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Mercury and Air Toxics Standards Analysis Deconstructed

*Changing Assumptions,
Changing Results*

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Abstract

Several recent studies have used simulation models to quantify the potential effects of recent environmental regulations on power plants, including the Mercury and Air Toxics Standards (MATS), one of the US Environmental Protection Agency's most expensive regulations. These studies have produced inconsistent results about the effects on the industry, making general conclusions difficult. We attempt to reconcile these differences by representing the variety of assumptions in these studies within a common modeling platform. We find that the assumptions, and their differences from the way MATS will be implemented, make a substantial impact on projected retirement of coal-fired capacity and generation, investments that are required, and emissions reductions. Almost uniformly, the actual regulation, when examined in its final form and in isolation, provides more flexibility than is represented in most models. We find this leads to a smaller impact on the composition of the electricity generating fleet than most studies have predicted.

Key Words: sulfur dioxide, mercury, air toxics, nitrogen oxides, carbon dioxide, electricity, technology, generation

JEL Classification Numbers: Q47, Q53, Q58

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1. Introduction

In 2011, the US Environmental Protection Agency (EPA) finalized two landmark environmental regulations aimed at curbing air pollution from the electricity sector. The Cross-State Air Pollution Rule (CSAPR) would have reduced sulfur dioxide (SO₂) and nitrogen oxide (NO_x) emissions that are crossing state lines and contributing to pollution problems downwind. The Mercury and Air Toxics Standards (MATS) is intended to reduce the emissions of hazardous air pollutants, such as mercury and acid gases, from coal- and oil-fired power plants. Both rules face legal challenges in the courts. In August 2012, the US Court of Appeals for the DC Circuit threw out CSAPR, remanding the rule to EPA to try again. As a result, CSAPR's predecessor, the Clean Air Interstate Rule (CAIR), remains in effect. MATS also faces legal challenge; however, the DC Circuit Court has agreed to take no action on a pending lawsuit while EPA reconsiders the rule's requirements for new power plants.

If CSAPR had remained in effect, EPA projected that the rule would have decreased SO₂ emissions in the affected region in 2014 by 6.4 million tons per year compared to 2005 emissions levels, to an expected level of 2.4 million tons. The rule would have decreased NO_x emissions by 1.4 million tons per year, to an expected level of 1.2 million tons (2011d). In contrast, CAIR achieves most of these reductions, although the levels vary among the states. If CAIR remains in effect, it is expected to achieve emissions levels of 2.5 million tons of SO₂ and 1.3 million tons of NO_x in affected states by 2015 (EPA 2012a). MATS, meanwhile, is estimated to reduce mercury emissions from coal-fired power plants by 90 percent and reduce acid gas emissions by 88 percent. The rule is also projected to reduce SO₂ emissions from power plants by 41 percent beyond what was projected from CSAPR. These reductions come at a cost to the electricity industry. EPA estimates that MATS will cost \$9.6 billion a year— one of the most expensive single regulations in the nation's history (EPA 2011a). CSAPR was expected to cost \$800

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million in 2014, along with \$1.6 billion a year in capital investments that were started under CAIR (EPA 2011d). The costs are almost entirely the result of new pollution control investments at coal-fired power plants.

The overall cost and the timing of the regulations have sparked debate within the electricity industry about the impacts of the rules. There is particular concern that the new requirements could cause reliability problems, including electricity supply disruptions, shortages of generation capacity, or problems meeting reliability standards. This has led to some political backlash, with various groups calling EPA's suite of new air pollution rules, including some rules that are anticipated but not yet proposed, a "regulatory train wreck" (Congressional Research Service 2011). Others, however, have found that the focus on the reliability of supply is unwarranted, with widespread supply disruptions resulting from CSPA and MATS unlikely. Several of those studies are analyzed in this paper, including work by the Bipartisan Policy Center (Macedonia and Kelly 2012) and Resources for the Future (RFF) (Burtraw et al. 2012a). However, the rules are not without impact. As shown in the RFF paper, MATS is likely to impact reliability in terms of changes to current electricity prices, industry revenues and costs, and profits.

