MODELING EPA'S CLEAN POWER PLAN: INSIGHTS FOR COST-EFFECTIVE IMPLEMENTATION

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This brief examines the findings of six economic modeling studies of the anticipated impacts of the proposed Clean Power Plan. It compares their projected impacts on power costs and the structure of the power sector, and on other fossil fuel consumers in the energy and transportation sectors. In general, the studies highlight the key role that energy efficiency programs can play in minimizing cost impacts to consumers and to power companies. All studies show declining power consumption and declining coal generation; most project rising natural gas generation, depending on how much energy efficiency is increased. Most of the studies project costs to the average U.S. household of less than 25 cents a day. Finally, the models suggest the Clean Power Plan as proposed is unlikely to boost zero-carbon renewable and nuclear power generation beyond the growth already forecast under business-as-usual scenarios.

INTRODUCTION

On June 2, 2014, the U.S. Environmental Protection Agency (EPA) released a proposed rule to reduce greenhouse gas emissions from existing power plants. The proposal, known as the Clean Power Plan, contains a set of state-specific carbon dioxide (CO_2) performance standards that must be met by 2030. The rule is scheduled to be finalized in the summer of 2015.[1] Each state would then have between one and three years, including up to a two-year extension for states submitting multi-state plans, to complete their plans.

In developing the proposed rule, EPA set a carbon reduction goal based on the "best system of emissions reduction" or BSER. The system relies on a number of specific actions and measures that EPA organized into four building blocks that together define the "best system" to reduce emissions from the power sector as a whole. These four building blocks include measures to: improve the efficiency of existing units; divert power generation from units that run on coal to those that use natural gas combined cycle technology; deploy new sources of zero-carbon generation, which include renewables and nuclear power; and reduce demand through end-use energy efficiency.[2]

EPA measured the capacity for each state to use each of these four building blocks to set a target emissions rate to be met by 2030, as well as an interim target to be met on average from 2020-29.[3] EPA's proposed rule, however, would not prescribe how state targets are met in practice. Rather, states would have flexibility to put together a strategy that combines one or more of the BSER approaches, or other approaches such as a price on carbon,[4] into a portfolio of actions.

This paper draws together key findings from six studies that used economic modeling to assess the potential impacts of the proposed Clean Power Plan. The first section summarizes the key insights from the models. The second section gives a short introduction to the models and lists their top-level findings on compliance costs. The third section looks at recent shifts in power sector generation technology, and contrasts the business-as-usual generation in 2030 with the six studies' forecasts of the generation mix under the Clean Power Plan. The fourth section takes a deeper look at the role of energy efficiency in each study, and the fifth section directly compares the models' reliance on energy efficiency relative to coal to gas switching as a compliance strategy. We conclude with some thoughts on how the insights can be incorporated into state planning actions.

KEY INSIGHTS FROM ECONOMIC MODELS

The six models reviewed provide different forecasts for the pattern of response to the proposed Clean Power Plan. Rather than picking any of the predictions as more correct than the others, we suggest that the best use of the models is to build our understanding of what influences the pattern of response to the proposal. While all models look to minimize overall costs, the differences in forecasts can be traced back to fundamental assumptions made by modelers that relate to the economics of electric power generation and consumption. Several high-level insights drawn from these studies could prove useful to policymakers and other stakeholders as states develop their plans for implementing the Clean Power Plan. Key takeaways include:

- **Energy efficiency is the most cost-effective way to reduce emissions and results in lower power consumption.** All studies project that energy efficiency will be the most used and least-cost option to implement the plan. This general finding holds regardless of particular modeling assumptions, including the cost assigned to energy efficiency programs. The studies also show that the effect of energy efficiency is large enough that overall electricity consumption declines.
- **Relying on energy efficiency also minimizes the impact on natural gas prices.** Moderately more reliance on natural gas over coal throughout the grid can occur with little impact on natural gas prices. However, when energy efficiency opportunities are assumed to be fully implemented or not implementable, the models turn increasingly toward natural gas for compliance, causing the price of natural gas to rise, spilling over into other sectors of the economy.
- **Cost impacts for the average U.S. household are minimal.** The majority of the studies project either cost savings to power users or increases of less than $10 billion a year. A cost of $10 billion a year would increase total U.S. power spending by less than 3 percent, and translate to less than $87 a year per household, or about 25 cents a day. Two studies showing higher costs are not directly comparable, as is explained below. None of the models account for the economic benefits of avoided climate change impacts.
- **Finally, renewables and nuclear power remain at business-as-usual** growth levels across all of the studies. In the case of renewables, business-as-usual growth is robust, with renewables projected to add more to generation between now and 2030 than have been added in the previous 16 years, meaning that their contributions to reducing emissions intensity are assumed to occur with or without the Clean Power Plan. There may be some modeling limitations behind this finding, as the utility-scale models used in these studies treat contributions from distributed renewable generation such as rooftop solar generation only minimally, and to the extent that additional distributed generation is somehow incentivized by the Clean Power Plan it could rise above forecast levels.

MODELING THE EFFECTS OF THE PROPOSED CLEAN POWER PLAN ON COSTS AND POWER GENERATION

There are multiple ways to evaluate what will happen if the Clean Power Plan is implemented as proposed, but this paper is focused on those studies that use an economic modeling approach. These studies are valuable because they provide insights into overall costs and into how the power sector and energy sector interact and affect the general economy over time. Because models make different assumptions and treat interactions and feedback differently, they come up with very different answers to the question of what compliance will cost and how the power sector is likely to adjust. We compare the assumptions and the findings across the studies, and in doing so provide insights about the potential impacts of the Clean Power Plan proposal.

Table 1 lists six economic models reviewed in this brief. Each model is differentiated by whether it focused on the power sector only (restricted to the fuels and output from the power sector) or whether it considered the power sector within the larger energy sector (showing impacts and decisions on all forms and uses of energy). While each of the studies attempted to demonstrate least-cost pathways to achieving EPA's targets as proposed, each had a slightly different approach to modeling the impacts of the proposed rule, and different assumptions regarding the costs of compliance options. For example, EPA and the National Resources Defense Council (NRDC) used the same Integrated Planning Model (IPM) of the power sector, but made different cost assumptions, and as a result came up with different solutions. Not all of the models were capable of showing the full portfolio of BSER activities, and therefore these activities would not even be considered for the solution set of least-cost compliance actions. Namely, the Clean Air Task Force (CATF) model did not model energy efficiency program measures, and the Energy Ventures Analysis (EVA) model did not model heat rate improvements within the coal fleet. In some cases, models included a 'sensitivity' to show the impact of excluding certain actions. For example, three of the studies reduced or eliminated the capacity to implement energy efficiency measures to show how costs would be affected.

