U.S. POLICY

INSIGHTS FROM A COMPARATIVE ANALYSIS OF CLEAN POWER PLAN MODELING

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September 2016

An updated context, including falling natural gas prices and the extension of federal tax credits, have prompted new modeling of the likely impacts of the Clean Power Plan. Five studies have recently been released analyzing the projected effects of the Clean Power Plan on outcomes including carbon dioxide emissions, the electricity generation mix, and electricity prices. These studies have also examined the probable impacts of different policy choices available to states in implementing the Clean Power Plan. This brief undertakes a comparative analysis of these studies, identifying results that are common across multiple studies and summarizing a few additional analyses of specific policy decisions.

INTRODUCTION

The U.S. Environmental Protection Agency (EPA) released the final version of the Clean Power Plan in August 2015, and many organizations, including EPA, modeled the impact of the rule. Since then, several developments have occurred that could affect the outcome of Clean Power Plan implementation, including the extension of the federal solar investment and wind production tax credits and a lower outlook for natural gas prices.

This paper describes key conclusions from five recent studies that used economic modeling to evaluate the likely impacts of the Clean Power Plan in light of these recent developments. We looked for findings that were consistent across models. Conclusions about the impact of particular policy choices that are consistent across multiple studies are the most robust, while impacts that are different between studies should be interpreted with more caution.

First, we review the most important insights from our multi-study analysis. We provide a short introduction to the studies included in the brief, and then offer a detailed look at prospective changes in the mix of electricity generation due to implementation of the Clean Power Plan. Finally, we describe various sensitivity studies around policy choices, such as: the choice between rate-based and mass-based approaches, the extent of interstate trading, and mass-based program design details. While we aim to cover all the major findings and relevant details from the modeling studies in this brief, it is not meant to be a comprehensive review of each study. Rather, this brief is intended to summarize the current state of knowledge regarding Clean Power Plan implementation modeling in an accessible way, and highlight additional analyses that might be of interest to more sophisticated readers.

KEY INSIGHTS

The five studies we reviewed use different assumptions and provide different projections of the likely effects of Clean Power Plan implementation. While the model projections within and between the studies are informative, results that are consistent across all models are the most robust. We have identified several high-level insights from this analysis that could be of use to policymakers and other stakeholders in the development of state implementation plans. Key insights include:

- **The Clean Power Plan reduces total power sector emissions** compared to business-as-usual (BAU) scenarios in every study. Market forces alone, i.e. lower costs for renewables and natural gas-fired generation, do not achieve the same level of reductions, even when accounting for the federal tax credit extensions. On average, the scenarios project total emissions in 2030 will be 18 percent lower than BAU because of the Clean Power Plan.
- **Renewables increase and coal decreases compared to business-as-usual** generation levels across all five studies. Nuclear and natural gas generation tend to increase due to the Clean Power Plan, though there is some model disagreement about how different implementation assumptions vary this impact.
- **The studies found the Clean Power Plan will have minimal impact on U.S. national average retail electricity rates**. Between the eight scenarios in the two studies that reported the likely influence of the Clean Power Plan on rates, the projected effect ranged from a 7 percent decrease to a 7 percent increase relative to business as usual. In most scenarios, the effect on prices falls between a 2 percent decrease and a 5 percent increase. This represents between a decrease of approximately $1.89 and an increase of $4.65 per month for the average U.S. household electricity bill. This estimate may not fully account for the fact that energy-efficiency measures could lower household consumption, thereby lowering monthly bills, or that people might choose to use less energy if rates go up.
- **Mass-based and rate-based plans yield similar cumulative reductions in emissions**. Across all five studies included in this brief, the reduction in total cumulative carbon dioxide emissions from the U.S. power sector through 2030 is approximately equal.
- **Emissions are higher under a patchwork scenario** in which states adopt different types of compliance approaches, some choosing rate-based plans and some mass-based plans. This result is driven by an increase in coal generation and a decrease in natural gas generation along with slower growth in renewables relative to uniform implementation of either rate-based or mass-based plans.
- **Total compliance costs are higher under rate-based plans** than under mass-based plans. While there is some regional variation, the studies agree that compliance costs will be higher if the states all adopt rate-based plans than if they adopt mass-based ones. Total compliance costs include the cost of building new power plants to meet demand.
- **EPA's proposed leakage protection provisions do not fully prevent** leakage from existing sources to new sources in the models**.** Two studies tested the effectiveness of the provisions in EPA's draft model rules for mass-based approaches. Both concluded that the provisions did not fully prevent leakage, and in fact the approach in the draft model rules led to leakage in the two models of about 100 million short tons, or about 5 percent of total power sector emissions.

OVERVIEW OF MODELS

Table 1 lists the five studies included in this report, the authors of which are MJ Bradley & Associates (MJB),[1] the Energy Information Administration (EIA),[2] the Bipartisan Policy Center (BPC),[3] a joint study by the Center for Strategic and International Studies (CSIS) and the Rhodium Group (RHG),[4] and the Nicholas Institute for

BOX 1: Glossary

Rate-based plans set a limit on the amount of carbon dioxide allowed per unit of electricity produced.

Mass-based plans set a limit on the total amount of carbon dioxide allowed, regardless of the amount of electricity produced.

Dual Rate is a type of rate-based plan which applies separate emissions performance rates for steam boiler and natural gas combined cycle units.

Blended Rate is a type of rate-based plan which applies a single performance rate for all fossil-fueled power plants.

Leakage in the context of this brief refers to two separate phenomena: one defined by EPA in which, under mass-based plans without the new source complement, generation from new fossil fuel-fired units replaces generation from existing units thereby leading to higher overall emissions; and another, applicable to patchwork scenarios, in which generation shifts from a state implementing a mass-based plan to a neighboring state implementing a rate-based plan.

Emissions refers to carbon dioxide emissions from the total U.S. power sector, including both existing plants, which are covered by the Clean Power Plan, and new plants, which are not covered.

New Source Complement (NSC) refers to the additional set of allowances EPA defines for each state implementing a mass-based plan that also covers new sources. The Clean Power Plan does not set a limitation on emissions from new sources, but EPA provides the NSC as an option to fulfill the Clean Power Plan requirement that mass-based plans take steps to prevent leakage.

