO_2$ emissions, fourteen states experience an emissions increase from coal-fired power plants in their state. In the other four states (California, Georgia, Massachusetts, and Oregon) plus DC, the emissions increases are mainly due to increased emissions from natural gas. Increases in state-level natural gas emissions could occur for several reasons that are specific to state and regional electricity markets. This pattern exposes another unintended consequence of the ACE that could diminish emissions reductions in some states.

Maryland has the greatest percent increase in emissions under the ACE compared to no policy in 2030 (8.7 percent) and provides an informative illustration of the emissions rebound effect. Maryland has two model coal plants in operation under the ACE, neither of which would be in operation with no policy in place. Thus, the shift in the generation mix towards coal drives up emissions by 0.8 million tons and causes an overall increase in emissions in the state (Figure 3c).

Interstate trade in electricity can exacerbate the emissions rebound in some states, because coal EGUs that become more efficient may compete not only with EGUs in their state but also others in their power market region. For example, the emissions intensity of coal in a net electricity exporting states like Alabama improves in 2030 under the ACE compared to no policy. However, coal generation and total generation increase in the state, suggesting that electricity exports increase. The increase in fossil generation drives up emissions by 2.2 million tons, offsetting the emissions intensity improvements and resulting in a net increase in emissions by 1 million tons.

### 3.4. Criteria Air Pollutant Emissions Changes

National $SO_2$ emissions in 2030 are projected by EPA to decrease by 0.7 percent under the ACE compared to no policy, with nineteen states showing $SO_2$ emissions increases (Figure 4). National $NO_X$ emissions are projected by EPA to decrease by 1.0 percent, with twenty states plus DC showing emissions increases (Figure 5). Compared to the CPP, national $SO_2$ emissions are projected by EPA to be 5.9 percent higher under ACE and $NO_X$ emissions are projected to be 5.0 percent higher.

## 4. Discussion

### 4.1. Comparison of Results

Our analysis of ACE impacts using EPA's RIA demonstrates the potential for a rebound effect to occur and limit decrease emissions reductions. Previous studies have found evidence that a rebound effect is associated with heat rate improvements at high-emissions rate facilities, and changes in the operation of these facilities diminishes the reduction in emissions that would otherwise occur (Linn et al. 2014). Moreover, because these facilities have lower operating costs after the heat rate improvements are made, they are likely to delay their ultimate retirement and may remain in service longer into the future (Burtraw et al. 2011). Our analysis suggests this is the case, because by 2050 $CO_2$ emissions under the ACE exceed emissions under no policy. This consideration is important since $CO_2$ is a stock pollutant that accumulates in the atmosphere each year.

We compare the results of this analysis to another study by the same authors (Keyes et al. 2018), in which the spatially explicit effects of scenarios constructed independently but similar to the ACE are modeled, including a source-based heat rate improvement standard. Keyes et al. (2018) uses results from IPM to compare their source-based scenario to a no-policy scenario and a systems-based scenario similar to the CPP. Because the modeling conducted for Keyes et al. (2018) is independent from that used by EPA in its ACE RIA, it provides an alternative estimate of emissions outcomes. Importantly, the results based on EPA's modeling can be compared only qualitatively to the Keyes et al. modeling results because baseline economic conditions differ between the two sets of model runs. Keyes et al. (2018) uses power sector modeling based on the electricity industry as it was configured in 2014, and the industry has since undergone substantial changes including retirement of many fossil units. Coal generation declined from 40 percent of total power generation in 2013 to 31 percent of total generation in 2017, and overall fossil fuels supplied 62 percent of total generation in 2017 compared to 67 percent in 2013 (EIA 2018). The analyses also employ different assumptions about policy design and implementation. For example, the source-based standard used in Keyes et al. (2018) includes cofiring up to 15 percent with natural gas or biomass as a compliance option, while the ACE does not consider cofiring as a candidate technology for BSER. Therefore, emissions projections in the EPA modeling results are lower for the no-policy case and the estimated emissions impacts of the source-based policy are smaller compared to Keyes et al. (2018) (Table 3). However, Keyes et al. (2018) affirm the finding that a rebound effect could lead to emissions increases at individual plants and in some states based on the EPA's modeling.