Most of the studies included partial equilibrium models. Partial equilibrium models of the Clean Power Plan proposal describe actions and outcomes for the power sector. Some of the models included the larger energy sector as well, showing how actions and outcomes related to all sources of energy both inside and outside the power sector. The EPA, NRDC, EVA, and CATF studies were power sector models. Power sector models are dispatch planning models that seek to minimize the costs of power generation capital stock and electric generation unit operation to meet a given level of power demand.[5,6,7,8] Rhodium-Center for Strategic and International Studies (CSIS) and the National Economic Research Associates (NERA) models were power and energy sector models, which means that in addition to

TABLE 1: Studies Showing Impacts of the Clean Power Plan

STUDY	MODEL USED	SECTORS MODELED	POLICY MODELED	SENSITIVITY CASES	FULL BSER RANGE
EPA	IPM	Power Sector only	State-based emission rate	N.A.	Yes
CATF	Northbridge	Power sector only	Mass budget, inter-state trading allowed	N.A.	No, did not model energy efficiency
EVA	AuroraXMP	Power sector only	State emission rate; inter-state trading allowed	N.A.	No, did not model heat rate improvements
NERA	NewERA	Power and energy sector	State emission rate; inter-state trading allowed	No energy efficiency	Yes
NRDC	IPM	Power Sector only	State-based emission rate	Limited energy efficiency	Yes
Rhodium-CSIS	RHG-NEMS	Power and energy sector	Regional emission rate.	No energy efficiency	Yes

the power sector modeling, these models also include modeling the decisions of the upstream coal, natural gas, and petroleum production basins as well as modeling fuel demand outside of the power sector.[9,10] The NERA model was also a general equilibrium model, which means that they modeled actions and impacts across all parts of the economy, including impacts on GDP. All modeled policy solutions meet the emissions rate targets as well as remain in compliance with existing environmental standards, including regional and state climate agreements and state renewable portfolio standards where they exist.

Note that all of the studies model the Clean Power Plan as it was proposed, meaning that they impose a constraint at the state level requiring all covered generation to collectively meet a pre-defined target rate in 2030, and to meet an interim target on average over the 2020-2029 period. In general, states are required to meet the regulation on average, meaning that some power generation could emit at a higher rate as long as it was balanced by other power generation emitting carbon dioxide below the target rate. Some exceptions to this approach follow. NERA and EVA modeled additional flexibility in addition to the 'compliance on average' approach by allowing contributions from across state lines of surplus reductions. Rhodium did not model state-specific targets at all, but instead modeled regional compliance. The CATF study modeled the regulation slightly differently, differentiating targets by fuel source, one for coal and one for natural gas.

In addition to modeling the main policy scenario, sensitivity analysis is a common method for showing how changes in one or more of the assumptions changes outcomes that policy makers and other stakeholders care about. Often, models will include sensitivities on how the targets are set or achieved, and the subsequent impact on total costs, emissions, and fuel for power generation. A single sensitivity case was included in this synthesis, a case where the use of energy efficiency programs and measures for compliance was limited (NRDC) or not allowed at all (Rhodium and NERA) but the overall stringency of the regulation was maintained. This sensitivity case illustrates what "programmatic" energy efficiency measures such as lighting standards and best practices deliver by showing what happens to costs if energy efficiency measures are not allowed in compliance demonstrations.

MODEL OUTCOMES AND COMPARISONS TO THE REFERENCE CASE

One of the most popular uses of models is to show the impact of a regulation. Impacts related to the environment (including emissions), structure (including types of energy used to generate power), and the economy (including costs of energy and power) can all be modeled to varying degree. Each model's forecast of cost impacts are assessed relative to what it would cost to continue along the current path, often referred to as "business-as-usual" baseline. The business-as-usual baseline for the studies included here are all consistent with the U.S. Energy Information Administration's (EIA) Annual Energy Outlook (AEO) 2013 (CATF and NRDC) or 2014 (EPA, Rhodium, and NERA), matching up as close as they can to what EIA says the power and energy sector will look like in the 2020-30 time period. Once their models can recreate the outcomes included in the AEO model through 2030, the modelers look for a new solution – one that complies with the Clean Power Plan proposed regulation over time and at least cost. Costs, then, are represented by the difference between the "business-as-usual" solution and the "policy" solution. An exception to this standard procedure is EVA, who did not publicly release the results of their reference case, and instead presented all cost impacts as relative to historical data rather than relative to business-as-usual, making it impossible to distinguish impacts due to influence of the Clean Power Plan versus other factors driving power and energy prices over the time period.

The costs included in the studies we show reflect the resources required to achieve the targets over time. These costs reflect shifts in prices and quantities of power and energy consumption over time. **Table 2** shows that annual average cost estimates[11] varied substantially for the program. The first column below shows the forecast change in retail electricity rates, including all pass-through costs of generation and the administrative cost of implementing energy efficiency programs. The rate impact does not include any costs estimated to be borne by participants in energy efficiency programs, such as the additional cost of purchasing a more efficient appliance. On average, over the 2020-2030 period the studies forecast wholesale power prices to rise about 1.5 percent (EPA) while retail prices are 6.9 (CATF) to 12 to 13 percent (NERA and Rhodium, respectively) higher than expected under business-as-usual.

The second column of **Table 2** shows the total power sector costs, in constant 2012 dollars, which consists of the rate impacts from column 1, adjusted for any reduction in power consumption due to energy efficiency, as well as any costs from energy efficiency programs that are priced into electricity rates as well as increased costs to consumers of capital purchases such as more energy-efficient appliances. We include estimates that report this cost impact relative to a business-as-usual baseline over an identical time period. Across studies, the annual costs associated with the program varied by $38 billion per year, from a savings of $4.5 billion to a cost of $33.5 billion per year, averaged over the 2020-2030 time period. The low cost of $-4.5 Billion reported by the NRDC study forecast only minimal adjustment costs because of the program, and overall consumer costs would actually be negative because of declining power consumption due to increased deployment of energy efficiency technologies. Likewise, the Rhodium, EPA, and CATF estimates indicate extremely low costs, all less than $10 billion per year.

The NERA study stands out by showing substantially higher costs of $33.5 billion. Note that the model used by NERA is an economy-wide model, and a component of the costs shown relate to how capital investments are deployed across all sectors of the economy. The model assumes that the proposed Clean Power Plan will shift planned capital spending away from more profitable uses, and this foregone opportunity to invest outside the power sector is a part of the overall cost of the regulation. Note that even though NERA assumes much more costly energy efficiency measures, these are passed through to consumers in the price that they pay for power. The retail electricity rate impacts forecast by NERA, as well as the impact on natural gas prices, are very similar to the impacts shown in the Rhodium study, so it appears that most of the compliance costs to the rule are due to the effects of capital scarcity outside of the power sector.

As a point of perspective on costs, total power spending in the US in 2012 was $364 billion[12], so the annual costs as a share of current spending ranged from negative (in the case of the NRDC finding) to 9.2 percent of current power spending (in the case of the NERA finding of $33.5 billion per year). If the comparison is to the full economy of roughly $16 trillion, an average annual bill of $33.5 billion is about 0.2 percent per year. Finally, **Table 2** shows the forecast impact on Henry Hub prices, the reference point commonly used for pricing natural gas in the United States. In general, dispatching fewer coal plants and more natural gas plants will increase natural gas prices, which in turn will spill over into energy markets as well, for example affecting heating and demand from households and businesses, as well as costs for natural gas use in industry. A low overall natural gas price, such as that realized in the NRDC forecast indicates that natural gas is not expected to be subject to strong demand, while a much higher natural gas price like EVA's reflects significant disruption to power and energy markets throughout the 2020-30 period.