Banking of emission allowances or emissions rate credits (ERCs) refers to holding those allowances or ERCs in an earlier time period for use or sale in a later time period.

Patchwork scenarios are those in which some states adopt mass-based compliance plans and some states adopt rate-based compliance plans.

Eastern Interconnection is one of the two major alternating-current electrical grids in the continental U.S. power transmission grid, covering most of the country east of the Rocky Mountains except most of Texas.

Western Interconnection is one of the two major alternating-current electrical grids in the continental U.S. power transmission grid, covering most of the country west of Texas.

ERCOT is the Electric Reliability Council of Texas which serves the minor alternating-current electrical grid covering most of Texas, and which is often used to refer to that grid itself.

Environmental Policy Solutions at Duke University.[5] The studies are differentiated by their choice of model, the number of different scenarios they include, and which policy choices they vary between scenarios. Additionally, the studies differed in their assumptions about the future costs of natural gas and installing new renewable generation capacity, though these assumptions are generally not explicitly laid out in the studies. Each study also includes business-as-usual (BAU) scenarios. These scenarios project what would happen if the Clean Power Plan is not implemented, but other regulations, such as the solar investment tax credit (ITC) and wind production tax credit, remain in place (PTC). The BAU projections are not equivalent between the different models as they are built from different assumptions, reflecting the uncertainties inherent to any modeling study. This underscores the idea that the most robust conclusions come from cross-scenario comparisons and analyzing the direction of change in each model, rather than the magnitude of change.

Several of the studies covered by this brief include multiple mass-based scenarios, some of which include

TABLE 1: Overview of Studies on Clean Power Plan Impacts

STUDY	MODEL USED	POLICY SCENARIOS INCLUDED IN STUDY					
		RATE VS. MASS	BREADTH OF TRADING	NSC VS. EXISTING-ONLY	PATCH-WORK	ALLOWANCE BANKING SENSITIVITY	VARIED AVAIL-ABLE ENERGY EFFICIENCY
MJ Bradley & Associates	IPM	✓	✓	✓			✓
Energy Information Administration	NEMS	✓	✓				
Bipartisan Policy Center	IPM	✓		✓	✓	✓	
Center for Strategic & International Studies/Rhodium Group	RHG-NEMS	✓					
Nicholas Institute	DIEM-Electricity	✓			✓		

IPM and DIEM-Electricity are dispatch planning models, while NEMS and RHG-NEMS are power and energy sector models. More detail is available in Appendix A.

the new source complement and some of which do not. For the sake of conciseness, throughout this brief, we frequently use "mass-based approaches," "mass-based compliance plans," or similar phrasing. Unless otherwise specified, this refers to a scenario in which the new source complement is included. This is also true for our discussion of patchwork scenarios, in which most states adopt mass-based approaches inclusive of the new source complement, while some states adopt rate-based approaches. In Appendix B, we provide a mapping of which scenario in each study is being referred to in the cases we discuss in our brief.

The five studies covered by this report also include a number of different Clean Power Plan implementation scenarios. Each of these scenarios varies one or more different policy choices. These choices include: a comparison of adopting mass-based plans versus rate-based plans, the geographic breadth of the secondary carbon market, whether the new source complement is included in mass-based plans, whether all states adopt the same type of compliance plan, whether banking of allowances is permitted, and variation in the amount of available energy efficiency. Though no study examines all of these choices, each contains two to four of them. An overview of the studies and the types of scenarios they include are detailed in Table 1.

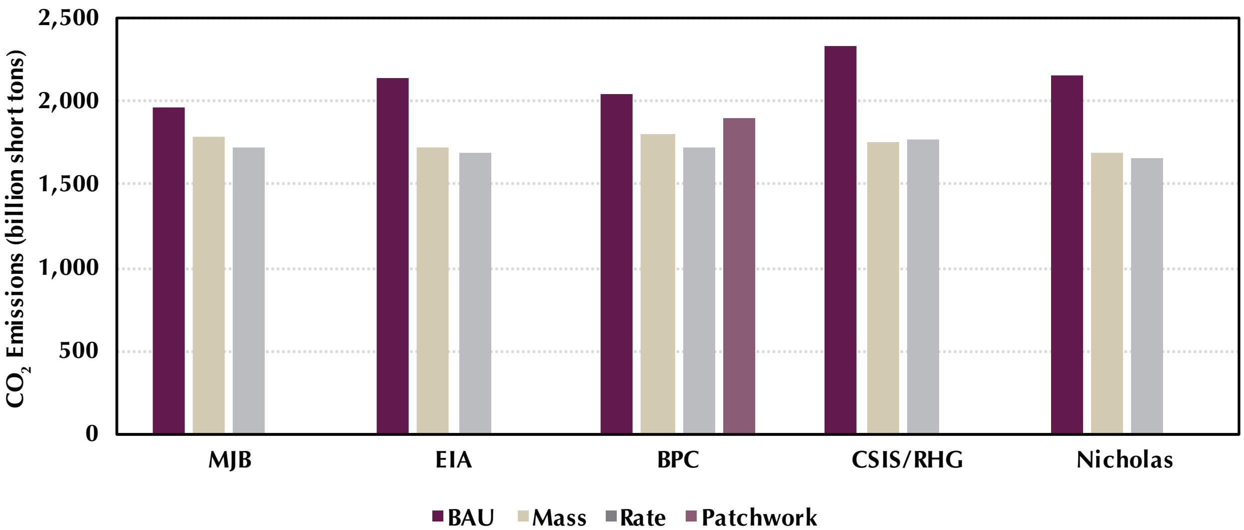
GENERAL CROSS-MODEL RESULTS

Despite the differences in assumptions made by each study, it can still be useful to examine outcomes of the different studies, both to observe any broad conclusions and to get a better sense of how the models differ from one another. Since the main objective of the Clean Power Plan is to reduce U.S. power sector emissions, we first analyze this key variable. For our summary, we compare the level of total carbon dioxide emissions from the entire power sector, both covered and uncovered sources of generation, thus including any potential emissions leakage from existing sources to new ones.