A notable result from EPA's RIA modeling is that the impact of the CPP on $CO_2$ emissions compared to no policy is small (4 percent reduction in 2030) compared to Keyes et al. (2018), EPA's 2015 RIA for the CPP final rule and the Energy Information Administration's 2017 Annual Energy Outlook (EPA 2015b, EIA 2017b). One reason for the relatively small impact of CPP in the ACE re-analysis is that EPA's ACE no-policy case includes less fossil fuel generation than previous RIAs. Another reason is the set of assumptions that EPA uses for CPP implementation in the ACE RIA, which assumes coverage only for existing generation sources rather than existing and new sources and no incremental energy efficiency investments. These assumptions reduce the projected emissions benefits under the CPP.

The proposed ACE rule, in addition to suggesting changes to power plant carbon standards, also would reform the NSR program for new and significantly modified facilities. As discussed above, the reform to NSR would allow power plants to avoid NSR review as long as their hourly rate of emissions do not increase. This reform may create a loophole for some plants to adopt HRI measures and potentially increase emissions. EPA's projections for the scenario incorporating NSR reform (4.5 percent HRI at $50/kW) and a scenario without NSR reform (2 percent HRI at $50/kW) shows minor impacts of NSR reform on $CO_2$ emissions.

## 4.2. Policy Implications

The $CO_2$ emissions impacts of the ACE have implications for the twenty states that have adopted greenhouse gas emissions targets (C2ES 2018). Twenty-two states plus DC are projected to have higher emissions under the ACE compared to the CPP, and eleven of these states plus DC currently have greenhouse gas emissions targets in place. These states can be expected to face more difficulty achieving their targets due to the replacement of the CPP. Further, of the eighteen states and DC projected to experience higher $CO_2$ emissions compared to no policy, seven—California, DC, Florida, Maryland, Massachusetts, New York and Oregon—have greenhouse gas emissions targets. For these states, achieving their emissions targets may be more difficult under the ACE compared to having no federal power plant carbon standard in place.

The possibility for the rebound effect to lead to emissions increases at individual plants and for entire states raises the question whether the heat rate improvement standard proposed under ACE qualifies as the "best system of emissions reduction" (BSER) that EPA is charged with identifying in its development of a power plant carbon standard under section 111(d) of the Clean Air Act. The projected impact of the rebound effect on $CO_2$ emissions under the ACE should be taken into consideration in determining whether the BSER requirement has been satisfied.

The change in emissions of co-pollutants under the ACE also has implications for regional air quality and public health. $SO_2$ and $NO_X$ are precursors to ambient $PM_{2.5}$ and $NO_x$ emissions contribute to ambient ozone, both of which have effects on premature mortality and morbidity. States with increased emissions may experience greater difficulty achieving or maintaining the U.S. National Ambient Air Quality Standards established under the Clean Air Act. EPA estimates that, nationally, the ACE will lead to a slightly lower number of $PM_{2.5}$- and ozone-related premature deaths compared to no policy in 2030, but it estimates that ACE will substantially increase premature deaths compared to the CPP.

## 5. Conclusions

Our analysis finds that the projected emissions rebound effect in EPA's ACE RIA undermines emissions reductions from the ACE rule compared to both the CPP and to no power plant carbon standard. Although the emissions intensity of modeled coal plants decreases, the number of operating coal plants and the amount of coal-powered electricity generation increases. Under the ACE central case, the rebound effect causes emissions to increase at 28 percent of coal plants in 2030. As a result, total $CO_2$ emissions increase in eighteen states plus DC and national $CO_2$ emissions decrease by only 0.8 percent in 2030. Further, emissions of $SO_2$ decline by only 0.7 percent with increases in nineteen states, and emissions of $NO_X$ decline by 1.0 percent with increases in 20 states plus DC. The other ACE scenarios evaluated show similar outcomes driven by a rebound effect.

Our finding that under a source-based power plant standard the rebound effect can undermine pollutant emissions decreases at the national level and lead to increased emissions at individual coal plants and in a number of states is substantiated by similar findings based on independent power sector modeling (Keyes et al. 2018). This result, which was not examined in the RIA for the ACE proposed rule, has implications for the defensibility of ACE as the Best System of Emissions Reductions, for the ability of some states to achieve their greenhouse gas emissions reduction targets, and for jurisdictions that experience poor air quality to protect public health.