TABLE 2: Clean Power Plan Compliance Cost Estimates for Six Studies, Annual Average

STUDY	INCREASE IN ELECTRICITY RATES (%), 2020-30 AVERAGE	POWER SECTOR COMPLIANCE COSTS ($BN 2012), 2020-30 AVERAGE	HENRY HUB PRICE ($2012/ MMBTU), 2020-30 AVERAGE
EPA	1.5*	7.4	6.07
CATF	6.9**	9.3	5.41
EVA	†	†	6.62
NERA	12**	33.5	5.28
NRDC	‡	-4.5	4.34
Rhodium	13**	2.7	5.34

* EPA reported wholesale price impacts.

** NERA, Rhodium and CATF price impacts are retail level impacts.

† EVA reported a 27% increase in power prices, and compliance costs of $98 billion, but these are expressed relative to a historical year rather than relative to a business as usual baseline and therefore not comparable to the other studies.

‡NRDC did not report an estimate of national power prices.

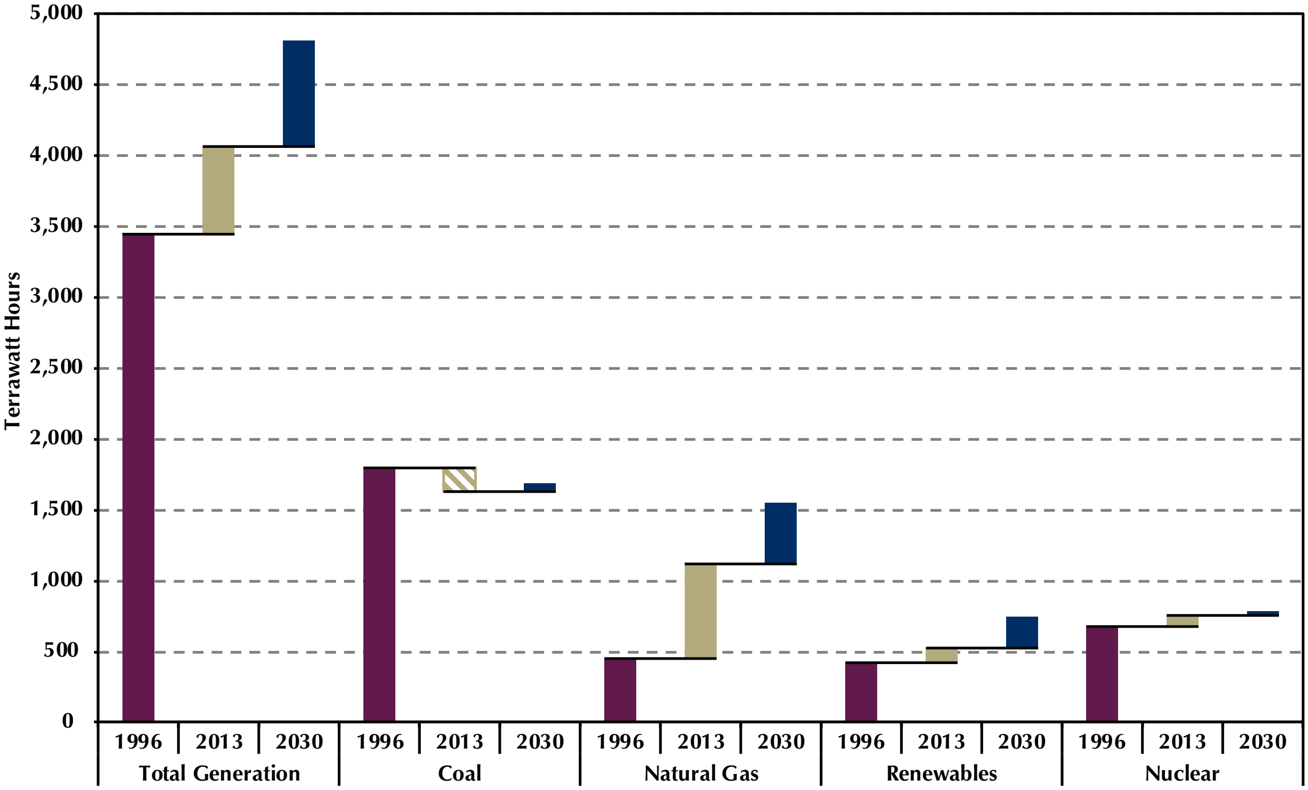
HISTORICAL AND PROJECTED IMPACTS ON POWER SECTOR STRUCTURE

Before delving deeper into the findings of the six Clean Power Plan studies themselves, we examine the business-as-usual forecast of the power sector, showing what the sector would look like through 2030 in the absence of the Clean Power Plan. To put the business-as-usual forecast from 2014 to 2030 in structural perspective, we compare the expected change alongside the actual changes that have occurred over an equivalent period of time, from 1997 to 2013.

Figure 1 compares the structure of the power sector in a "waterfall" chart. The chart contains three data points for total power generation and for each of the four fuel types used in power generation. The first data point, shown as a red bar, indicates the starting point for each series, beginning in 1996. Inclusion of the 1996 starting point is useful for putting the change across the subsequent two time periods in perspective. The second point, shown by the blue bar, reflects the change in total power generation and the change for each of the fuels that occurred over the next 17 years, i.e., from 1996 to 2013. The third point, shown by the green bar, indicates the expected growth in generation across the fuel types under business as usual in 2030, as determined by the EIA.[13]

Figure 1 is useful for showing big jumps and reversals in trends over time, and a consistent trend would generally be indicated by a stair step pattern. We see a consistent, stair-step pattern for total power generation (adding 622 Terawatt hours (TWh) over the past 17 years and projected to add 748 TWh through 2030 absent the implementation of the Clean Power Plan or other new policies. Natural gas is responsible for most of the

FIGURE 1: **Power Generation in 1996, 2013, and 2030 (Under Business-as-Usual Forecast) for Different Fuel Types, TWh**