All five studies we examined report values for total power sector emissions in 2030, see Figure 1. They each have a different business-as-usual (BAU) estimate for total emissions due to differences in the assumptions used, such as different levels of available energy efficiency and different projected natural gas prices. Despite this, they all show reductions under any Clean Power Plan implementation scenario. On average, the scenarios we examine project that if all states adopt the same type of compliance plan, total emissions would be between 10 and 24 percent lower than BAU in 2030, or 18 percent lower on average.

Most of the studies included in this brief suggest that total sector emissions from 2022 to 2030 will be similar under a national uniform adoption of rate-based plans

FIGURE 1: 2030 Carbon Dioxide Emissions from the U.S. Electric Power Sector



Source: C2ES analysis of studies from MJ Bradley & Associates (June 2016), Energy Information Administration (June 2016), Bipartisan Policy Center (June 2016), Center for Strategic and International Studies and Rhodium Group (May 2016), and the Nicholas Institute for Environmental Policy Solutions (July 2016).

and under a national uniform adoption of mass-based plans. The different compliance approaches tend to result in different emissions trajectories, so that emissions in individual years may be quite different. Overall, however, either approach results in a total cumulative level of emissions that is very similar provided all states adopt the same type of compliance approach in four of the five studies. An exception, however, is the study by MJ Bradley & Associates that projects cumulative emissions will be lower under a national uniform adoption of mass-based plans than under a national uniform adoption of rate-based plans.

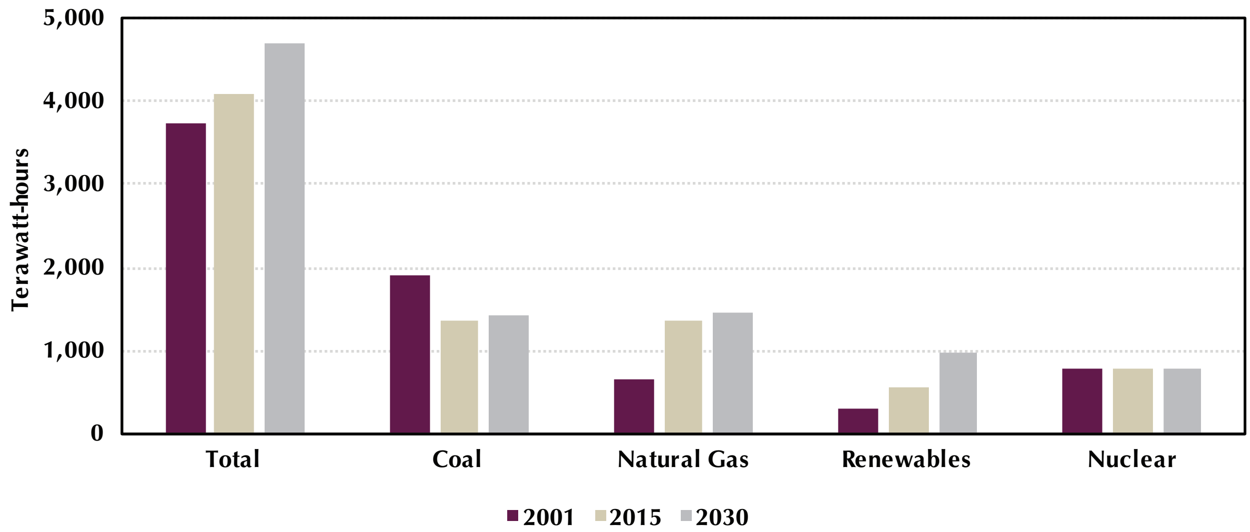
PROJECTED IMPACTS ON NATIONAL GENERATION MIX

Prior to examining the likely effects of the Clean Power Plan on the U.S. national generation mix, it is useful to survey both its recent history and the forecasts for its near future if the Clean Power Plan were not implemented. Such a review provides valuable context for an analysis of the consequences of both the Clean Power Plan as a whole as well as of the various policy decisions that can be made within the plan's overarching framework.

Figure 2 illustrates the historical, current and future fuel mix of the power sector over the course of approximately three decades (without the Clean Power Plan) through 2030. The figure shows total generation and also includes the data broken down into four fuel types—coal, natural gas, renewables including hydro, and nuclear—which together account for more than 95 percent of total generation. It combines data from 2015, with data from a decade and a half ago, and with projections of a decade and a half in the future.

There are a number of trends evident from looking at Figure 2. First, total generation growth over the next 15 years remains below 1 percent annually, mirroring growth over the last 15 years. In most of the studies, that growth primarily comes from renewables, principally solar and wind, though the study from MJ Bradley projects only modest growth in new renewable capacity driven by the Clean Power Plan. Under that business-as-usual scenario, half of the studies see coal generation increasing from 2015 to 2030 while the other half see it

FIGURE 2: Power Generation in 2001, 2015, and 2030 Under a Business-As-Usual Scenario



Source: "Net generation for all sectors, monthly," U.S. Energy Information Administration, accessed September 7, 2016, http://www.eia.gov/electricity/data/browser/#/topic/0. 2030 data from U.S. Energy Information Administration, "Annual Energy Outlook 2016" (Washington, DC: U.S. Energy Information Administration, 2016), http://www.eia.gov/forecasts/aeo.

falling. Across all the studies, natural gas is projected to continue to grow, though at a reduced pace relative to its growth since 2001.

