DISCUSSION PAPER

November 2012 ■ RFF DP 12-52

Modeling the Electricity Sector

A Summary of Recent Analyses of New EPA Regulations

Blair Beasley and Daniel Morris

1616 P St. NW
Washington, DC 20036
202-328-5000 www.rff.org

RESOURCES FOR THE FUTURE

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Abstract

Several different economic models have been applied to try to understand how new regulations by the U.S. Environmental Protection Agency (EPA) could impact coal-fired generation in the United States as well as the electricity system as a whole. This paper provides an overview of many of the key studies and the models used to analyze the potential impacts of EPA's rules. The regulations surveyed include the Cross-State Air Pollution Rule (CSAPR), the Mercury and Air Toxics Standards (MATS), the proposed Clean Water Act (CWA) Section 316(b) rule, and the proposed Coal Combustion Residuals (CCR) rule. The models generally agree that these regulations will result in coal plant retirements, though there is far less agreement on how much generation may retire. Assumptions about the price of natural gas and the expected stringency of regulations play a key role in determining modeling results. The models provide useful guidance for policymakers when considering the potential impact of EPA regulation.

Key Words: Clean Air Act, electricity, EPA regulation, modeling, power plant retirement

JEL Classification Numbers: C69, L51, Q47, Q48, Q52

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Blair Beasley and Daniel Morris*

Introduction

Over the past decade, the U.S. Environmental Protection Agency (EPA) has proposed and finalized several regulations affecting the electricity sector—and, in particular, coal-fired power plants. These regulations will profoundly influence the continued development and operation of the nation's energy generation over the coming decades. This paper provides an overview of many of the key studies that used economic models to analyze the potential impacts of these rules.[1] The regulations surveyed include the Cross-State Air Pollution Rule (CSAPR), the Mercury and Air Toxics Standards (MATS), the proposed Clean Water Act (CWA) Section 316(b) rule, the proposed Coal Combustion Residuals (CCR) rule, and, to a lesser extent, possible modifications to sulfur dioxide (SO_2) and nitrogen oxide (NO_x) National Ambient Air Quality Standards (NAAQS). Analyses of greenhouse gas regulations are not considered here.

The studies reviewed seek to shed light on pressing questions about how coal-fired power plants, and the electricity system as a whole, will adapt to the new regulations. For example, will the new rules raise the cost of electricity or lower profits for utility companies? How much coal-fired capacity will companies retire in coming years rather than install pollution controls to comply with the new regulations? And if large amounts of capacity shut down, will the reliability of the electricity system be put in jeopardy? With multiple regulations affecting the power sector at once, the studies also seek to address questions of short-term reliability problems as plants go offline to install new control technologies.

Analysts have reached varying conclusions about the impact of the EPA regulations. Many of these differences can be traced back to the assumptions that underlie the models used in the analyses. Important assumptions include how much natural gas will cost, the types of

* Blair Beasley is a research assistant at RFF; Daniel Morris is a center fellow at RFF's Center for Climate and Electricity Policy, morris@rff.org.

[1] This summary paper is a review of economic modeling studies looking at non-CO_2 pollution regulation that were published as of September 1, 2012. It includes the proceedings of a workshop hosted by Resources for the Future and sponsored by the Electric Power Research Institute that took place July 19, 2012.