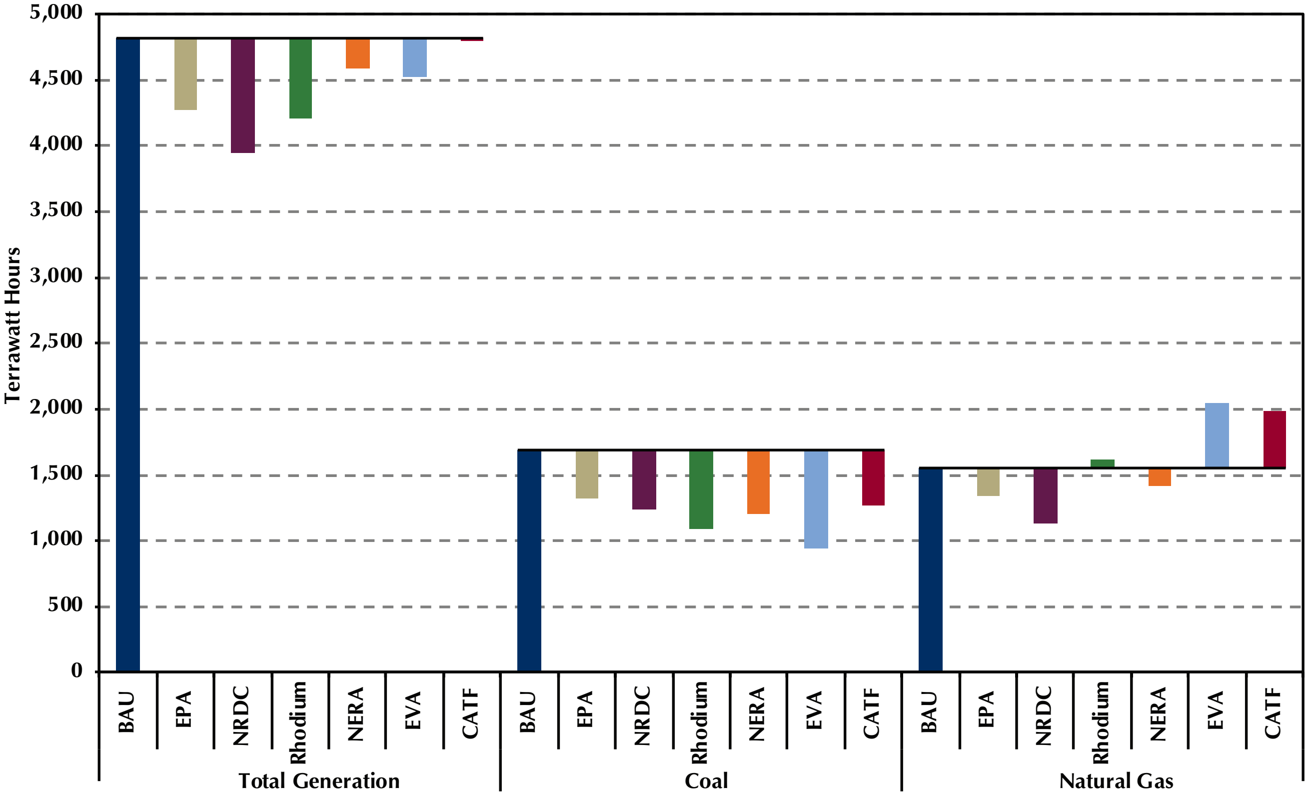
Total TWh of power generation on the rise through 2030, fueled by growth in natural gas and renewable generation.
Source: Energy Information Agency.

growth in total generation over the past 17 years as well as for the next 17. Natural gas generation started at less than 500 TWh in 1996 and by 2030 is expected to grow to over 1500 TWh per year. Coal, the largest source of power generation in 1996, has actually generated less power over time, shrinking by 166 TWh in 2013, but is expected to recoup a portion (62 TWh) of its lost generation by 2030 as fuel prices favor increasing the amount of generation dispatched from existing coal units, and remain the most common fuel type in 2030 in the absence of the Clean Power Plan although natural gas is expected to essentially pull even under business as usual. Utility-scale renewable generation (including hydropower, wind, solar, biomass, and geothermal) has grown over the past 17 years but is poised for even greater growth through 2030, mostly due to increased generation from wind. Nuclear generation levels have been fairly constant across both periods.

CLEAN POWER PLAN IMPACTS ON POWER GENERATION

The impacts of the Clean Power Plan, as forecast by each of the six studies included in this synthesis, are shown in **Figure 2**. The studies show big changes across total generation and across coal and natural gas generation, in some cases reinforcing and in other cases reversing the trajectory of business-as-usual shown in **Figure 1**. **Figure 2** excludes each studies' forecast impacts to renewable and nuclear power generation because none of the studies showed any impact to renewables or nuclear generation that deviated from the 2030 business-as-usual outlook. Recall that the business-as-usual outlook for both renewables and nuclear power is that they will continue to grow in terms of total generation. Essentially, the models indicate that the Clean Power Plan won't result in an increase in their levels of

FIGURE 2: Modeled Effects of Clean Power Plan on Total, Coal, and Natural Gas Generation



The dark blue bars show EIA's 2030 BAU forecast total power generation, coal, and natural gas generation. The remaining bars show the change from this level on average over the 2020-30 level, according to each model.

Source: BAU from Energy Information Agency, study from author calculations of reported results.

generation, as other strategies are instead used to reduce emissions from the power sector.

Overall, the 'waterfall' chart in **Figure 2** shows a distinct and consistent pattern of response to the Clean Power Plan regulation, which is forecast to result in less total power generation, less coal generation, and more natural gas generation. Because not all of the studies included annual breakout totals for power generation by fuel, we cannot report single year totals that are common across all studies. Instead, we use the data that each study reports across the 2020-2030 period and construct an average.

Nearly all of the studies shown in **Figure 2** forecast a dramatic shift from the historical trend of steadily increasing power generation over time, as shown by the set of bars on the far left-hand-side. Programmatic improvements in energy efficiency, driven by implementation of a variety of deliberate programs and standards, is shown in five of the six studies (CATF did not model the impact of programmatic energy efficiency) to reduce overall energy consumption. In these studies the combination of programmatic energy efficiency and (in some cases) price-induced reductions in consumption was so pronounced that the business-as-usual forecast increase in power generation of 722 TWh is largely and in some cases even entirely avoided, leaving total generation at today's levels. Later, we will show results when programmatic energy efficiency is excluded as a compliance mechanism.

The middle set of bars in **Figure 2** show each of the six studies' projection of coal generation. Note that each model predicts coal generation will be substantially lower than the business-as-usual forecast, and recall from **Figure 1** that the business-as-usual forecast for coal generation was that after losing a substantial amount of generation over the past 17 years it would increase slightly over the coming 17 years through 2030. All of the studies indicate that coal will lose at least as much as it did over the past 17 years, and none show growing coal generation. However, the six studies are split on exactly how much generation coal cedes to natural gas and to energy efficiency as a result of the Clean Power Plan. At the low end of forecast losses, EPA's model shows that coal will lose about 20 percent of its business-as-usual generation. At the high end, EVA's forecast is that coal generation will decline by 44 percent from business-as-usual, dropping below 1000 TWh of generation per year during the period.

The findings across models for natural gas generation, shown as the bars on the far right-hand-side of **Figure 2**, are more mixed. The models from EPA, NRDC, and NERA show average natural gas generation to be below the 2030 business-as-usual forecast, while Rhodium, EVA, and CATF forecast generation above business-as-usual. The EPA, NRDC, and NERA findings all reflect outcomes where overall generation is declining due to energy efficiency measures, and declining natural gas generation follows the trend. Energy efficiency measures in these models reduce the total amount of natural gas generation as well as coal generation. While Rhodium's forecast increase in natural gas is quite small, where energy efficiency is not modeled (CATF) or is available in only limited quantities (EVA) the model seeks reductions in emissions intensity primarily through coal to gas switching, and the resulting increase in natural gas generation can be quite large. Note that despite the mixed outlook relative to the business-as-usual forecast, all models forecast that natural gas generation will exceed coal generation, except for NRDC which show them roughly equal.