Complicating the reliability debate is the impact of low natural gas prices and electricity demand on the electricity sector. Burtraw et al. (2012b) found that changes in relative fuel prices and electricity demand within the electricity sector that would have occurred in the absence of EPA regulation are expected to have a much larger effect on changes in capacity and generation mix than will MATS or CSAPR. Since the beginning of 2010, natural gas prices have fallen considerably, driven by the new shale gas boom. In addition, electricity demand growth has slowed in the wake of the economic downturn and increased energy efficiency. The lower gas prices are expected to drive electricity generation away from coal-fired plants and toward natural gas, while the reduced demand is associated with a reduction in the growth of electricity generation. A comparison between a baseline scenario that uses 2009 natural gas supply and electricity demand data and a baseline scenario that uses 2011 data highlights this trend. When 2011 data is used instead of 2009 data, coal generation falls by 14.7 percent. By comparison, the addition of MATS to the 2011 baseline scenario reduced coal generation by only 1.5 percent.

All of this change in the industry and associated uncertainty have led many to consult predictions from economic models that explore the impacts of EPA's proposed rules. Several studies have used economic models to attempt to quantify and explain the potential effects of CSAPR and MATS, but these studies typically come to quite different conclusions. One reason is that the analyses were done at different points in time with different information. Moreover, the studies made different assumptions and used different models to reach their conclusions. It is

challenging to extract the effects of the regulations from the important differences in the modeling assumptions used and the policies modeled. All of these variables contribute to a general confusion about the likely impacts of the regulations.

This paper provides a review of several key analyses and attempts a reconciliation of the results by deconstructing the differing assumptions within a common modeling platform. We focus primarily on analyses of MATS, since CSAPR has been remanded to EPA. However, several of the studies include CSAPR in their baselines or model CSAPR alongside MATS, and we also investigate some of these scenarios. We conduct the reconciliation using RFF's Haiku electricity market model. This eliminates variability among the modeling platforms, one of the key sources of variation among the studies. We then vary the assumptions and scenarios within Haiku to represent choices made by other modeling teams.

In brief, our finding is that models that most closely mirror the requirements of the final MATS rule and portray MATS without the confounding influence of other proposed EPA regulations find the impact of the rule to be less severe. In particular, the way researchers modeled the acid gas requirements under MATS had a large impact on the forecasted amount of coal-fired capacity and generation going forward, as well as the pollution controls that would be installed at these units and their emissions of acid gases. Those studies that allowed plants to meet either a SO₂ or a hydrochloric acid (HCl) emissions standard, as laid out in the final MATS rule, tended to find less of an impact on coal-fired plants than those studies that forced plants to strictly comply with the SO₂ standard. As described below, the rule measures compliance for some substances by proxy and provides flexibility for a facility in choosing among alternative compliance strategies. The flexibility to choose which standard to meet, as set forth in the rule, appears to lower costs importantly and reduces the impact on the coal fleet. Those studies that forced plants to comply specifically with the SO₂ standard also tended to find greater use of SO₂ controls and thus greater reductions of SO₂ emissions. In addition, the studies that introduced a price on carbon dioxide (CO₂) emissions or required selective catalytic reduction controls (SCR) retrofits in anticipation of a future tightening of the NO_x National Ambient Air Quality Standards (NAAQS) saw relatively large reductions in predicted coal capacity and generation and reductions in CO₂ and NO_x emissions, respectively, compared to studies that did not model these future regulations.

2. EPA Policies That Are Modeled

Mercury and Air Toxics Standards (MATS)

EPA finalized MATS in December 2011. The rule regulates emissions of heavy metals and acid gases from new and existing coal- and oil-fired power plants. This includes emissions of mercury, arsenic, chromium, nickel, HCl, and hydrofluoric acid. The rule sets numerical emissions limits for the pollutants and allows for some alternative compliance measures. For example, under MATS, all coal-fired units must meet emissions limits for mercury, particulate matter, and HCl. However, in place of the HCl standard, coal generators can opt to meet an alternative SO₂ limit.