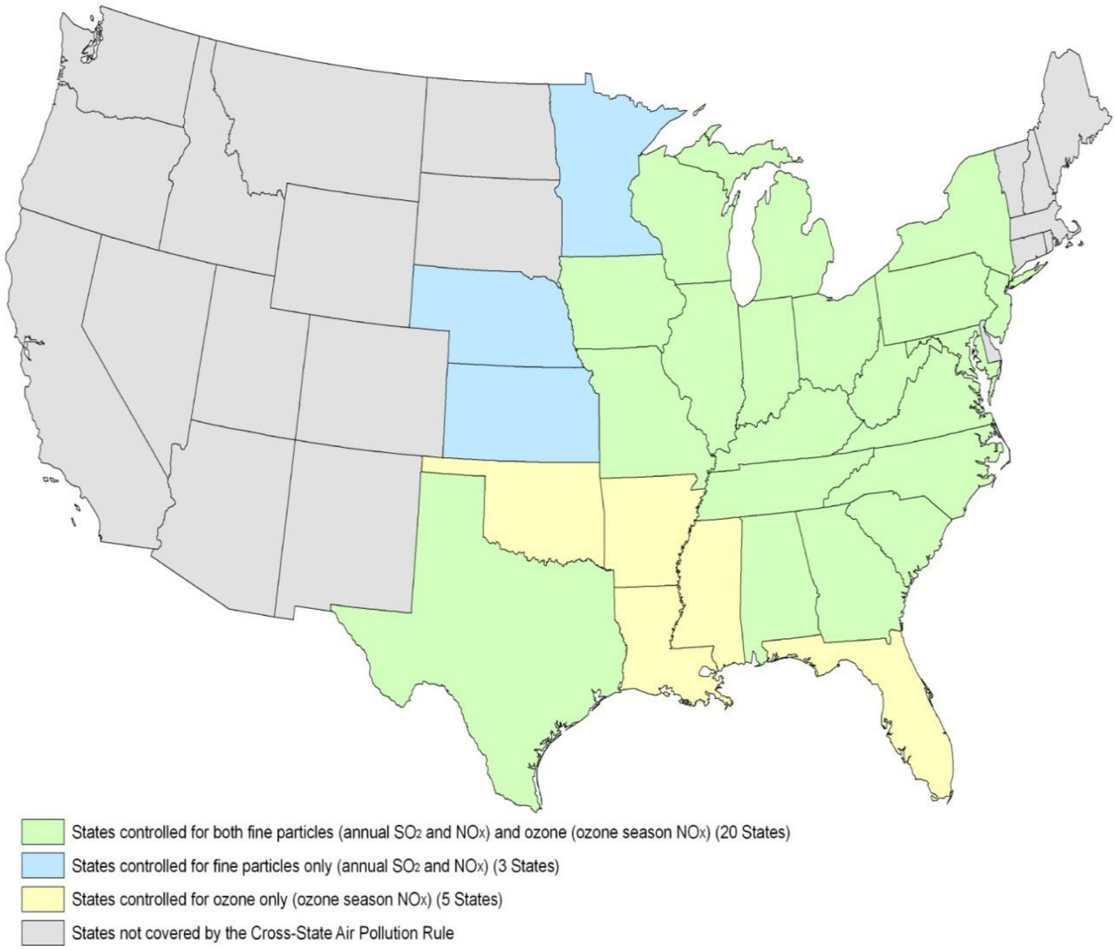
pollution control technologies that will be available to generators, and which EPA regulations will be in effect. In addition, the timing of the studies is key to understanding the predicted outcomes. Studies conducted prior to the release of the final or proposed EPA regulations often assume more stringent regulatory requirements and, therefore, find more retirements of coal-fired plants.

Relevant EPA Policies

EPA finalized CSAPR on July 6, 2011, as a replacement for the 2005 Clean Air Interstate Rule (CAIR), which was vacated by the U.S. Court of Appeals for the D.C. Circuit in December 2008 and remanded to EPA. CSAPR has not had an easier road to implementation. In December 2011, the D.C. Circuit Court of Appeals stayed the rule pending judicial review, which resulted in the rule being struck down in August 2012 and leaving CAIR in effect for the time being. Both CSAPR and CAIR are intended to regulate air pollution that crosses state lines and prevents downwind states from meeting EPA air standards for ozone or fine particulate pollution. CAIR instituted a cap-and-trade program intended to reduce SO_2 and NO_x emissions in 28 eastern states. The rule allowed for unlimited interstate trading of emissions credits. Under CSAPR, 23 states in the eastern half of the country are required to substantially reduce annual SO_2 and NO_x emissions, and 25 states are required to reduce ozone season NO_x emissions (Figure 1). The first phase of compliance would have begun in January 2012, with a second phase of SO_2 reductions beginning in 2014.

CSAPR establishes four cap-and-trade programs, including two SO_2 programs and two NO_x programs. The two SO_2 programs separate the 16 states with more stringent SO_2 reduction standards from 7 other states that face less stringent requirements. Both groups must meet SO_2 reduction limits beginning in 2012. Those facing a more stringent standard must achieve further SO_2 reductions beginning in 2014. The NO_x programs are divided into annual NO_x requirements, which all 23 states facing SO_2 standards must meet, and a seasonal NO_x program, which covers a separate group of states, including 20 states with SO_2 requirements and 5 states without SO_2 requirements. Power plants subject to the regulation can trade within their cap-and-trade group, but not across groups. Although intragroup trading among facilities is unlimited, individual states do have their own emissions caps. If states exceed those caps by more than 20 percent, the responsible sources have to pay a penalty and submit additional allowances. The studies reviewed in this paper assumed that CSAPR would be upheld by the courts in some form, and their results reflect those assumptions.

Figure 1. States Covered by CSAPR NO_x and SO_2 Limits



Source: EPA, Large Map of Transport Rule States, http://www.epa.gov/airtransport/statesmap.html.