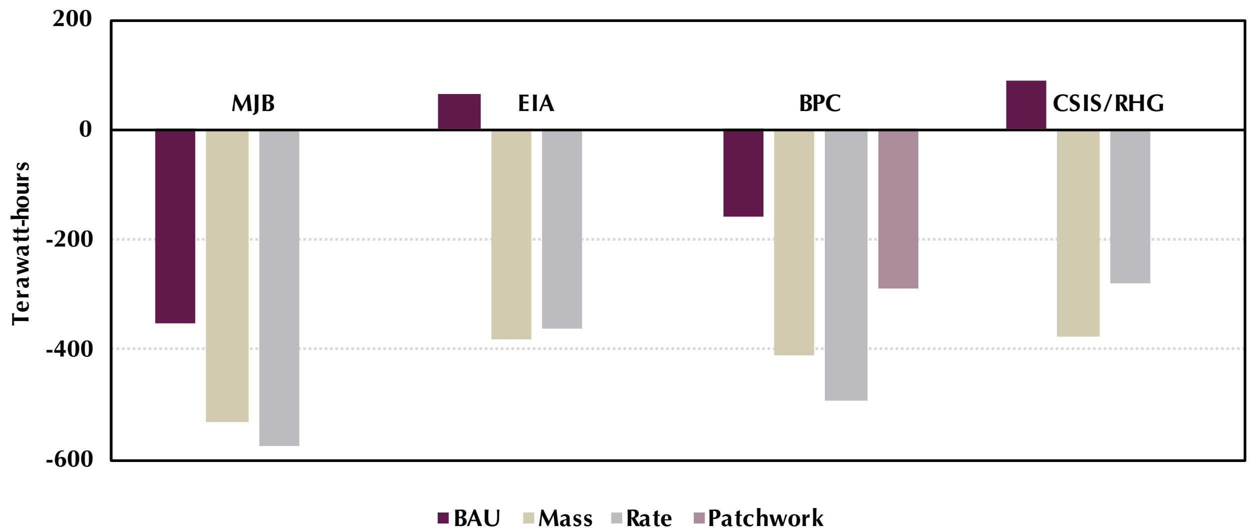
Moving to the scenarios with Clean Power Plan Implementation, most suggest that total generation in 2030 will be only slightly reduced by the implementation of the Clean Power Plan, falling from almost 4,700 terawatt hours under business as usual (BAU) as seen in Figure 2, to just below 4,600 terawatt-hours in EIA's projections of Clean Power Plan implementation. One determinant that impacts the level of total generation under the Clean Power Plan framework is the amount of energy efficiency incentivized. Scenarios that assume a high level of energy efficiency deployment see total generation numbers fall the most, between 3 and 7 percent from BAU. Energy efficiency is incentivized when either electricity prices rise or the cost of efficiency falls, which the Clean Energy Incentive Program (CEIP) portion of the CPP aims to incentivize. That program is a voluntary component of the Clean Power Plan to incentivize renewable and energy efficiency projects via early distribution of assets that will be tradable in Clean Power Plan markets.[6] In contrast to total generation levels, however, the studies suggest that many choices made in implementing Clean Power Plan are likely to have an impact on the mix of fuel types.

COAL

Under business-as-usual (BAU) conditions, the studies are split on the future of coal-fired generation, with half seeing a small increase in coal generation and the others projecting a continued decline. The essential difference underlying these varying results is the near-term future of natural gas prices, with those studies predicting lower prices of natural gas also predicting lower coal use for electricity generation. All studies, however, agree that the implementation of the Clean Power Plan will result in coal-fired generation continuing to decline over the next 15 years.

The degree to which coal declines at the national level, however, will be influenced by some of the choices policymakers make in their state implementation plans. One key choice is whether, within mass-based plans, states opt for only covering existing sources or whether they also include new sources and utilize the new source complement (NSC). Selecting the former results in a smaller decline in coal generation. Including the NSC causes coal generation to decrease approximately twice as much relative to BAU, as it does if the NSC is not included. It should be noted, however, that the study this comparison was drawn from did not include any leakage protection under the existing-only scenarios, while EPA

FIGURE 3: Change in Coal Generation, 2015–2030



Source: C2ES analysis of studies from MJ Bradley & Associates (June 2016), Energy Information Administration (June 2016), Bipartisan Policy Center (June 2016), and the Center for Strategic and International Studies and Rhodium Group (May 2016).

requires states to have some sort of protection included in their plans, suggesting that the practical impact of this choice will be less severe than the outcomes of the models.

A patchwork scenario, one in which states are divided between those implementing mass-based plans and those implementing rate-based plans, yields different results for the future output of coal-fired power plants. Only the Bipartisan Policy Center (BPC) and the Nicholas Institute reported a patchwork scenario. In the BPC study, most states pursue mass-based plans while six states (Florida, Georgia, Iowa, New Jersey, South Carolina, and Tennessee) opt for a dual-rate plan. The Nicholas Institute study includes five patchwork scenarios. In both studies, coal generation decreased less than it does when all the states implemented the same type of plan. National coal generation, which is only reported in the BPC study, falls by 11 percent in a patchwork scenario compared to BAU instead of 21–28 percent in other scenarios.

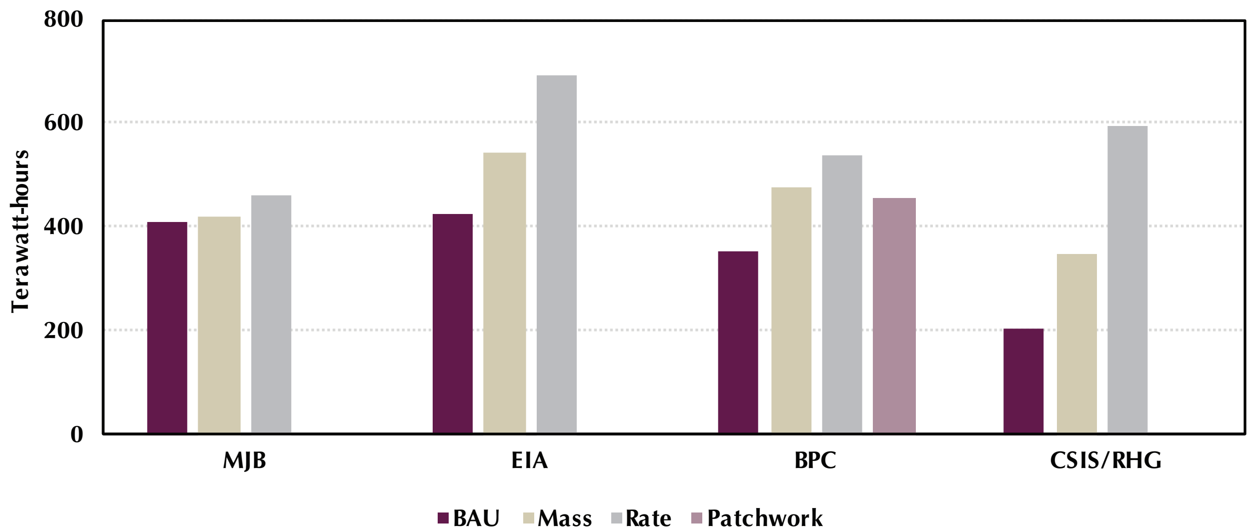
The decline in coal generation is also curbed, albeit not to the same degree as under a patchwork or mass-based existing-only scenario, by widening interstate trading and by increasing energy efficiency. Wider interstate trading in the models (at the interconnect or national level) tends to result in a smaller decline in coal generation, likely because a broader trading market lowers the price of allowances in states or regions that have a large proportion of their electricity currently generated by coal. Similarly, increasing energy efficiency in the models also increases coal generation due to lower total generation creating less demand for emission allowances and thus lower prices.