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## Tables

**Table 1**

**National Power Sector $CO_2$ Emissions (million short tons)**

| | No Policy | CPP | 4.5% HRI at $50/kW (ACE Central Case) | 2% HRI at $50/kW | 4.5% HRI at $100/kW |
|---|---|---|---|---|---|
| 2021 | 1,710 | 1,701 | 1,709 | 1,709 | 1,707 |
| 2023 | 1,801 | 1,754 | 1,814 | 1,801 | 1,802 |
| 2025 | 1,829 | 1,780 | 1,812 | 1,816 | 1,799 |
| 2030 | 1,811 | 1,737 | 1,797 | 1,798 | 1,785 |
| 2035 | 1,794 | 1,728 | 1,787 | 1,783 | 1,772 |
| 2040 | 1,849 | 1,782 | 1,841 | 1,840 | 1,829 |
| 2045 | 1,843 | 1,782 | 1,832 | 1,833 | 1,821 |
| 2050 | 1,804 | 1,753 | 1,815 | 1,801 | 1,808 |
| **2021-2050 Cumulative (interpolated)** | **54,469** | **52,694** | **54,261** | **54,195** | **53,920** |

**Table 2**

**Comparison of model coal plants between ACE Central Case and No-Policy Case, 2030**

| | No Policy | ACE Central Case | Change (level) | Change (percent) |
|---|---|---|---|---|
| Number of Model Coal Plants in Operation | 333 | 338 | 5 | 1.5% |
| Total Generation (GWh) | 937,757 | 975,633 | 37,877 | 4.0% |
| Total Emissions (Thousand short tons) | 1,027,456 | 1,020,897 | -6,559 | -0.6% |
| Emissions Intensity (kg/kWh) | 0.99 | 0.95 | -0.04 | -4.5% |
| Heat Rate (Btu/kWh) | 10,395 | 9,930 | -465 | -4.5% |

## Table 3

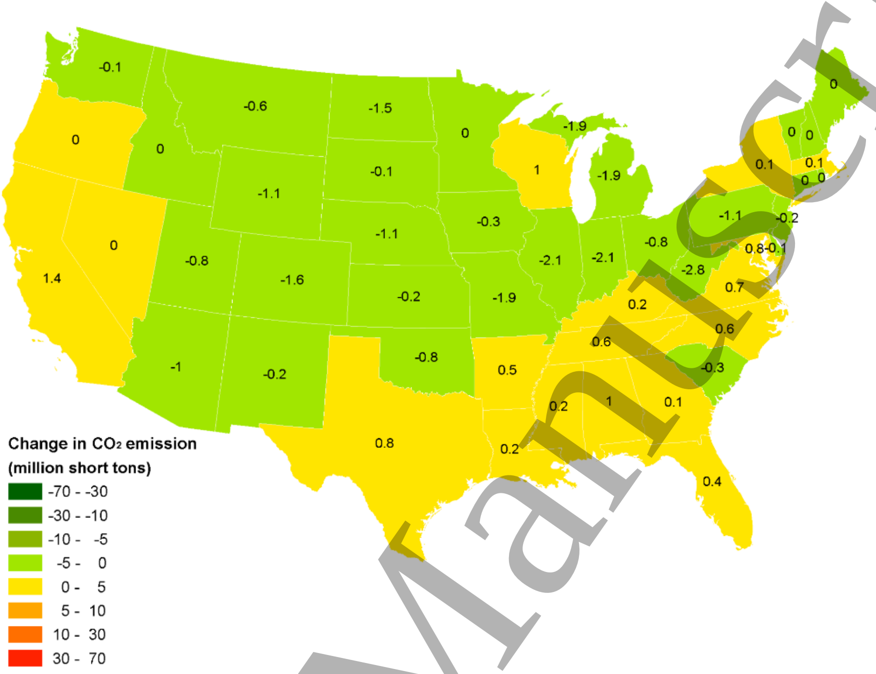
**Comparison of source-based scenario modeling results for 2030.**

| | Current Analysis based on EPA's ACE RIA | Keyes et al. (2018) |
|---|---|---|
| $CO_2$ Emissions under Source-based scenario, million short tons | 1,797 | 2,386 |
| $CO_2$ Emissions under No-Policy scenario, million short tons | 1,811 | 2,451 |
| *Difference* | *-0.8%* | *-2.6%* |
| $CO_2$ Emissions under Systems-based scenario, million short tons | 1,737 | 1,466 |
| *Difference* | *3.5%* | *63%* |
| Number of States with Emissions Increase Compared to No Policy scenario | 18 states plus DC | 8 states |
| Number of States with Emissions Increase Compared to Systems-based scenario | 22 states plus DC | 46 states |