EPA finalized MATS on December 16, 2011. The rule requires new and existing coal- and oil-fired power plants to reduce emissions of mercury and other heavy metals (e.g., arsenic, chromium, and nickel), as well as acid gases (e.g., hydrogen chloride and hydrogen fluoride). The rule sets numerical emissions limits for the pollutants and allows for some alternative compliance measures. For example, the rule sets limits for hydrogen chloride emissions, a surrogate for all toxic acid gases, but generators can comply with an alternative SO_2 limit instead. To meet these standards, power plants can use a range of pollution control technologies, such as wet and dry scrubbers, dry sorbent injection systems, activated carbon injection systems, and fabric filters. MATS requires plants to come into compliance by 2015. However, EPA has said that most plants will be given an extra year from state permitting authorities to complete the retrofits if needed, pushing the compliance deadline out to 2016. In addition, EPA released a memo stating that plants that play an important reliability role and are unable to comply by 2016 can apply for an additional year to attain compliance.

Other key EPA regulations have yet to be finalized. In particular, the CWA Section 316(b) rule, proposed on March 28, 2011, would regulate cooling water intake safeguards in an effort to reduce injuries and deaths of fish and other aquatic organisms. The proposed rule would affect existing power plants and manufacturing facilities that withdraw at least 2 million gallons of cooling water each day. Most facilities would be allowed under the rule to select technologies that reduce the number of organisms that are killed by being pinned against intake screens. They could also choose to reduce water intake velocities to levels that would allow most fish to safely swim away from the cooling water intake of a facility. Larger facilities that withdraw at least 125 million gallons of water per day would be required to conduct studies to help permitting authorities determine what site-specific controls, if any, are required to reduce the number of organisms sucked into the cooling water systems. Finally, existing facilities that add generation capacity would be required to add technologies equivalent to closed-cycle cooling. Closed-cycle cooling systems, also known as cooling towers, are expensive but effective controls. They reduce the number of organisms harmed by allowing a facility to recycle its cooling water, reducing the amount of cooling water it has to pull in from the outside. The agency was under a court-ordered deadline to issue a final rule by July 27, 2012, but it has delayed the release of the rule by one year.

The CCR rule was proposed by EPA on June 21, 2010, and has not yet been finalized. The rule would regulate the residuals of coal combustion, also known as coal ash, that are produced by coal-fired power plants. Ash waste is currently stored in liquid form in surface impoundments and in solid form at landfills. The rule aims to prevent pollutants in coal ash, such as mercury, cadmium, and arsenic, from leaching into groundwater. EPA is considering regulation under Subtitle C or Subtitle D of the Resource Conservation and Recovery Act. If regulated under Subtitle C, the federal government would issue disposal requirements and could, along with states, enforce management and disposal practices. Under Subtitle D, EPA would set performance standards for the waste management facilities. These standards would be primarily enforced by states and through citizen lawsuits.

Finally, some analysts have begun considering the impacts of potential future updates to SO_2 and NO_x NAAQS. The Clean Air Act calls for EPA to set NAAQS for six criteria pollutants: SO_2, NO_x, ozone, particulate matter, carbon monoxide, and lead. EPA sets primary standards, which are intended to protect public health, and secondary standards, which are intended to protect public welfare. The law requires the agency to review and, if appropriate, revise the requirements every five years. The NAAQS for SO_2 and NO_x were last updated in 2010.

Modeling Overview

This review considers analyses based on economic models used by consulting, policy, and research organizations to study the impacts of the new EPA regulations discussed above. Box 1 summarizes the basic structure of the models reviewed in this paper. The models include the Framework for Analysis of Climate-Energy-Technology Systems (FACETS), the Haiku electricity market model, the Integrated Planning Model (IPM), the PI version of the U.S. Energy Information Administration's National Energy Modeling System (NEMS), the NewERA Model, the North American Electricity and Environment Model (NEEM), and the U.S. Regional Economy, Greenhouse Gas, and Energy model (US-REGEN).

Box 1: Summary of the Models

FACETS

KanORS's Framework for Analysis of Climate-Energy-Technology Systems (FACETS) model is a bottom-up linear programming model of the U.S. power sector and its associated fuel supplies. A full-sector energy model is planned, with domestic and imported energy supplies, transformation processes, and end-use demands. FACETS is built within the Veda-TIMES model generator framework. The model divides the country into flexible geographic regions. For example, electricity generation is mapped to NERC subregions, while electricity demand is mapped to census divisions. The model includes 15,000 existing power plants. It allows for endogenous plant-by-plant retirement and retrofit decisions (Wright and Kanudia 2012).