To meet these standards, power plants can use a range of pollution control technologies, such as wet and dry scrubbers, dry sorbent injection (DSI) systems, activated carbon injection systems, fabric filters, and electrostatic precipitators. MATS requires plants to come into compliance by 2015. However, EPA has said that it will allow state permitting authorities to give an extra year to most plants to complete the retrofits if needed— pushing the compliance deadline out to 2016 (EPA 2011c). 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 (EPA 2011b). The rule faces legal challenges. However, the DC Circuit court has agreed to take no action on the pending lawsuit while the agency reconsiders the rule's requirements for new power plants. EPA issued a proposed rule addressing emissions limits at new power plants in November 2012. The agency does not expect the proposed rule to significantly alter the costs, emissions reductions, or health benefits of MATS (EPA 2012b).

Cross-State Air Pollution Rule (CSAPR)

EPA finalized CSAPR in July 2011. The rule was written to replace the 2005 emissions rule, CAIR, which was vacated by the DC Circuit Court in December 2008 and remanded to the agency (EPA 2011d). However, in August 2012, the courts overturned CSAPR. As a result, CAIR remains in effect.

CSAPR was intended to regulate NO_x and SO₂ air pollution that crosses state lines and prevents downwind states in the eastern half of the country from meeting EPA standards for ground-level ozone and fine particulate pollution. CSAPR covered a similar, but not identical, group of states to those covered under CAIR. The first phase of CSAPR compliance would have begun in January 2012, with a second phase of SO₂ reductions beginning in 2014. Power plants subject to the regulation were allowed to trade or bank emissions allowances. However,

individual states were subject to their own emissions caps, which could not be exceeded without penalty (EPA 2011d).

National Ambient Air Quality Standards (NAAQS)

The Clean Air Act requires EPA to set NAAQS for six criteria pollutants: SO₂, 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 SO₂ and NO_x were last updated in 2010 (EPA 2012c). Some researchers have begun to model a tightening of the NO_x NAAQS by requiring all coal plants to install SCR units in some future year, while others have begun to model a tightening of the SO₂ NAAQS by requiring all coal plants to meet an SO₂ emissions rate standard more stringent than that introduced by MATS.

Carbon Dioxide (CO₂)

There has been a lot of debate in recent years about how to best limit CO₂ emissions from new and existing power plants. Due to uncertainty about the final regulatory or legislative outcome, some modeling teams used a tax on CO₂ as a proxy for a future CO₂ emissions standard. The size of the tax proxy varies from model to model. The models covered in this review have assumed a CO₂ tax that starts between \$10 and \$25 per ton and grows over time.

Other Rules

Several other environmental regulations relevant to the electricity sector have been announced recently or are anticipated in the coming years. These include the Clean Water Act 316(b) rule, the Coal Combustion Residual rule, and Regional Haze rules. Although some modelers have begun to include these rules in their analyses, they are not the focus of this study and will not be discussed in detail.

3. Methodology

This paper compares results from nine studies that modeled the impacts of MATS and attempts to reconcile differences in the study findings by conducting simulations of the MATS rule using a common modeling platform. The simulations are run in Haiku and are intended to explore the influence of key assumptions made by the studies on several key outcomes, such as capacity mix, generation mix, emissions of relevant pollutants, and installations of pollution control technologies.

The following lists the assumptions explored as well as the associated scenario number as described in Table 1: a baseline against which changes are compared (1); whether the models analyzed MATS only (2) or CSAPR alongside MATS (3); whether the models require plants to comply with the acid gas standard under MATS by meeting the SO₂ standard (4 and 9), the HCl standard (5), or either standard (2 and 3); whether the models allowed DSI (2 and 3) or restricted its installation as a compliance technology under MATS (6 and 9); whether the models required all coal plants to install SCR units to simulate compliance with a future NO_x NAAQS (7); or whether models imposed a price on CO₂ to simulate a future greenhouse gas policy (8). Table 1 summarizes the scenarios modeled in Haiku that simulate these assumptions.