RENEWABLES AND HYDRO

All models project that generation by renewables will experience growth in the coming years under business-as-usual (BAU) scenarios. Though our classification includes wind, solar, hydroelectric, biomass, geothermal, and other technologies, it is wind and solar that will account for more than 80 percent of the sector's growth. Furthermore, the models universally agree that the implementation of the Clean Power Plan drives further growth in renewable generation, with that growth occurring almost exclusively via an increase in solar and wind generation.

The foundational question for state compliance plans, whether to pursue a rate-based or a mass-based plan, impacts renewable generation. Under rate-based plans, new renewable generation produces emission rate credits

FIGURE 4: Change in Renewable Generation (including hydro), 2015–2030



Source: C2ES analysis of studies from MJ Bradley & Associates (June 2016), Energy Information Administration (June 2016), Bipartisan Policy Center (June 2016), and the Center for Strategic and International Studies and Rhodium Group (May 2016).

(ERCs) which can produce an additional revenue stream for project developers while under mass-based plans renewables receive less direct financial incentives. Thus, under rate-based plans, renewable generation increases more than it does under mass-based plans. The magnitude of this margin does vary among models. The average difference in the degree of increase across the five studies is 7 percent.

The growth of renewable generation is slowed under three scenarios relative to the appropriate baseline—patchwork plan implementation, increased energy efficiency, and mass-based approaches that do not adopt the new source complement. In the patchwork scenario analyzed by BPC, the six states adopting dual-rate compliance plans have plentiful low-cost generation of emission rate credits due to the prevalence of under construction nuclear power and abundant opportunities for new renewable generation. These states also have limited options to sell those ERCs, a situation which allows for increased fossil fuel generation to substitute for some renewable generation that would otherwise have been needed. Scenarios with higher incremental energy efficiency saw lower growth of renewable generation.

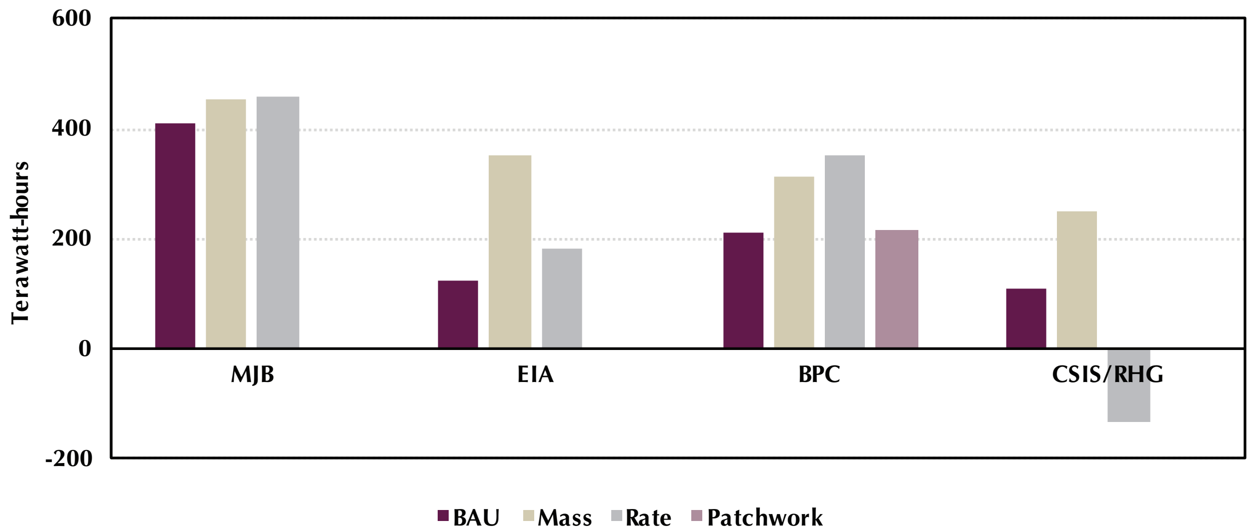
Energy efficiency is likely to have complex impacts on the electricity generation mix. MJ Bradley & Associates (MJB) investigated the impact of energy efficiency, analyzing scenarios with three levels of potential energy efficiency. In the medium level, there was less renewable generation relative to the low level, and in the high level there was also less natural gas generation. This is due to the fact that increased energy efficiency likely displaces the need for new higher cost electricity generation capacity, particularly new renewable and natural gas builds.

The new-source complement (NSC) for mass-based plans is also important to the future course of renewable generation growth. The studies from BPC and MJB suggest that not including the NSC results in lower growth in new renewables capacity compared to including the NSC, with that load being served instead by higher levels of coal generation in those scenarios as discussed above. Although the scenarios not including the NSC in the MJB study do not include any leakage protection measures, the studies from the Nicholas Institute and BPC suggest that such measures are not completely successful in preventing leakage, as detailed later in this brief.

NATURAL GAS

Similar to renewables, natural gas is primed, even under business as usual, to experience continued growth in generation. That growth, however, is likely to be slower than in the recent past, with generation increasing

FIGURE 5: Change in Natural Gas Generation, 2015–2030



Source: C2ES analysis of studies from MJ Bradley & Associates (June 2016), Energy Information Administration (June 2016), Bipartisan Policy Center (June 2016), and the Center for Strategic and International Studies and Rhodium Group (May 2016).

between 8 and 30 percent from 2015–30 under business as usual (BAU) compared to more than 100 percent growth between 2001–15. The Clean Power Plan drives further increases in natural gas generation in almost all scenarios.