Haiku Electricity Market Model

Resources for the Future's Haiku electricity market model is a deterministic partial equilibrium model of the U.S. electricity sector. It models electricity markets in 22 linked regions of the contiguous United States. Each region balances energy and capacity supply and demand, subject to transmission grid constraints and endogenous investment in new generation capacity and retirement of existing facilities. The model aggregates individual generators into model plants that are able to respond to new environmental regulations in numerous ways—for example, by retrofitting with pollution controls, switching to different fuels, or retiring. Haiku has price-responsive electricity demand functions for three customer classes that vary by season and time of day, and price-responsive natural gas and coal supply modules (Burtraw et al. 2012).

IPM

The Integrated Planning Model (IPM) is run by ICF International for a variety of clients, including EPA, the Bipartisan Policy Center, and the Edison Electric Institute. IPM is a multiregional, dynamic, deterministic linear programming model of the electricity sector. It includes every electric boiler and generator in the U.S. power market (ICF International n.d.). The model endogenously determines generator capacity; transmission expansion; unit dispatch; compliance decisions; and prices for electricity, coal, and allowances (Macedonia et al. 2011).

NEEM

The North American Electricity and Environment Model (NEEM) is Charles River Associates' model of the electricity sector. It divides the United States into more than 30 connected regions that reflect transmission constraints and environmental regulations. The model includes a detailed representation of the coal sector. This includes coal supply curves that represent 21 coal supply regions and coal types. NEEM optimizes generation in each geographic region over a 40- to 60-year period, as well as retirements, electricity prices, pollution control retrofits, and investment in new capacity (Shavel and Gibbs 2010; Charles River Associates n.d.).

NewERA Model

NERA Economic Consulting's NewERA Model is an economywide model that combines a macroeconomic model of all sectors of the economy with a detailed representation of the electricity sector. The macroeconomic portion of the NewERA Model is a computable general equilibrium model that includes final demand in the economy as well as all production sectors (except the electricity sector). The electricity sector is modeled at the level of the electricity generating unit. Generators can respond to regulations by retrofitting, retiring, fuel switching, or redispatching. The model finds the least-cost solution while meeting several constraints, such as demand, peak demand, emissions limits, and transmission limits (NERA 2012; Smith et al. 2012).

PI-NEMS

PI-NEMS is a version of the U.S. Energy Information Administration's National Energy Modeling System (NEMS) that is run by OnLocation for the U.S. Department of Energy's Office of Policy and International Affairs. The model covers the entire energy economy based on assumptions about macroeconomic and financial factors and world energy markets. Among other things, the model projects energy supply, energy demand, imports, and prices. PI-NEMS divides the U.S. electricity sector into 22 regions. Electricity generated within a region can be transmitted freely anywhere within that region. Some limitations are placed on transmission between regions (DOE 2011).

US-REGEN

The U.S. Regional Economy, Greenhouse Gas, and Energy model (US-REGEN) is the Electric Power Research Institute's general equilibrium model of the national economy with a detailed representation of the electricity and transportation sectors. This includes a detailed model of vehicle technologies and intermodal choices, as well as energy efficiency choices and pollution control technologies. The model divides the United States into 12 regions and solves for intertemporal optimization over five-year time blocks. Among other things, the model endogenously solves for interregional transmission builds (EPRI 2012).

Understanding the assumptions made in each model is critical for interpreting their analyses of impending policies, especially because the requirements to comply with regulations in question are uncertain until final versions are released, and choices made about their stringency or coverage can significantly impact the outcome of model runs. Model assumptions can generally be grouped into three categories: regulatory, technology, and markets.[2] Regulatory assumptions can vary as a result of unclear wording in the proposed rules or because modelers deem that different compliance mechanisms may be available to regulated parties. As a result, modelers may at times use their own judgment to determine the stringency of a rule or regulation. One model may not allow a certain technology to deploy in the future because the modelers think it cannot reasonably come into compliance with regulations, whereas another model may envision a less stringent regulation that allows the technology to deploy. Assumptions about pollution control technologies for plants vary as a result of their cost and the uncertain timing of new technology developments. Economic growth, electricity demand, and other exogenous market forces can lead to a wide range of assumptions across different models as well.

In some areas, the models have moved closer to agreement over multiple iterations. The expected timing of regulation implementation, costs of pollution controls like scrubbers and dry sorbent injection systems, electric load growth, and cost of new generation capacity like nuclear have begun to converge on more consistent values across different models in recent years. Other areas, such as the possible impact of greenhouse gas policies, are still highly unpredictable. Table 1 below lists important characteristics and assumptions of 13 modeling studies conducted over the past two years.