Table 1. Summary of Scenarios Modeled in Haiku

Scenario name	Policy modeled
1. Baseline	This scenario includes CAIR and other existing state and federal policies. It does not include CSAPR or MATS.
2. MATS	This scenario includes MATS as well as CAIR and other existing state and federal policies.
3. MATS/CSAPR	This scenario includes MATS and CSAPR (instead of CAIR).
4. MATS SO ₂	This scenario is identical to the MATS scenario, but with all plants meeting the MATS SO ₂ standard for acid gases.
5. MATS HCl	This scenario is identical to the MATS scenario, but with all plants meeting the MATS HCl standard for acid gases.
6. MATS no DSI	This scenario is identical to the MATS scenario, but with no option for DSI.
7. MATS SCR	This scenario is identical to the MATS scenario, but with all coal plants required to install SCR to meet a future NO _x NAAQS.
8. MATS CO ₂	This scenario is identical to the MATS scenario, but with all fossil plants also facing a CO ₂ tax that begins in 2016 and increases annually by 5 percent, hitting \$10/ton in 2020.
9. MATS SO ₂ no DSI	This scenario is identical to the MATS SO ₂ scenario, but with no option for DSI.

The studies reviewed in this paper are all national in scope and use economic models to make predictions about the impacts of MATS on the electricity sector. Regional studies and those that rely on qualitative analysis were not included.¹ Table 2 summarizes the studies analyzed in this report and provides an overview of some of the relevant assumptions made by the modeling teams. Some studies modeled multiple scenarios. The table below only describes the assumptions of the scenarios reviewed in this report.

¹ For a more complete list of studies and additional analysis, see Beasley and Morris (2012) .

Table 2. Summary of Studies Reviewed

Organization, authors, and date of publication	Publication title	Policies analyzed	Policies in the baseline	Natural gas assumptions	Treatment of acid gases under MATS	Limits on installing DSI	Coal capacity predicted to retire in the baseline	Year in which key rules are assumed to take effect	Model	Closest match to Haiku-modeled scenario
Bipartisan Policy Center (BPC), Macedonia and Kelly, 2012 (July)	BPC Modeling Results: Projected Impact of Changing Conditions on the Power Sector	CSAPR, MATS	Existing state and federal regulations as of summer 2011, such as CAIR	Annual Energy Outlook (AEO) 2012 early release	Model SO ₂ and HCl compliance options, including HCl compliance using low-chlorine coal with a DSI	All units can install DSI	40 GW by 2016	CSAPR (2013, 2014), MATS (retrofits of ACI, DSI and ESP upgrades, 2015; scrubber and fabric filters, 2016)	IPM	MATS/CSAPR
Charles River Associates (CRA), Shavel and Gibbs, 2012 (July)	Electric Sector Impacts: CSAPR, MATS, etc.	CSAPR, MATS, proposed CWA 316(b), \$10 per metric ton CO ₂ policy, NO _x policy requiring SCRs	CSAPR	AEO 2012 and futures through 2014	Model SO ₂ compliance option, not HCl. Most plants can comply with wet scrubbers. Dry scrubbers are not modeled. Not all plants can choose to install DSI.	Only units that burn western coal, are smaller than 200 MW, and are not utility-owned can install DSI	23.2 GW by 2020	CSAPR (2013, 2014), MATS (2015 or 2017), CWA 316 (b) (2020), CO ₂ (2020)	NEEM	MATS, MATS SCR, MATS CO ₂