The possibility of a national patchwork scenario would appear to limit the growth from natural gas-fired generation, with both BPC and Nicholas Institute studies seeing 6–8 percent less gas generation under this approach relative to scenarios where all states implement the same approach. As mentioned previously, a patchwork scenario sees higher generation in rate-based states at the expense of generation in mass-based states. Because of the interconnectedness of the electricity system, the changes in the rate-based states in the patchwork scenarios affect the national profile, including the total outlook for natural gas.

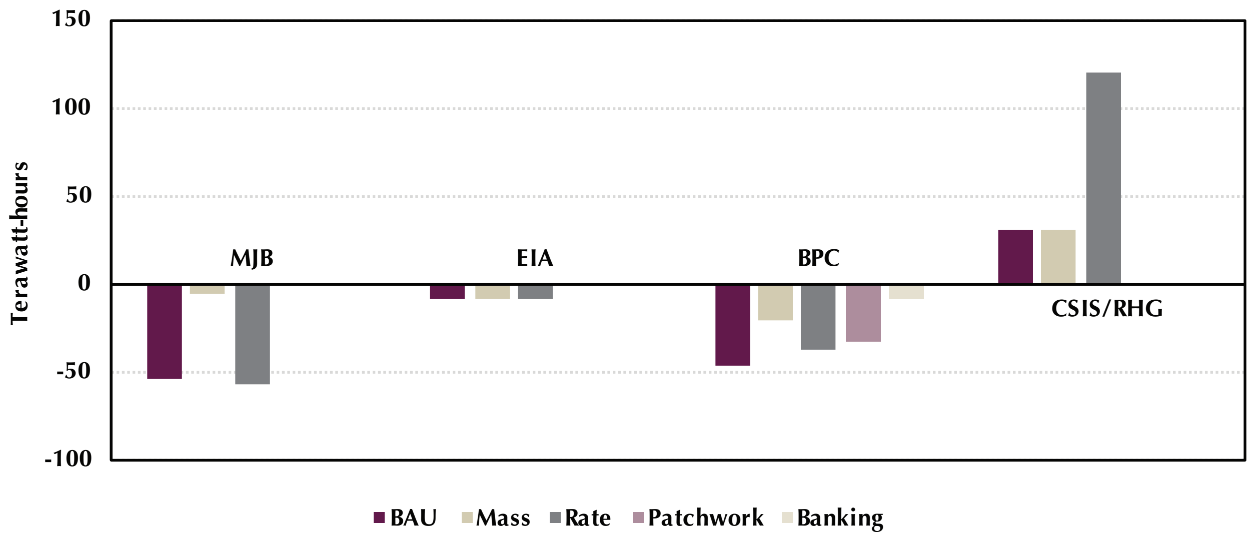
The breadth of the market for emission allowances appears to also impact natural gas-fired generation, though the models disagree to what extent. Broader trading scenarios result in lower allowance prices, which tend to protect existing fossil fuel-fired generation at the expense of new natural gas buildout. The EIA and MJB studies examined this variable under a mass-based approach including the NSC. EIA found that natural-gas fired generation was 6 percent lower under an interconnect-wide trading scenario relative to a scenario with more limited interstate trading, while MJB found the change was about 1–2.5 percent.

NUCLEAR

In recent decades, nuclear power's share of total generation has been slowly but steadily declining. The five studies examined see that as likely to continue in the near future, though they also project the changes in absolute generation numbers to be much smaller than for other fuel types. The studies generally predict more nuclear generation under the Clean Power Plan than under business as usual (BAU). Different implementation assumptions can change both the direction and magnitude of projected nuclear generation changes in the scenarios we examined, though not always. For example, the EIA projections see approximately the same level of nuclear generation through 2030 regardless of Clean Power Plan implementation scenario. These observations make it difficult to draw conclusions about how nuclear generation might be affected by Clean Power Plan implementation.

One policy design option does appear to have a clear impact on nuclear generation—allowance banking under a mass-based approach. Relative to the national adoption of mass-based standards, the BPC study finds

FIGURE 6: Change in Nuclear Generation, 2015–2030



Source: C2ES analysis of studies from MJ Bradley & Associates (June 2016), Energy Information Administration (June 2016), Bipartisan Policy Center (June 2016), and the Center for Strategic and International Studies and Rhodium Group (May 2016).

that allowing the banking of allowances reduces the early retirement of nuclear plants, thereby lessening the decline in nuclear generation. This result stems from the fact that incentivizing early reductions in emissions is acutely important for nuclear power, as it bolsters the case for preserving the existing nuclear fleet.

RATE-BASED PLANS VERSUS MASS-BASED PLANS

The central choice at the heart of formulating a state's compliance plan is whether to pursue a rate-based or a mass-based plan. Most of the scenarios in the five studies included in this report examine variations of mass-based plans, though each study does include one scenario in which the states all choose to implement rate-based plans. The EIA assumes in its rate scenario that the nine Northeast and Mid-Atlantic states in the Regional Greenhouse Gas Initiative (RGGI) and California will implement the Clean Power Plan through rate-based plans despite already having state mass-based regulations in place, while the BPC, MJB, CSIS/Rhodium, and the Nicholas Institute studies assume that in all scenarios, RGGI and California will continue to comply via their previously established internal regulations, thereby preventing trade of emission rate credits with the rest of the country.

Only the BPC and Nicholas Institute studies had data on compliance costs, and both found that at a national level they are higher under rate-based approaches than under mass-based approaches. The Nicholas Institute finds that a rate-based approach was approximately 40 percent more expensive than mass-based and the BPC study finds it approximately 70 percent more expensive. This compliance cost difference is caused by the changes to the generation fleet, particularly the increased retirements of nuclear facilities and an increase in new renewable generation under rate-based plans, which can be costly changes to the electricity system. A secondary impact seems to be greater addition of new natural gas-fired capacity in rate-based scenarios, which may also be costlier than using the existing fossil fuel-fired fleet.

The BPC and Nicholas Institute studies also reported compliance costs at a sub-national level. The BPC found that those costs were more than twice as high for the Eastern and Western Interconnects when all states implemented rate-based plans, but that for ERCOT compliance costs were approximately 70 percent higher when all states implemented mass-based plans. The Nicholas Institute study also found subnational differences in compliance costs between a rate-based approach and a mass-based approach, with about half of the regions having higher costs under rate-based plans and half having higher costs under mass-based plans.