[2] An extensive presentation of these assumption categories and their implications for assessing modeling analysis was presented at the July workshop.

Table 1. Summary of Studies Reviewed

Organization	Report authors	Publication title	Date of publication	Policies analyzed	Policies in the baseline	Treatment of natural gas	Coal capacity predicted to retire in the baseline	Year in which key rules are assumed to take effect	Model
Bipartisan Policy Center	Jennifer Macedonia, Joe Kruger, Lourdes Long, Meghan McGuinness	Environmental Regulation and Electric System Reliability	June 2011	Proposed CSAPR, Proposed MATS, Proposed CWA 316(b), Proposed CCR (Subtitle D)	Existing state and federal regulations, such as CAIR and state mercury standards	AEO 2010 (base case), sensitivity case includes minus $1/million Btus below AEO 2010–based supply curve	14 GW by 2030	Proposed CSAPR (2012), proposed MATS (2015), CWA 316(b) (2022 for fossil and 2027 for nuclear), CCR (2015), NO_x from NAAQS and BART (2018)	IPM
Bipartisan Policy Center	Jennifer Macedonia, Colleen Kelly	BPC Modeling Results: Projected Impact of Changing Conditions on the Power Sector	July 2012	CSAPR, MATS	Existing state and federal regulations, such as CAIR	AEO 2012 early release	40 GW by 2016	CSAPR (2013, 2014), MATS (retrofits of ACI, DSI and ESP upgrades, 2015; scrubber and fabric filters, 2016)	IPM
Charles River Associates	Ira Shavel, Barclay Gibbs	A Reliability Assessment of EPA's Proposed Transport Rule and Forthcoming Utility MACT	December 2010	Proposed CSAPR, MATS (written prior to proposal)	Unclear	Combination of NYMEX futures and AEO 2010	6 GW by 2015	Proposed CSAPR and MATS (2015)	NEEM
Charles River Associates	Ira Shavel	Electric Sector Impacts: CSAPR, MATS, etc.	Slides presented July 2012	CSAPR, MATS, proposed CWA 316(b), $10 per tonne CO_2 policy, NO_x policy requiring SCRs	CSAPR	AEO 2012 and futures through 2014	23.2 GW by 2020	CSAPR (2013, 2014), MATS (2015 or 2017), CWA 316(b) (2020), CO_2 (2020)	NEEM

DOE	DOE	Resource Adequacy Implications of Forthcoming EPA Air Quality Regulations	December 2011	CSAPR, MATS	Existing state and federal regulations, such as CAIR	AEO 2011, sensitivity cases include gas supply from EIA's High Shale EUR side case	8 GW by 2015	CSAPR (2012, 2014), MATS (2015)	PI-NEMS
Edison Electric Institute	Steven Fine, Shanyn Fitzgerald, Jesse Ingram	Potential Impacts of Environmental Regulation on the U.S. Generation Fleet	January 2011	Proposed CSAPR, MATS (written prior to proposal), CCR, CWA 316(b) (written prior to proposal), CO_2 regulation	Existing state and federal regulations, such as CAIR and state mercury standards	Prices constructed from EPA v4.10 supply curves for 2015 and 2020, sensitivity cases include a \$1.50 and a \$3.00 increase in gas prices	22 GW in 2015, 25 GW in 2020	MATS (2015), CWA 316(b) (2022, 2027), CO_2 (2017), CCR (Subtitle D) (2017), CSAPR (2017, 2018)	IPM
EPA	EPA	Regulatory Impact Analysis for the Federal Implementation Plans to Reduce Interstate Transport of Fine Particulate Matter and Ozone in 27 States; Correction of SIP Approvals for 22 States	June 2011	CSAPR	Existing state and federal regulations, with the exception of CAIR	AEO 2011	1–4.8 GW by 2020	CSAPR (2012, 2014)	IPM