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<p>Department of Energy (DOE), DOE, 2011 (December)</p>	<p>Resource Adequacy Implications of Forthcoming EPA Air Quality Regulations</p>	<p>CSAPR, MATS</p>	<p>Existing state and federal regulations, such as CAIR</p>	<p>AEO 2011</p>	<p>Require all coal units to install wet scrubbers in its stringent scenario</p>	<p>Does not allow DSI in its stringent scenario</p>	<p>8 GW by 2015</p>	<p>CSAPR (2012, 2014), MATS (2015)</p>	<p>PI-NEMS</p>	<p>MATS/CSAPR, MATS no DSI</p>
<p>Edison Electric Institute (EEI), Fine, Fitzgerald, and Ingram, 2011 (January)</p>	<p>Potential Impacts of Environmental Regulation on the US Generation Fleet</p>	<p>Proposed CSAPR, MATS (written prior to proposal), CCR, CWA 316(b) (written prior to proposal), CO₂ regulation, NO_x policy requiring SCRs</p>	<p>Existing state and federal regulations, such as CAIR and state mercury standards</p>	<p>Prices constructed from EPA v4.10 supply curves for 2015 and 2020</p>	<p>Require all coal plants to install a scrubber</p>	<p>Does not allow</p>	<p>22 GW in 2015, 25 GW in 2020</p>	<p>MATS (2015), CWA 316(b) (2022, 2027), CO₂ (2017), CCR (Subtitle D) (2017), CSAPR (2017, 2018)</p>	<p>IPM</p>	<p>MATS/CSAPR, MATS SCR (primary scenario); MATS CO₂ (alternative CO₂ policy case)</p>

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<p>Environmental Protection Agency (EPA), EPA, 2011 (December)</p>	<p>Regulatory Impact Analysis for the Final Mercury and Air Toxics Standards</p>	<p>MATS</p>	<p>Existing state and federal regulations, CSAPR, no state-level mercury standards</p>	<p>AEO 2011</p>	<p>Model SO₂ and HCl compliance options</p>	<p>Units must be at least 25 MW and burn low-sulfur coal</p>	<p>7 GW by 2015</p>	<p>MATS (2015)</p>	<p>IPM</p>	<p>MATS</p>
<p>Electric Power Research Institute (EPRI), EPRI, 2012 (October)</p>	<p>Prism 2.0: The Value of Innovation in Environmental Controls</p>	<p>MATS, CWA 316(b), CCR, SO₂, NO_x, O₃, and PM NAAQS, Regional Haze</p>	<p>Existing state and federal regulations, such as CSAPR</p>	<p>AEO 2011</p>	<p>Modeled SO₂ compliance option only</p>	<p>Not allowed in the reference case</p>	<p>5 GW by 2020</p>	<p>MATS (2015), CWA 316(b) (2018), CCR (Subtitle D by 2020), SO₂, NO_x, O₃, and PM NAAQS, Regional Haze (2018)</p>	<p>US-REGEN</p>	<p>MATS SO₂ no DSI, MATS SCR</p>

<p>KanORS/ DecisionWare (KanORS), Wright and Kanudia, 2012 (July)</p>	<p>Analysis of CSAPR and MATS in FACETS</p>	<p>CSAPR, MATS</p>	<p>Existing state and federal policies, excluding CAIR</p>	<p>AEO 2011</p>	<p>Modeled HCl compliance option only</p>	<p>Plants 25 MW or larger can install DSI</p>	<p>8.5 GW by 2020</p>	<p>CSAPR (2014), MATS (2017)</p>	<p>FACETS</p>	<p>MATS HCl</p>
<p>NERA Economic Consulting (NERA), Smith, Bernstein, Bloomberg, Mankowski, and Tuladhar, 2012 (March)</p>	<p>An Economic Impact Analysis of EPA's Mercury and Air Toxics Standards Rule</p>	<p>MATS</p>	<p>Included two baselines, one with CSAPR and one with CAIR</p>	<p>To account for uncertainty in shale gas's impact on prices, NERA includes resource supply curves for US gas; NERA also includes supply and demand curves for US imports and exports.</p>	<p>Modeled HCl compliance option only. Plants could use DSI or scrubbers to meet the standard. Plants could also choose to burn low-chlorine coal.</p>	<p>Units smaller than 300 MW that burn sub-bituminous coal can install DSI</p>	<p>15 GW by 2015 (in the baseline with CAIR)</p>	<p>MATS (2015)</p>	<p>NewER A</p>	<p>MATS HCl, MATS no DSI</p>
<p>Resources for the Future (RFF), Burtraw, Palmer, Paul, Beasley, and Woerman, 2012 (May)</p>	<p>Reliability in the Electricity Industry under New Environmental Regulations</p>	<p>CSAPR, MATS</p>	<p>Existing state and federal policies, including CAIR</p>	<p>AEO 2011</p>	<p>Model SO₂ and HCl compliance options</p>	<p>Units must be at least 25 MW and burn low-sulfur coal</p>	<p>13.5 GW</p>	<p>CSAPR (2012, 2014), MATS (2016)</p>	<p>Haiku</p>	<p>MATS, MATS/CSAPR</p>