Despite the difference in total compliance costs, the choice of mass- or rate-based plans does not have a detectable impact on national average retail electricity rates, at least in the studies that reported this variable. Both the MJB and the EIA studies find that the Clean Power Plan will have modest impacts on consumer bills and retail electricity rates, with most scenarios in the two studies projecting those impacts to fall between a 2 percent decrease and a 5 percent increase. The variation appears to be due to different model assumptions, particularly with regard to the level of available energy efficiency. Both studies, however, found that these impacts would be very similar for the rate- and mass-based scenarios, provided that the level of available energy efficiency remains constant.

While the studies disagree on the trajectory to achieve the 2030 target under rate-based or mass-based approaches, most agree that either compliance approach will have a similar impact on cumulative total power sector carbon dioxide emissions through 2030 provided all states adopt the same type of plan.

IMPLICATIONS OF A PATCHWORK SCENARIO

Most of the scenarios analyzed in the five studies assume that every state in the country will all adopt the same type of plan, in both its broad outlines and its specific details. This assumption is made in large part to simplify the modeling process because state-by-state differences are difficult to incorporate in the national-scale models used in the studies we examined. However, the BPC and Nicholas Institute studies were able to examine a patchwork scenario. BPC's analysis, in their patchwork scenario where mass-based plans include the new source complement (NSC), provides a more comprehensive description of the likely effects of such an approach, and thus that study provides much of the basis for the conclusions drawn in this section, with additional detail on results and variation in state choice provided by the study from the Nicholas Institute. While the results below provide an illustration of the general trends likely to occur if there is divergence in state compliance plans, the precise outcomes may change, particularly if the grouping of states differ from these scenarios.

One result in BPC's patchwork scenario is national carbon dioxide emissions will be higher, both in 2030 and cumulatively from 2020 to 2030, than under either of the nationally uniform scenarios. Emissions initially fall at approximately the same rate as the in the national mass scenario, but around 2025 begin to diverge appreciably, resulting in 2030 power sector emissions between those under business as usual (BAU) and those in the national uniform scenarios. The reason for this is the six states that adopt dual-rate plans have large amounts of under-construction nuclear capacity or natural gas combined-cycle capacity, and thus plentiful low-cost generation of emission rate credits (ERCs). Since they cannot trade with the rest of the country, however, they have limited opportunities to sell them. This situation incentivizes increased fossil fuel generation in those six states, who then export electricity to neighboring states, thereby decreasing total national renewables and natural gas generation, driving up emissions. Thus, in many of the dual-rate states, emissions climb to levels even above those of business as usual, eventually balancing the emission reductions in the other states. However, the patchwork scenarios analyzed by the Nicholas Institute suggest that these and other results can change depending on which states choose to adopt rate-based plans and which adopt mass-based plans. Under a patchwork scenario, the benefits and costs experienced by any given state depends to a large extent on the choices made by others.

Another noteworthy result in the BPC patchwork scenario is reduced national compliance costs. National average annual compliance costs between 2022–32 fall to a bit more than \$3 billion in the patchwork scenario, compared to a bit more than \$5 billion in the mass scenario and almost \$9 billion in the dual-rate scenario.

These lower compliance costs are due to the fact that the reduction in emissions under a patchwork scenario is much smaller. This large decrease in compliance costs at a national level is not necessarily mirrored at a state level. In the BPC study, two-thirds of the states that adopt dual-rate plans actually see their compliance costs increase, as their less stringent plans result in them building additional natural gas capacity and exporting electricity to neighboring states.

OTHER FINDINGS

Scenarios in all of the studies also reviewed various policy design effects including allowance banking, implementing mass-based plans with the new source complement (NSC), wider allowance or ERC trading, and emissions leakage. The BPC study, for example, tested the impact of allowance banking. The basis of that scenario was the adoption of mass-based compliance plans inclusive of the NSC by all states, with the sensitivity case permitting the banking of emission allowances from 2022–40. The most direct effect this has is on the price of those allowances, which are higher in the early years of the Clean Power Plan, incentivizing early reductions and also stabilizing the allowance price over time. Allowance prices in the later years of the Clean Power Plan also converge across the three interconnections (which are also the trading regions), rising in the Eastern Interconnect and Electric Reliability Council of Texas (ERCOT) but falling in the Western Interconnect. Permitting allowance banking in the model reduced both total compliance costs and total emissions through 2030.

Allowance banking also affects the generation mix, as shown in the BPC study. Under a scenario where banking is allowed, coal generation decreases by 6 percent and natural gas generation increases by about 2 percent, relative to a no-banking scenario. Banking also facilitates a small increase in the growth of renewable generation and a decrease in the decline in nuclear generation. These changes in generation are principally driven by the fact that banking adds value to early reductions. This increases the price of allowances in the early years of the Clean Power Plan, which incentivizes existing nuclear power plants, renewables and natural gas, at the expense of coal-fired generation.

While some scenarios evaluated the impact of using the NSC, interpreting these results is complicated by the fact that some of the comparable mass-based scenarios with existing sources only do not model a provision to protect against leakage. The Clean Power Plan requires mass-based plans to address this issue, with the NSC being one presumptively approvable way to do so. With that caveat in mind, the studies suggest that covering only existing sources increases total power sector emissions and decreases compliance costs, relative to NSC scenarios. This is explained by an increase in total generation and greater reliance on coal-fired generation in non-NSC scenarios relative to mass-based scenarios with the NSC.

One decision which had relatively small effects in the modeling done by the studies is the geographic breadth of the secondary carbon market. Some scenarios only permitted this market to exist within individual states or very small regions while others extended the market to the level of the three interconnects or across the entire country. Broadening the extent of the market did have a few effects, with scenarios with markets covering a broader geography slightly increasing power sector emissions due to increased coal generation at the expense of less natural gas and nuclear generation relative to scenarios with narrower markets. It did not, however, have any appreciable impact on national average retail prices, though it is possible that it may have an effect on prices at the sub-national level.

Only the Nicholas Institute and BPC studies tested the effectiveness of the provisions in EPA's draft model rules for mass-based approaches at preventing leakage of generation from existing to new sources. Both concluded that the provisions did not fully prevent leakage, and in fact the approach in the draft model rules led to leakage in the two models of about 100 million short tons, or about 5 percent of total power sector emissions. These results are consistent with the findings of a previous analysis by Resources for the Future (RFF) on the final rule. (We have not included the RFF study in this brief since its baseline assumptions do not include the federal tax credit extensions.)