EPA	EPA	Regulatory Impact Analysis for the Final Mercury and Air Toxics Standards	December 2011	MATS	Existing state and federal regulations, such as CSAPR; no state-level mercury standards	AEO 2011	Unclear	MATS (2015)	IPM
EPRI	Victor Niemeyer, Francisco De La Chesnaye, Bryan Hannegan	Prism 2.0: The Value of Innovation in Environmental Controls	Summary released May 2012	MATS, CWA 316(b), CCR, SO_2 and NO_x NAAQS	Existing state and federal regulations, such as CSAPR	+$2 and -$2 MMBTU from AEO 2011	Unclear	MATS (2015), CWA 316(b) (2018), CCR (Subtitle D by 2020), NO_x and SO_2 NAAQS (2018)	US-REGEN
KanORS/Decision Ware	Evelyn Wright, Amit Kanudia	Analysis of CSAPR and MATS in FACETS	Slides presented July 2012	CSAPR, MATS	Existing state and federal policies, excluding CAIR	AEO 2011	8.5 GW by 2020	CSAPR (2014), MATS (2017)	FACETS
NERA Economic Consulting	David Harrison, Jr., Andrew Foss, James Johndrow, Eugene Meehan, Bernard Reddy, Anne Smith	Potential Impacts of EPA Air, Coal Combustion Residuals, and Cooling Water Regulations	September 2011	CSAPR, proposed MATS, CWA 316(b), CCR	Existing state and federal regulations, such as CAIR (through 2011) and state mercury standards	AEO 2011	3.1 GW by 2015	CSAPR (2012, 2014), MATS (2015), CCR (2015), CWA 316(b) (2015)	NEMS, REMI PI+ (for economic impacts)
NERA Economic Consulting	Anne Smith, Paul Bernstein, Scott Bloomberg, Sebastian Mankowski, Sugandha Tuladhar	An Economic Impact Analysis of EPA's Mercury and Air Toxics Standards Rule	March 2012	MATS	The paper included two baselines, one with CSAPR and one with CAIR	To account for uncertainty in shale oil's impact on prices, NERA includes resource supply curves	15 GW by 2015 (in the baseline with CAIR)	MATS (2015)	NewERA

						for U.S. gas; NERA also includes supply and demand curves for U.S. imports and exports			
Resources for the Future	Dallas Burtraw, Karen Palmer, Anthony Paul, Blair Beasley, Matt Woerman	Reliability in the Electricity Industry under New Environmental Regulations	May 2012	CSAPR, MATS	Existing state and federal regulations such as CAIR, Title IV, state mercury standards	AEO 2011 prices	13.2 GW by 2020	CSAPR (2012, 2014), MATS (2016)	Haiku

Notes: ACI, activated carbon injection; AEO, Annual Energy Outlook; CO_2, carbon dioxide; DSI, dry sorbent injection; EIA, U.S. Energy Information Administration; ESP, electrostatic precipitator; GW, gigawatts; MACT, maximum achievable control technology; NYMEX, New York Mercantile Exchange; SIP, state implementation plan; REMI PI+, Policy Insight Plus model developed by Regional Economic Models, Inc.

Notable Results and Common Themes

The models reviewed here and discussed in the July workshop come to varying conclusions about how EPA regulations will impact the electricity sector—particularly the future composition of capacity and generation and the level of investment in pollution control technologies. The models provide great insight into future patterns, even if they do not settle on specific numbers. Indeed, no one model can provide 100 percent reliable estimates, but by comparing methods and results, modelers can confidently develop a range of regulatory outcomes. Despite differences in baselines and modeling approaches, many common themes emerge.

Capacity

Some current estimates have announced coal plant retirements equating 53 GW of production, though there are many factors that may keep that capacity in the grid. Regardless, coal capacity will likely experience some major changes in the coming years. The reviewed models produce a wide range of estimates for the amount of coal capacity expected to retire in coming years and the type of capacity expected to replace those retired units (Table 2).

Table 2. Estimated Coal Retirements

	Coal retirements in policy cases	Coal retirements in BAU
Bipartisan Policy Center (2011)	15–18 GW by 2015	14 GW by 2015
Bipartisan Policy Center (2012)	16 GW by 2016	40 GW by 2016
Charles River Associates (2010)	33 GW by 2015	6 GW by 2015
Charles River Associates (2012)	12.3–120.9 GW by 2020	23.2 GW by 2020
DOE (2011)	29 GW by 2015 (stringent case)	8 GW by 2015
DOE Presentation (2012)	30–80 GW by 2020	49 GW by 2020
Edison Electric Institute (2011)	17–76 GW by 2020	25 GW by 2020
EPRI (2012)	25–115 GW by 2020	Unclear
NERA Economic Consulting (2011)	39 GW by 2015	3.1 GW by 2015
NERA Economic Consulting (2012)	19–23 GW by 2015	15 GW by 2015
Resources for the Future (2012)	4–5 GW by 2020	13.2 GW by 2020

Notes: BAU, business as usual; GW, gigawatts

Estimated coal retirements vary depending on when the modeling was conducted and which regulations the model includes. Studies conducted prior to the release of final or proposed rules often assume that more stringent or more limited control technologies will be required and that more units will have to invest in these controls. In addition, studies that model more regulations tend to result in more retirements because the additional regulations compound compliance costs. For example, a paper published in January 2011 by Fine et al. predicts that up to 76 gigawatts (GW) of coal capacity will retire by 2020 if MATS, CSAPR, CWA 316(b), CCR

(Subtitle C), and a $25 per ton carbon dioxide price are enacted. At the time of publication, EPA had not finalized any of the regulations, and some regulations, such as the CWA 316(b) rule and MATS, had not yet been proposed. As a result, the authors' assumptions about control requirements are substantially more stringent than the rules ultimately required (Fine et al. 2011).