SENSITIVITY ANALYSIS: THE CASE OF ENERGY EFFICIENCY

Given the central role of energy efficiency highlighted by all of the studies, it is worthwhile to look at what happens to compliance costs when the stringency of the Clean Power Plan is held constant but energy efficiency measures are not allowed. Three of the studies included a sensitivity analysis that can be applied to this question. The NRDC study looked at what happened when the total quantity of programmatic energy efficiency is reduced rather than eliminated, and the Rhodium and NERA studies looked at what happens when programmatic energy efficiency is not allowed at all.

In general, these studies find large impacts when states cannot take credit for energy efficiency program measures within the Clean Power Plan. Without energy efficiency, compliance will be more costly. It would also result in even greater declines in coal generation and greater increases in natural gas generation as well, compared to the case where energy efficiency programs count. The models forecast that the increased dependence on natural gas generation by the power sector could be costly due to its effect on the prevailing (Henry Hub) price of natural gas. Rising natural gas prices impact more than the power sector itself, affecting energy users outside of the power sector as well to the extent that they rely on natural gas as a fuel or a feedstock.

Table 3 shows each model's energy efficiency sensitivity case next to their general policy case findings. For each study we show the annual aggregate impact to power sector customers under the base case (these numbers are repeated from **Table 2**) as well as any impacts that spill over to non-power customers as seen by changes in the cost of fuels consumption outside of the power sector.

The results of the sensitivity analysis indicated that when programmatic energy efficiency is constrained, the models turn to a next-best portfolio of solutions to meet the carbon reduction goal. All models respond to the constraint by dispatching less coal generation and more natural gas generation. The NRDC model also included marginally more renewables and some coal with carbon capture and storage, indicating that when energy efficiency is less available the use of other more expensive options are considered in order to reach compliance. In the case of the NRDC model, costs rose $9.2 billion per year, from $-4.5 billion to $4.7 billion per year. Note that the NRDC model only included the power sector, so non-power and combined costs are not shown in Table 3 for the NRDC study. However, because natural gas prices increase significantly between the two cases it stands to reason that there would be some impact on the energy sector as well.

The solutions to the Rhodium and NERA model represent a simultaneous consideration of the power and energy sectors and are capable of showing impacts on energy consumers. Rhodium identifies a positive spillover in their general policy. Specifically, the Rhodium model of the Clean Power Plan proposal forecasts that oil prices would decline as the demand for rail transport for coal declines, reducing overall energy costs by $9.7 billion. However, in Rhodium's sensitivity case where energy efficiency efforts were not allowed, power sector costs balloon to $33.1 billion as natural gas prices increase, and some of the $12 billion in cost savings generated for other users is eroded. Considering the sum of both the power and energy sector effects, the Rhodium model forecasts a $24.1 billion increase in net costs to energy and power consumers under the sensitivity case, compared to the policy case showing annual combined power and energy costs of $-9.7 billion.

The NERA model had a much more dramatic impact on both power and energy costs, showing much higher costs for Clean Power Plan compliance to begin with, and in the absence of energy efficiency measures the dramatic increase in natural gas generation increased power sector costs by $40.4 billion per year, and the spillover costs to the energy sector are $16.7 billion, compared to the base policy case estimate of $1.8 billion in spillover costs. Combining power costs and spillover costs, the total cost in the NERA model, absent energy efficiency measures, is estimated to be $57.1 billion per year. The cost comparison is interesting because it shows that while energy efficiency is a policy-efficient tool, assumptions about how much energy efficiency is available, and what it costs program administrators and participants in the end, can result in a wide variation in overall compliance costs.

TABLE 3: Sensitivity Analysis Results

	TOTAL COMPLIANCE COSTS, BASE POLICY CASE ($2012 BN)			TOTAL COMPLIANCE COSTS, EXCLUDING ENERGY EFFICIENCY MEASURES ($2012 BN)		
STUDY	POWER	NON-POWER	TOTAL ENERGY	POWER	NON-POWER	TOTAL ENERGY
NERA	33.5	1.8	35.3	40.4	16.7	57.1
NRDC	-4.5	N.A.	N.A.	4.7	N.A.	N.A.
Rhodium	2.7	-12.4	-9.7	33.1	-9	24.1

Models show that costs to power and other energy customers rise sharply when energy efficiency measures are not allowed under the Clean Power Plan.

A MORE DETAILED LOOK AT ENERGY EFFICIENCY ASSUMPTIONS

A comparison of all models' treatment of energy efficiency indicates that there is a wide range of assumptions about how much energy efficiency programs 'cost' to deploy as well as a wide range of how much energy efficiency is available. **Table 4** shows the key assumptions related to the average cost of deploying energy efficiency (Column 1). Column 2 list any additional cited studies supporting their assumptions. Column 3 lists each model's assumed limits to 'potentially achievable' programmatic energy efficiency deployment. Columns 4 and 5 provide additional modeling detail, and indicate whether each study modeled the levels of energy efficiency and energy consumption as a "choice" within the model's optimization framework (referred to as 'endogenous') or whether energy efficiency and energy consumption were held at pre-determined ('exogenous') levels outside of the model.

We begin with the EPA assumptions. EPA cites a study by Eldridge[14] as well as EPA's own meta-analysis[15] for their assumption that the administrative costs of deploying energy efficiency programs are 7.8 cents per kWh on average, which makes the creation of energy efficiency cost-competitive given a retail price of electricity of about 9.8 cents per kWh. This only reflects the costs to states from administering the energy efficiency programs. Additionally, consumers will ultimately incur their own incremental costs from energy efficiency programs. For example, energy efficiency programs can impact the costs of new appliances that meet program requirements. EPA assumes that participant costs are roughly equivalent to the administrator costs. EPA assumes a limit to how quickly energy efficiency can ramp up to reduce overall power consumption, and how much consumption can ultimately be scaled back. EPA assumes that energy efficiency, measured in terms of foregone power consumption, can ramp up 0.2 percent per year, up to a maximum of 1.5 percent per year. EPA made a further assumption that energy efficiency measures had a predefined lifetime of services, such that half of the energy efficiency measures created through programs would cease to deliver energy efficiency after 10 years.

In contrast to EPA, NRDC assumed substantially lower administrative costs of energy efficiency (2.7 cents per kWh) on average and a commensurately higher annual rate of energy efficiency gains of up to 2 percent reductions per year. NRDC based these assumptions on energy efficiency costs from Synapse Energy Economics[16], and estimated the limits to energy efficiency growth from a Lawrence Berkeley National Laboratory[17] study. NRDC's approach also differed from EPA's in that their version of IPM allowed for the quantity of energy efficiency to be 'optimized,' with the ultimate level of adoption decided simultaneously with other reduction options. Rather than assuming some level of energy efficiency that must be included, NRDC's model chose to deploy energy efficiency only where it was cost-effectively pursued. In modeling parlance, forcing 'exogenous' deployment as EPA did can be contrast with an 'endogenous' choice of deployment level as NRDC did. In the end, the capability to choose an 'optimal' level of energy efficiency made little difference, as the NRDC model deployed all of the energy efficiency at its disposal anyway.