4. RFF's Haiku Electricity Market Model²

The Haiku model solves for investment and operation of the electricity system in 22 linked regions in the continental United States, starting in 2013 and solving out to the year 2035. Each simulation year is represented by three seasons (spring and fall are combined) and four times of day. For each time block, demand is modeled for three customer classes (residential, industrial, and commercial) in a partial adjustment framework that captures the dynamics of the long-run demand responses to short-run price changes. Supply is represented using 58 model plants in each region. Thirty-nine of the model plants aggregate existing capacity according to technology and fuel source from the complete set of commercial electricity generation plants in the country. The remaining 19 model plants represent potential new capacity investments, again differentiated by technology and fuel source. Each coal model plant has a range of capacities at various heat rates, representing the range of average heat rates at the underlying constituent plants.

Operation of the electricity system (generator dispatch) in the model is based on the minimization of short-run variable costs of generation, and a reserve margin is enforced based on margins obtained by the Annual Energy Outlook (AEO) for 2011 (EIA 2011). Fuel prices are benchmarked to the AEO 2011 forecasts for both level and supply elasticity. Coal is differentiated along several dimensions, including fuel quality and content and location of supply, and both coal and natural gas prices are differentiated by point of delivery. The price of biomass fuel also varies by region, depending on the mix of biomass types available and delivery costs. All fuels are modeled with price-responsive supply curves. Prices for nuclear fuel and oil, as well as the prices of capital and labor, are held constant.

Investment in new generation capacity and the retirement of existing facilities are determined endogenously for an intertemporally consistent (forward-looking) equilibrium, based on the capacity-related costs of providing service in the present and into the future (going-forward costs) and the discounted value of going-forward revenue streams. Existing coal-fired facilities also have the opportunity to make endogenous investments to improve their efficiency. Discounting for new capacity investments is based on an assumed real cost of capital of 7.5 percent. Investment and operation include pollution control decisions to comply with regulatory constraints for SO₂, NO_x, mercury, HCl, and particulate matter (PM), including equilibria in emissions allowance markets where relevant. Table 3 lists the pollution controls included in

² For detailed documentation of Haiku, see Paul et al. (2009).

Haiku and the primary pollutants they control. All currently available generation technologies as identified in AEO 2011 are represented in the model, as are integrated gasification combined cycle coal plants with carbon capture and storage and natural gas combined cycle plants with carbon capture and storage. Ultra-supercritical pulverized coal plants and carbon capture and storage retrofits at existing facilities are not available in the model.

Table 3. Pollution Abatement Control Technologies Modeled in Haiku

Control technology	Acronym	Primary pollutants abated
Selective catalytic reduction	SCR	NO _x
Selective noncatalytic reduction	SNCR	NO _x
Wet flue gas desulfurization	Wet FGD	SO ₂ and HCl
Dry flue gas desulfurization	Dry FGD	SO ₂ and HCl
Dry sorbent injection	DSI	SO ₂ and HCl
Activated carbon injection	ACI	Mercury
Fabric filters	FF	Particulate matter
Electrostatic precipitator	ESP	Particulate matter

Price formation is determined by cost-of-service regulation or by competition in different regions corresponding to current regulatory practice. Electricity markets are assumed to maintain their current regulatory status throughout the modeling horizon; that is, regions that have already moved to competitive pricing continue that practice, and those that have not made that move remain regulated.³ The retail price of electricity does not vary by time of day in any region, though all customers in competitive regions face prices that vary from season to season.