Assumptions about natural gas prices have a strong impact on estimates of retirements from existing capacity and what type of new capacity will come online. Estimated natural gas prices have varied greatly in recent years, but cheap and readily available natural gas has to some degree supplanted regulations as the main driver of coal plant retirements. Most models use the U.S. Energy Information Administration's Annual Energy Outlook (AEO) for gas price forecasts. Models that use older versions of the AEO include higher gas prices than those that draw on more recent versions. When gas prices are lower, retrofitting coal plants becomes less economical, and more investment in new gas-fired capacity is expected. The 2010 analysis by Shavel and Gibbs, for example, concludes that many actual announced retirements captured in the baseline and projected retirements modeled in the policy scenarios are driven by lower gas prices. The authors state, "[i]f we had used the higher natural gas prices that had existed only a few years ago in our modeling of the utility [maximum achievable control technology]/CAIR NO_x policy, the predicted retirement results would have been very different" (Shavel and Gibbs 2010, 12).

Many studies highlight these differences by running models with a range of natural gas price assumptions. For example, in its 2011 study, DOE runs a low natural gas case in which the price of delivered natural gas in 2015 falls from $4.8 per thousand cubic feet in the base case to $4.0 per thousand cubic feet in the low natural gas case. The lower price of natural gas leads to more coal retirements in both the new base case and the new policy case. More natural gas–fired capacity is built to help fill this void (DOE 2011). Similarly, the 2011 report by Macedonia et al. includes a sensitivity case in which natural gas prices are $1 per million Btus less than in the regular policy case. In all years modeled, more coal capacity is expected to retire in the low natural gas case than in the regular policy case. In addition, when natural gas prices are higher, the model predicts that more new coal plants will be built to replace the retired plants. In the low natural gas case, the economics shift toward new natural gas facilities, with fewer new coal plants predicted to come online (Macedonia et al. 2011).

The MATS rule was of particular interest to some modelers because, when fully implemented, the rule is projected to have the greatest impact of all impending air regulations on available generation capacity (North American Electric Reliability Corporation 2010). Some industry actors argue that the stringency and timing of MATS will negatively impact capacity and lead to high costs because (a) it lacks the flexibility provided by a compliance market like the one established in CSAPR, and (b) the compliance time frame is not long enough to install the proper retrofits, which could force more plants to retire. Some modeling reflects these concerns. In one instance, Fine et al. (2011) assume that all coal plants must install scrubbers, activated carbon injection, and fabric filters by 2015 to comply with MATS. The study was conducted, however, before the release of the final MATS rule, which allows for more flexibility, including lower-cost dry sorbent injection systems to control for SO_2. EPA also expects that most plants will be able to take an extra year to come into compliance.

In a more recent analysis from 2012, Smith et al. compare their MATS-specific modeling with EPA estimates from the regulatory impact analysis. The study finds similar compliance costs, but Smith et al. project higher retirements (5 GW in the EPA regulatory impact analysis compared with 19 GW for Smith et al.) specifically due to MATS. Smith et al. take their cost analysis farther than EPA to project macroeconomic impacts of the rule, finding that it may result in gross domestic product losses of between $84 billion and $112 billion by 2035 (Smith et al. 2012). On the lower end of estimated retirements, Burtraw et al. (2012) estimate that under MATS, 4.4 GW of coal capacity will retire by 2035, beyond those retirements expected in the baseline scenario. When CSAPR is also included in the analysis, predicted coal retirements rise to 5 GW. These estimates are based on a simulation of the final MATS and CSAPR rules, and unlike the Fine et al. study, the regulatory scenarios analyzed by Burtraw et al. (2012) do not include water, coal ash, or carbon dioxide regulations.