Rhodium's analysis used similar cost and quantity assumptions as EPA's, with the exception that Rhodium accounted for the quantity of energy efficiency measures that were already included in the business-as-usual baseline. Rhodium's model did not allow states to count business-as-usual energy efficiency towards the emission rate targets. Rhodium cited EPA data that indicates existing energy efficiency policies already reduce consumption by 0.18 percent today, and as a result the maximum annual rate of energy efficiency should be 1.32 percent rather than 1.5 percent. Like EPA, programmatic energy efficiency was assumed exogenous to the modeling system. However, unlike EPA's model, Rhodium's allowed the price of power to freely determine final consumption levels, rather than setting it at a pre-determined level. As a result, when power sector costs grow due to increases in natural gas prices, the Rhodium model will reduce a portion of energy consumption due to a "price effect" as well as a "program effect."

NERA's model allowed for endogenous choice of the level of energy efficiency as well as the ultimate level of power consumption. Energy efficiency followed EPA in allowing up to 1.5 percent annual growth in efficiency based on a 'supply curve' of energy efficiency. NERA's model, however, assumed that energy efficiency was much more costly than EPA, Rhodium, or NRDC, citing work by Allcott and Greenstone[18] that estimated the cost of energy efficiency at 12.5 cents/kWh, on average, about 60 percent more costly than EPA's assumption and more than 4 times more expensive per kWh than

TABLE 4: Key Modeling Assumptions Related to Programmatic Energy Efficiency and Overall Power Consumption

STUDY	SOURCE FOR EFFICIENCY COSTS	AVERAGE EFFICIENCY COSTS	LIMITS TO EFFICIENCY DEPLOYMENT	EFFICIENCY IS ENDOGENOUS?	POWER CONSUMPTION IS ENDOGENOUS?
EPA	Eldridge, EPA	7.8	Up to 1.5 percent of annual retail sales, max 506 TWh of foregone generation in 2030	No	No
CATF	Did not model efficiency	N.A.	N.A.	N.A.	Yes
EVA	EPRI	3.5	Up to 179 TWh of annual foregone generation by 2020.	No	No
NERA	Alcott and Greenstone	12.5	Up to 1.5 percent of annual retail sales.	Yes	Yes
NRDC	LBNL, Synapse	2.7	Up to 2.0 percent of annual retail sales, max 709 TWh of foregone generation in 2025	Yes	Yes
Rhodium	EPA	7.8	Up to 1.32 percent of annual retail sales.	No	Yes

Across the models, the costs of energy efficiency ranged from a low of 2.7 to a high of 12.5 cents per kWh, and was assumed to deploy up to 2 percent incremental energy efficiency per year. While most models assume a fixed rate of energy efficiency rather than have the model choose an optimal level of energy efficiency over time, it was more common to allow a model to choose the optimal level of power consumption than assume a fixed level of consumption.

NRDC's assumption. In the face of these assumed higher costs, and with NERA's capacity to reduce adoption of programmatic energy efficiency in the face of less costly alternatives, it is interesting to note that the NERA model showed full uptake of all available energy efficiency measures, meaning that energy efficiency is competitive with alternative actions, even at the higher price NERA assumes. NERA's economy-wide model included some additional general equilibrium cost impacts from energy efficiency adoption, which they identify as 'interaction' effects between capital used for regulatory compliance and "crowding out" productive investment by regulated industries and consumers.

Energy Ventures Analysis limited energy efficiency to 179 TWh, about a third of what EPA estimates is likely, based on an estimate of achievable energy efficiency from the Electric Power Research Institute (EPRI).[19] EVA assumed that programmatic energy efficiency would cost 3.5 cents per kWh on average and that all energy efficiency opportunities would be taken up. Overall power consumption was assumed to continue to grow, unresponsive to rising power prices.

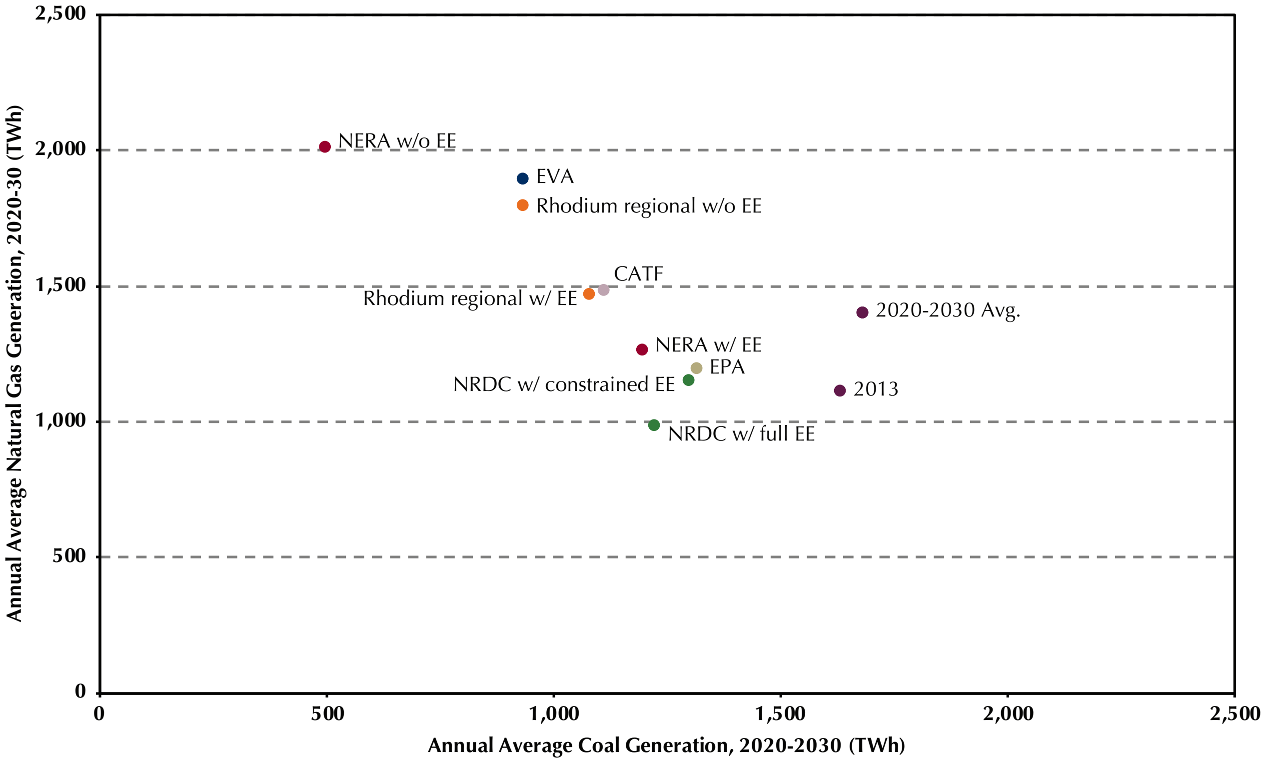
In sum, it is worth noting that regardless of whether models treated energy efficiency choices endogenously or whether they assumed an overall level of energy efficiency that must deploy did not matter much in the final outcome, as all opportunities to invest in energy efficiency were taken up, even in the cases where energy efficiency was assumed to be above the average retail price of electricity. More relevant to the final outcome was whether models allow for the amount of power to consume to adjust endogenously in response to changing power prices or alternatively whether the overall power consumption was assumed outside of the model.