# Figures

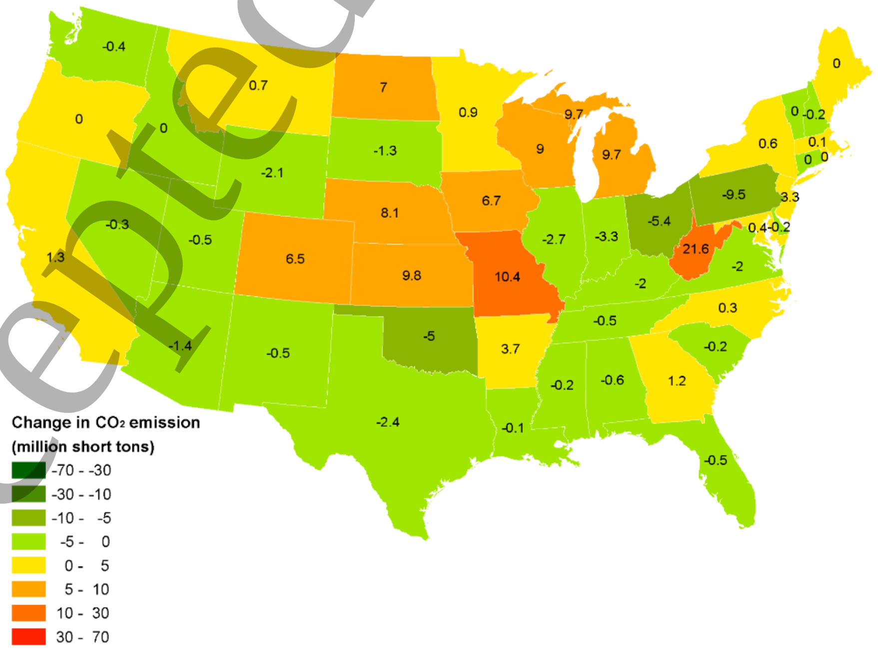
## Figure 1

CO$_2$ Emissions under ACE Central Case compared to No-Policy Case, 2030

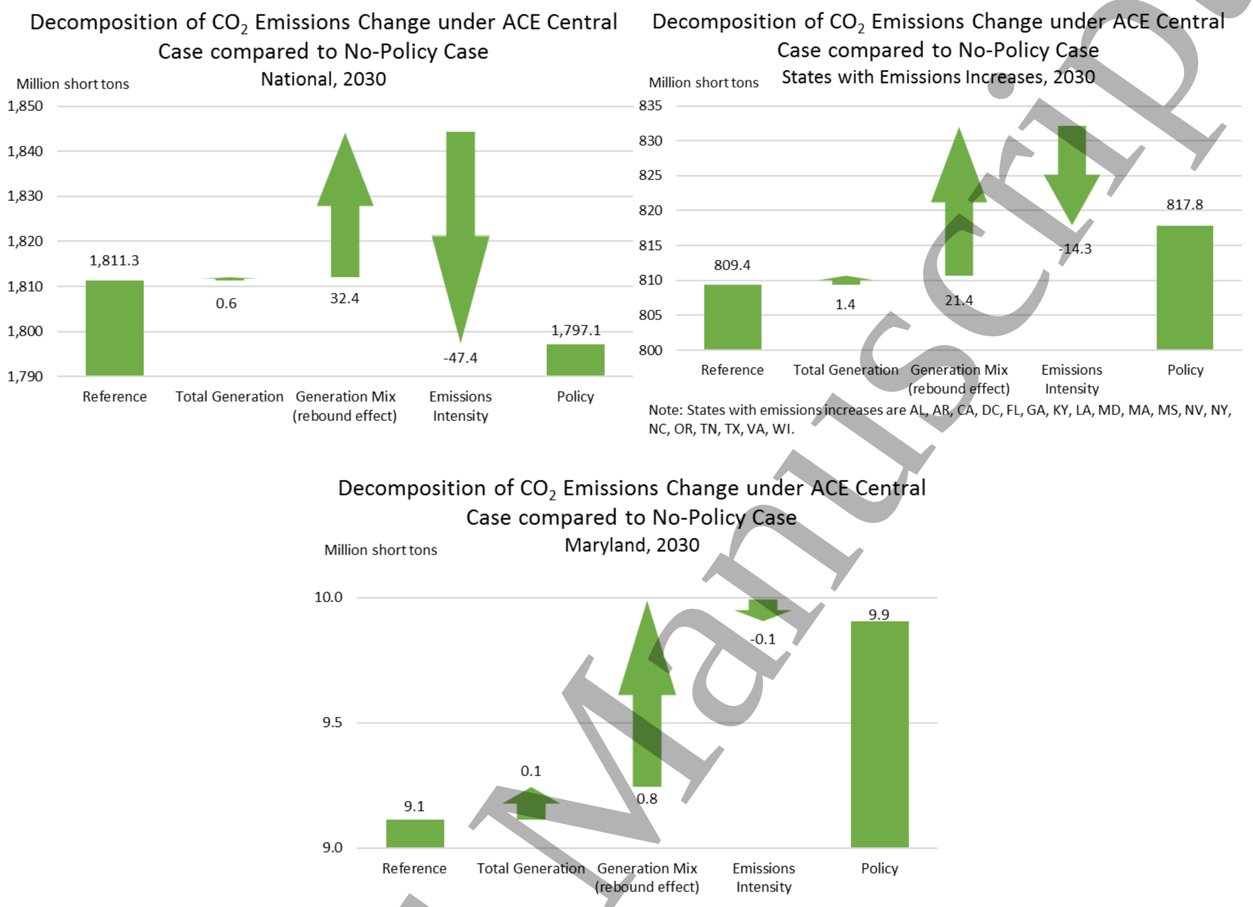


## Figure 2

CO$_2$ Emissions under ACE Central Case compared to CPP Case, 2030



## Figures 3a, 3b, 3c


Decomposition of $CO_2$ Emissions Change under ACE Central Case compared to No-Policy Case
National, 2030

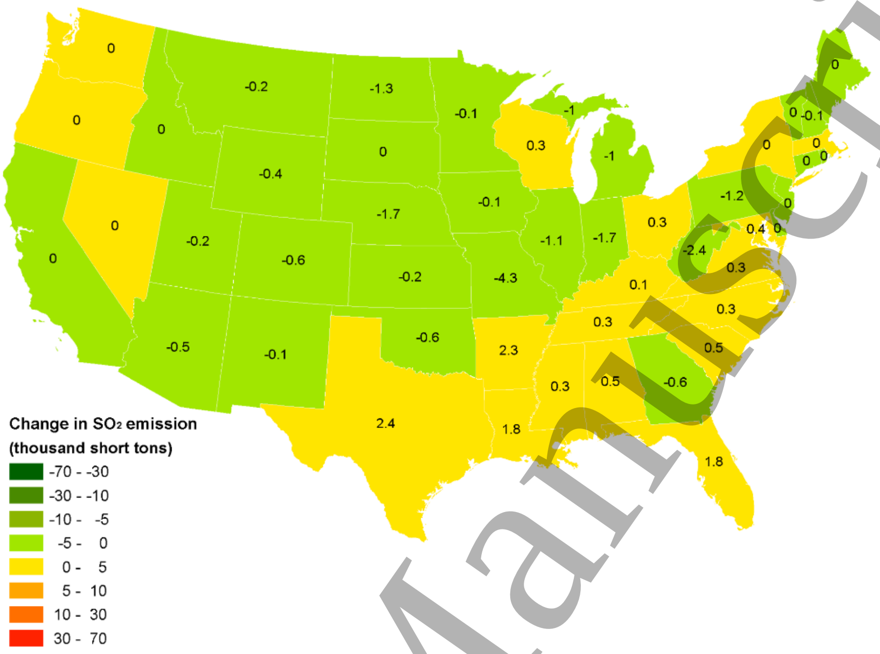
Decomposition of $CO_2$ Emissions Change under ACE Central Case compared to No-Policy Case
States with Emissions Increases, 2030

Note: States with emissions increases are AL, AR, CA, DC, FL, GA, KY, LA, MD, MA, MS, NV, NY, NC, OR, TN, TX, VA, WI.

Decomposition of $CO_2$ Emissions Change under ACE Central Case compared to No-Policy Case
Maryland, 2030

## Figure 4

### $SO_2$ Emissions under ACE Central Case compared to No-Policy Case, 2030



## Figure 5

### $NO_x$ Emissions under ACE Central Case compared to No-Policy Case, 2030