The price of natural gas is also likely to have an impact on effects of implementing the Clean Power

Plan. While most of the studies covered by the brief assumed very similar natural gas prices, the study from the Nicholas Institute included a sensitivity analysis for low, medium, and high gas prices. This analysis found that low prices would incentivize increased natural gas generation at the expense of generation from coal as well as reducing the incentives for new renewable generation, while high gas prices would have the opposite effect. As a result, high natural gas prices would likely raise compliance costs substantially, with costs under high prices being approximately six times more than under moderate prices. Low natural gas prices, however, could reduce compliance costs, cutting them by 50 percent or more.

CONCLUSIONS

While there is some divergence amongst the models employed by the studies published by CSIS/Rhodium Group, MJ Bradley & Associates, the Energy Information Administration, the Bipartisan Policy Center, and the Nicholas Institute, consistencies provide key insights into several issues. First, the Clean Power Plan reduces total power sector emissions relative to business as usual (BAU), even when the BAU scenario includes the extension of federal tax credits for wind and solar. It does so by accelerating some of the existing generation fuel mix trends, such as the continued decline in coal generation and the growth of renewables and natural gas generation, while at the same time highlighting the potential decline in nuclear generation. While the direction of these changes is likely to be similar in any implementation of the Clean Power Plan, the magnitude depends on the decisions made by policymakers.

In complying with the Clean Power Plan, states can choose between rate-based or mass-based approaches. Another consistent finding across the studies we examined was that either approach yields similar reductions in cumulative emissions through 2030, assuming all states adopt the same type of plan. However, under a patchwork scenario in which some states adopt rate-based plans and others mass-based plans, emissions are higher than if they all adopt the same type of plan. Moreover, the leakage protections in EPA's draft model rules are unsuccessful in fully preventing leakage of generation from existing to new sources of generation.

Another result common across multiple studies was that the Clean Power Plan is likely to have a small impact on national average retail electricity rates. In most of the scenarios, that impact ranges between a decrease of $1.89 to an increase of $4.65 per month for the average U.S. household electricity bill. Furthermore, this estimate may not fully account for the reduced consumption and thereby reduced monthly bills from either energy-efficiency measures or consumer choices. Additionally, the impact on average rates is the same between mass-based and rate-based compliance approaches, although total compliance costs to the sector are higher under rate-based plans.

The decisions made by state policymakers on these issues will play a significant role in determining how the Clean Power Plan affects their constituents and on how effective it is in helping the United States move closer to its commitments under the Paris agreement.

APPENDIX A: MODELS

The five studies included in this brief use three models in total: IPM, DIEM-Electricity, and NEMS. The first two are dispatch models while the third is a power and energy sector model, and these two types of models differ in important and fundamental ways.

The integrated planning model (IPM), developed by ICF International, is a dispatch model that seeks to minimize total production costs across North America. The model integrates wholesale power, system reliability, environmental constraints, fuel choice, transmission, capacity expansion, and operation elements of generators on the power grid in a linear optimization framework to determine the least-cost method of meeting electric generation energy and capacity requirements while complying with any and all specified constraints.

DIEM-Electricity is a component model of the broader Dynamic Integrated Economy/Energy/Emissions Model (DIEM) developed at Duke University's Nicholas Institute for Environmental Policy Solutions. The component, which is the only part used in the study covered by this brief, is an electricity dispatch dynamic linear programming model of U.S. wholesale electricity markets, similar to IPM. The model minimizes the present value of generation costs subject to electricity demands, reserve margins, and any other policy constraints.

The National Energy Modeling System (NEMS), developed by EIA, is used both in the EIA study and, in a modified form, by the CSIS/Rhodium study. The model projects the production, consumption, conversion, import, and pricing of energy based on economic, demographic, policy, and any other included constraints. The model is composed of several component modules, which, unlike IPM and DIEM-Electricity, allow for feedbacks between the power sector and broader energy markets. An example of this type of feedback is that increased natural gas generation in the power sector will affect both the consumption of natural gas in other sectors and the production of natural gas, both of which will then affect the power sector in the future.

APPENDIX B: SPECIFIC SCENARIOS REPORTED IN THIS BRIEF

For the bulk of our discussion we refer simply to a 'business-as-usual', 'mass-based' or 'rate-based' scenario from each study. The following is a list of the scenario names from each study that we used in our discussion. The original modeling studies can provide more details about each scenario. In some cases, data reported in our brief was provided directly by the modeling group responsible and not included in their published reports.

TABLE B1: Scenarios Utilized from Each Study

STUDY	C2ES SCENARIO NAME	STUDY SCENARIO NAME
MJ Bradley & Associates	Business as usual	RCb
	Mass-based	MB03 and MB04
	Rate-based	DR01
	Other	MB01, MB02, MB05, MB06, MB07
Energy Information Administration	Business as usual	No CPP case
	Mass-based	Reference case
	Rate-based	CPP Rate case
	Other	CPP Interregional Trading case
Bipartisan Policy Center	Business as usual	Reference
	Mass-based	Mass (E+N)
	Rate-based	Dual Rate
	Other	Mass (E+N, Banking), Patchwork (E+N)
Center for Strategic and International Studies/Rhodium Group	Business as usual	Reference
	Mass-based	Mass
	Rate-based	Rate
Nicholas Institute	Business as usual	Standard Assumptions
	Mass-based	National mass cap over all units
	Rate-based	National dual-rate
	Other	All patchwork scenarios

ENDNOTES

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3 Jennifer Macedonia, Blair Beasley, and Erin Smith, *Modeling the Evolving Power Sector and Impacts of the Final Clean Power Plan* (Washington, DC: Bipartisan Policy Center, 2016), http://cdn.bipartisanpolicy.org/wp-content/uploads/2016/06/BPC-Energy-Clean-Power-Plan-Modeling.pdf.

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The Center for Climate and Energy Solutions (C2ES) is an independent nonprofit organization working to promote practical, effective policies and actions to address the twin challenges of energy and climate change.