CONTRASTING IMPACTS FROM ENERGY EFFICIENCY VS COAL TO NATURAL GAS SWITCHING

Across the Clean Power Plan studies, using as much energy efficiency as possible was the most common strategy in meeting the target emission rate. Deploying energy efficiency to bring down emissions rates allows for the pursuit of the target with minimal change to the existing mix of coal and natural gas on the grid. Eventually, though, once energy efficiency becomes maxed out at a predetermined capacity, the model must turn to additional intensity reductions. For the models studied, that means switching from a high-emitting fossil fuel, coal, to a lower-emitting fossil fuel, natural gas, in the power dispatch order. Across the studies, when energy efficiency made the greatest inroads (EPA and NRDC) coal showed the greatest capacity to maintain their existing level of coal-based generation. In contrast, EVA and CATF studies had the lowest level of crediting for energy efficiency across all of the studies, and not coincidentally these also resulted in the least amount of coal generation remaining online. Sensitivity analysis carried out by two of the studies, Rhodium and NERA, show the tradeoffs between coal, natural gas, and energy efficiency explicitly by taking away the option of energy efficiency entirely as a compliance mechanism, and all show the same general trend of substituting away from coal towards natural gas. Other low-carbon generation alternatives, such as renewables and nuclear power, did not play a large role due to the fact that they are more expensive to deploy relative to energy efficiency and coal-to-gas dispatch. In practice, states along with some stakeholders may wish to emphasize certain types of low-carbon deployment, but the models show that this is unlikely to occur on its own without other supportive policies.

Figure 3 below shows the combinations of coal and natural gas generation for all of the solutions included in the studies, the combinations of coal and natural gas

FIGURE 3: **Fuel Switching Effects of Proposed Clean Power Plan, 2020-30 Averages, TWh**



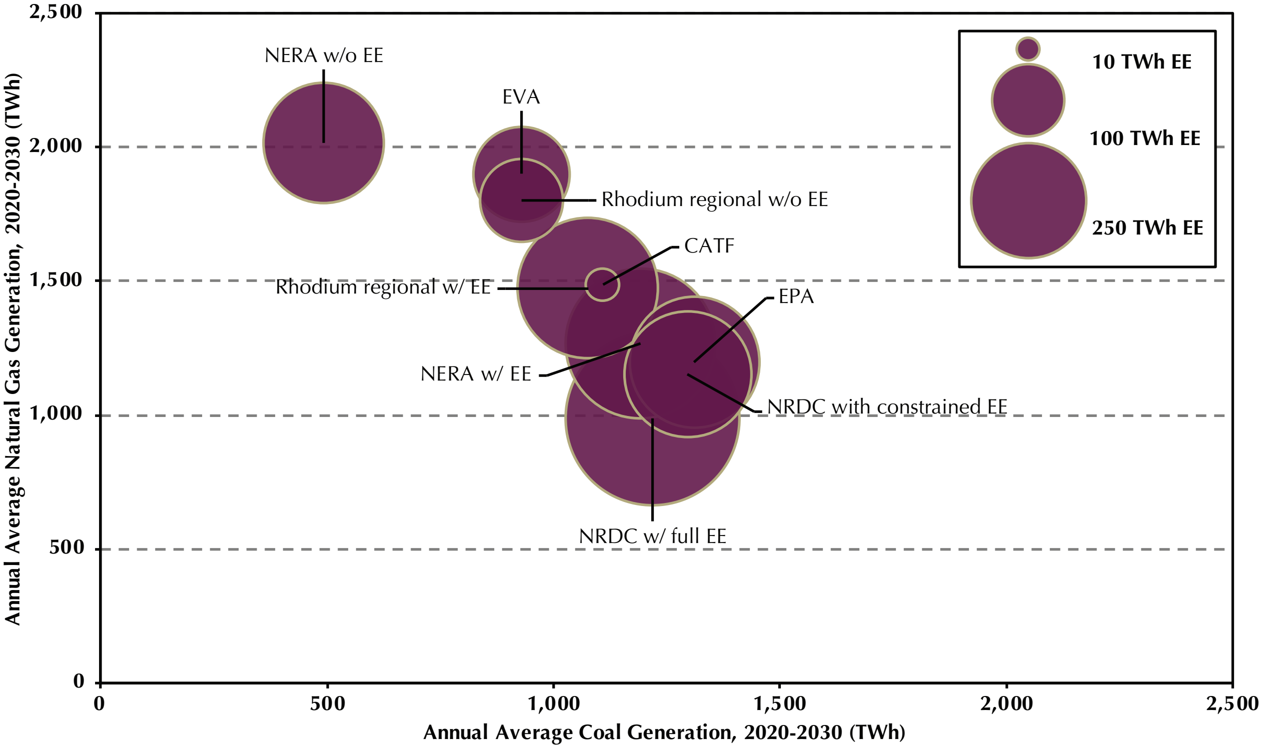
Models display a coal and natural gas generation tradeoff frontier.

generation that were recorded in 2013 as well as what is predicted by the business-as-usual baseline for the 2020–2030 average. Note that the trend of substitution of natural gas for coal is more dramatic than what was seen from 1997 to 2013, and greater than what we expect under business-as-usual through 2030. Each study's solution point on the chart represents considerably less coal, and often more gas, than we have today. However, the studies differ widely. One interpretation is that there are a number of ways in which the intensity targets of the proposed Clean Power Plan could be met, but each one is the result of an important interplay between relative costs of deploying coal, natural gas, and energy efficiency.

In **Figure 4**, each study's results with respect to coal and natural gas generation is shown at precisely the same points as in **Figure 3**; however, a third variable, the size of the overall reduction in power generation under each study, is added as a scalable bubble. Notably, the magnitude of reductions in power consumption reductions varies significantly across the studies. In general, the solutions where the most energy efficiency is used are those with the highest levels of coal-based generation and lower levels of natural gas power generation. The sensitivity cases carried out by NERA and Rhodium show extreme levels of natural gas generation as well as some reduction in power consumption resulting from higher prices. **Figure 4** shows that in general, when energy efficiency becomes constrained, it becomes more important to find ways to reduce coal generation in favor of natural gas generation to reduce emissions, and that these solutions can run up natural gas commodity prices and could reduce overall power consumption.

Growth in use of natural gas for power generation will have an effect on natural gas prices, and each model provides an explicit forecast of this effect. The business-as-usual baseline used by most of the models from AEO 2014 forecast that Henry Hub prices will rise from their

FIGURE 4: Reduction in Total Power Generation, due to Energy Efficiency Programs and Higher Power Prices, compared to 2020-30 Business as Usual Averages



Models display a coal and natural gas generation tradeoff frontier. The reductions in power consumption for models at higher levels of coal generation are because of greater levels of energy efficiency, while reductions in power consumption for models at lower levels of coal generation are because of higher power prices.

current levels of about $4 to an average of $5.22 per MMBTU over the 2020-2030 period, even without the Clean Power Plan regulation in place. All studies except for NRDC's (which sees a $4.34 Henry Hub price over the period) forecast higher natural gas prices as a result of the Clean Power Plan compared to business as usual. NERA, Rhodium, and CATF forecast moderate increases in the Henry Hub price, rising to no more than $5.41 among the three, while EPA forecasts a slightly higher price of $6.07. The 'no energy efficiency' sensitivity cases prepared by Rhodium and NERA likewise estimated even greater price rises for Henry Hub. Rhodium's impact was relatively small, raising Henry Hub to $5.75, while NERA showed a much higher Henry Hub price of $6.68 in the absence of energy efficiency measures. Like, NERA's special case, EVA's policy case forecast very high natural gas prices, up to $6.62.