Generation

For many studies, the decrease in coal capacity does not yield an equally large decrease in coal generation. This discrepancy occurs because many of the coal-fired facilities predicted to retire are older, smaller, less efficient units that do not run at full capacity. The retirement of these coal facilities has important reliability and emissions implications because coal is a primary source of many regulated air pollutants. For example, in Macedonia and Kelly’s 2012 analysis of CSAPR and MATS, 74 percent of the retiring coal units are at least 40 years old, 50 percent have capacities of 200 megawatts (MW) or less, and 55 percent have a heat rate of at least 11,000 million Btus. As a result, despite retirements, coal remains the dominant generation source throughout the modeling timeline (Macedonia and Kelly 2012).

Nonetheless, in some studies, as coal plants retire, the demand for coal falls, leading to a decrease in the price of coal. This reduced price helps coal remain competitive with natural gas–fired units. For example, in their 2011 analysis of CSAPR, MATS, CWA 316(b), and CCR, Harrison et al. estimate that about 39 GW of coal-fired capacity will retire by 2015. But coal generation decreases by only 11.1 percent between the baseline and the policy case. In this scenario, the decreased demand for coal leads to a 5.7 percent decrease in coal prices under the policy case compared with the base case (Harrison et al. 2011).

Pollution Control Technologies

Finally, the studies reviewed predict that a range of pollution control investments will be built to comply with the EPA regulations. As with the capacity estimates, some of the differences in modeling results can be attributed to which rules were modeled and when the reports were written. For example, studies conducted prior to the release of the proposed CWA 316(b) rule tend to assume that more cooling towers would be built than did studies conducted after the proposed rule was released. Similarly, many studies released prior to the final MATS rule made conservative assumptions about control technologies. For example, a study by Shavel and Gibbs in 2010 assumes that all coal plants will have to use the most expensive control technologies to comply with the rule, namely, activated carbon injection systems, fabric filters, and wet scrubbers.

In addition, the studies differ in how they treat new control technologies, such as dry sorbent injection systems, which control for emissions of SO_2. Although they are not as effective as scrubbers, they are less expensive to install. Some studies assume that only relatively large units can install this technology. The report by Macedonia et al. (2011), for example, assumes that plants must be 300 MW or smaller to install dry sorbent injection systems, whereas the study by Burtraw et al. (2012) assumes that facilities must be 25 MW or larger. EPA (2011b) also assumes, in its final MATS analysis, that plants 25 MW or larger could select this technology.

Modeling Limitations

While these modeling studies have provided useful insights and clear themes for policymakers and stakeholders, they are limited in some meaningful ways. The electricity sector’s response to EPA regulations will be determined to some degree by the vintage of current capital assets and the availability of financing to develop capital in the future. The challenge for operators of older and smaller facilities is not limited to considering capital costs for retrofits against a market with cheaper natural gas; it includes their ability to procure streams of financing in the face of falling investment ratings. These dynamics are not easily captured by the models. Incorporating financing aspects like risk-adjusted rates of return is difficult because they present levels of uncertainty that may be too big for the models to handle appropriately. Some rates apply to specific facilities in a way that broader computable general equilibrium (CGE) models cannot represent, and partial-equilibrium models cannot include dynamically.

Similarly, the models cannot give a clear representation of the impact that retirements and retrofits will have on employment in the electricity sector. CGE models, such as the NewERA model, can estimate to some degree the opportunity costs of capital and what impacts to the labor market may occur from capital being used for retrofits instead of new development. These calculations, however, can give only a sense of the impact on labor markets relative to their baseline and certainly would not generate precise numbers of jobs lost or gained.

Conclusions

Analysts have used several different economic models to try to understand how new EPA regulations could impact coal-fired generation in the United States as well as the electricity system as a whole. Important questions addressed by these analysts include how much coal-fired capacity is expected to retrofit or shut down and how those retirements will affect the reliability of the electricity system. The models provide great insights into the implications of impending regulations and the proper context through which to view changes in the country's electricity generation fleet, but they do not paint a uniform picture of the future.

Instead, outcomes depend on the assumptions underlying the analyses, including natural gas price projections over time, the requirements for compliance with each regulation, and costs of technologies necessary for compliance. These assumptions have evolved over time as regulations have developed and as natural gas markets have evolved. For example, earlier studies relied on older versions of the AEO, which included higher natural gas price estimates than later versions. Earlier studies also had less information about what EPA would ultimately require in the regulations. In addition, studies produced at similar points in time make differing choices about which regulations to model or when the policies will come into effect. As a result, despite many common trends, the studies come to differing conclusions about the changes the industry can expect in coming years. As the electricity sector copes with both changing market dynamics and finalized regulations, these models will continue to provide a spectrum of results that policymakers and stakeholders can use to guide investment and regulatory decisions.

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