In general, the pattern of response across the models is to turn to natural gas when energy efficiency options are limited in some way. The overall level of natural gas consumption is price-sensitive, however, and large shifts in natural gas generation will result in higher natural gas prices, which feed through to higher power prices as well as spillover impacts onto non-power energy consumers. As a result, the highest costs are found in models where natural gas is the primary pathway compared to those where energy efficiency grows and coal retains a relatively high market share. The models where the highest overall costs are recorded are also those that forecast significantly higher Henry Hub costs.

Higher costs were also associated, in some studies, with a price-induced reduction in the level of power consumption. While three of the models (EPA and EVA) set power demand exogenously, the remainder allowed for a 'price effect' to determine final consumption levels, and the response was significant in both the NERA and Rhodium studies. The price effect was particularly important for understanding the findings of the energy efficiency sensitivity cases because these were the cases where costs rose the most. For example, the 189 TWh reduction in power consumption from the 'price effect' in the NERA model rivaled the 238 TWh reduction from the energy efficiency programs themselves, and in the NERA scenario that excluded energy efficiency programs the 'price effect' due to higher electricity costs served to decrease consumption by 275 TWh. Rhodium's analysis also found a noticeable electricity 'price effect' that reduced power consumption, and this effect grew at the margin as electricity prices increased such as energy efficiency was not permitted. However, Rhodium's price effect was only about half the size of NERA's forecast.

The forecast change in state power generation strategies brought about by eliminating energy efficiency would affect more than the costs and the structure of power generation. The scenarios by Rhodium and NERA also indicate that eliminating energy efficiency will result in greater overall emissions reductions compared to the reductions forecast when energy efficiency is forecast, with up to 64 million more tons per year according to Rhodium's model and up to 369 million tons more pear year according to NERA's model (see Table 5).

The reason that emissions reductions are greater when energy efficiency is not part of the mix is because states can use a different mix of strategies in the absence of energy efficiency. When energy efficiency is used, the quantity of foregone power consumption is reflected in the state emissions rate as if it were zero-carbon generation. However, in the case where energy efficiency is assumed to be ineligible to meet the plan's goals, the choices that states have to bring down the emissions rate are more limited, and they must either deploy an equal amount of zero-carbon generation from some other source, or alternatively reduce the quantity of carbon emitted per unit of fossil generation. Both Rhodium and NERA find that it is cheaper to get to the emissions rate target by the latter strategy, by dispatching more natural gas and less coal, compared to the option of generating more zero-carbon generation. The scenarios without energy efficiency reductions result in the same emission rate as when energy efficiency is allowed, but a greater level of absolute emissions reductions compared to when energy efficiency is allowed.

Table 5 below shows some analysis of emission levels as they relate to coal and natural gas generation, both in terms of tons of emissions of carbon dioxide and in the carbon intensity of emissions. Note that high-emissions scenarios (including the EPA scenario) had the greatest level of coal generation in the final solution, highlighting that while energy efficiency keeps coal generation in the mix, the solutions are higher-emitting than when natural gas is used in lieu of coal.

TABLE 5: Summary of all Model Results, 2020-30 period

STUDY	GENERATION (TWH)				REDUCTIONS IN POWER CONSUMPTION (TWH)			ANNUAL AVERAGE CO2 EMISSIONS (MMT)	HENRY HUB ($/ MMBTU)	COMPLIANCE COSTS ($BN)		
	COAL	NATURAL GAS	OTHER	TOTAL	PROGRAMS	PRICE	PROGRAMS & PRICE			POWER SECTOR	ENERGY	TOTAL
EPA	1311	1199	1561	4071	325	0	325	1774	6.07	7.4	**	**
CATF	1134	1217	1775	4126	N.A.	25	25	1761	5.41	9.3	**	**
EVA	929	1900	1495	4324	179	0	179	1613	6.62	*	*	*
NERA w/ EE	1191	1269	1928	4388	238	189	427	1624	5.28	33.5	1.8	35.3
NERA w/out EE	492	2015	1866	4373	N.A.	275	275	1255	6.68	40.4	16.7	57.1
NRDC w/ constrained EE	1296	1154	1560	4010	302	0	302	1571	5.12	4.7	**	**
NRDC w/ full EE	1219	990	1534	3743	573	0	573	1514	4.34	-4.5	**	**
Rhodium regional w/ EE	1075	1474	1457	4006	244	128	372	1641	5.34	2.7	-12.4	-9.7
Rhodium w/ out EE	929	1802	1510	4241	N.A.	134	134	1577	5.75	33.1	-9.0	24.1

*EVA reported power sector compliance costs of $98 billion per year and energy sector compliance costs of $75 billion per year, for a total of $173 billion per year, however these were not estimated relative to business as usual but relative to a 2012 base year, making them incomparable with the other estimates.

** These studies (EPA, NRDC, and CATF) were power sector only models and did not show spillover impacts to the energy sector.

Source: C2ES Analysis (2015)

CONCLUSIONS

The models paint a fairly consistent picture of meeting the objectives of the proposed Clean Power Plan. First, energy efficiency is projected to be the least-cost strategy. Second, moderate levels of switching from coal to natural gas generation can occur without pushing up natural gas prices. Third, when the above occur as planned, overall implementation costs will be manageable. Fourth, while renewable generation growth will play a role in meeting plan targets, other policies would be needed if states wish to give renewables an additional boost.

These insights suggest actions states and regions can take in developing their plans. For example, states can minimize the costs of implementing the Clean Power Plan by pursuing energy efficiency. The cost of implementing energy efficiency programs will be priced into power and energy markets directly. Because consumers will ultimately pay for and benefit from these programs, plans should be designed to optimize the efficiency savings per dollar spent and be phased in over time.

Also, states should note that all of the models show declining coal generation throughout the compliance period. In the models, energy efficiency reduces switching to natural gas. Reduced natural gas dispatch is a result of a reduced rate of decline in coal generation. One of the results of the uptick in energy efficiency, then, is that states will have more flexibility to smooth their transition into low-carbon generation. Smoothing the transition pathway may benefit future deployment of technologies that are at an early stage and are currently cost-prohibitive, such as carbon capture and storage, critical for reducing future fossil emissions. States could use the transition period to develop supportive programs for affected sectors.

Finally, the studies included here indicate that while increases in renewables and nuclear will help states achieve their targeted reductions under the proposed Clean Power Plan, the proposal does little to drive additional zero-carbon generation beyond the growth projected in business-as-usual scenarios. If demand for electricity grows more than expected, then states that have fully deployed energy efficiency will have to take additional actions, including adding more renewable energy. If states look to reduce emissions intensity by bringing on greater levels of zero-carbon generation, they will have to consider additional policy interventions to stimulate them, because these generation sources are not assumed to be competitive with a combination of energy efficiency and switching from coal to natural gas.

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