An important part of the model is the requirement that each region have sufficient capacity reserve to meet requirements drawn from the North American Electric Reliability Corporation. The reserve price reflects the scarcity value of capacity and is set just high enough to retain sufficient capacity to cover the required reserve margin in each time block. The model does not model separate markets for spinning reserves and capacity reserves. Instead, the fraction of reserve services provided by steam generators is constrained to be no greater than 50 percent of the total reserve requirement in each time block.

Table 4 outlines some key differences between assumptions used in the studies reviewed for this paper and the assumptions made in Haiku.

³ There is currently little momentum in any part of the country for electricity market regulatory restructuring. Some of the regions that have already implemented competitive markets are considering reregulating, and those that never instituted these markets are no longer considering doing so.

Table 4. Differences between Study Assumptions and Scenarios as Modeled in Haiku

Sponsoring organization, authors, and publication date	Key differences from scenarios as modeled in Haiku
Bipartisan Policy Center (BPC) , Macedonia and Kelly, 2012	BPC uses AEO 2012 early release electricity demand growth and natural gas forecasts, while Haiku uses AEO 2011. BPC requires all plants that use low-chlorine coal to comply with the MATS acid gas standard to install DSI (although the plant does not have to pay operating costs for the control). Haiku does not have this requirement.
Charles River Associates (CRA) , Shavel and Gibbs, 2012	CRA includes CSAPR in its baseline instead of CAIR. In its scenarios with a CO ₂ price and SCR requirement, it also models the Clean Water Act 316(b) rule, unlike Haiku. MATS compliance begins in 2015 or 2017; compliance begins in 2016 in Haiku. CRA doesn't allow dry scrubbers and significantly restricts DSI in its MATS modeling. It also requires all units to install ACI to comply with MATS and doesn't allow the combination of wet scrubbers and SCR to be used as a compliance strategy. These options are allowed in Haiku. CRA uses AEO 2012 natural gas prices instead of AEO 2011.
Department of Energy (DOE) , DOE, 2011	DOE requires coal units to install wet scrubbers and fabric filters by 2015 to comply with MATS under its stringent policy scenario. Plants cannot use DSI. DOE also models CSAPR SO ₂ regions 1 and 2 as one trading region. All new investments in pollution controls must be paid back within 10 years. Haiku does not impose these restrictions.
Edison Electric Institute (EEI) , Fine, Fitzgerald, and Ingram, 2011	In its primary air case, EEI requires every coal plant to install a scrubber, ACI, and fabric filter to comply with MATS by 2015. DSI is not allowed. In Haiku, all pollution control investments are selected endogenously, with the exception of particulate matter controls. EEI also requires all coal plants in the eastern US to install SCRs by 2018. Haiku's SCR case requires SCR installation beginning in 2020. EEI models its primary air case along with the Coal Combustion Residual rule and the Clean Water Act 316(b) rule. Haiku does not model these. The alternative CO ₂ case requires carbon capture and sequestration beginning in 2020. Haiku does not impose this requirement. EEI imposes a carbon tax of \$10 per ton in 2017, escalating at 5%. This is slightly different than in Haiku.
Environmental Protection Agency (EPA) , EPA, 2011	EPA includes CSAPR in the baseline instead of CAIR. Compliance with MATS begins in 2015 instead of 2016.
Electric Power Research Institute (EPRI) , EPRI, 2012	EPRI includes CSAPR in the baseline instead of CAIR. It also requires all plants to comply with the MATS SO ₂ standard. Plants can comply with the HCl or SO ₂ standard in Haiku. EPRI includes more policies than Haiku models, including the Clean Water Act 316(b) rule and the Coal Combustion Residual rule. EPRI requires SCR units at all coal plants beginning in 2018 instead of 2020. In its reference case, EPRI does not allow for DSI as a compliance option for MATS.
KanORS/DecisionWare (KanORS) , Wright and Kanudia, 2012	The KanORS model begins MATS compliance in 2017 instead of 2016. It requires all plants to comply with the MATS HCl standard, whereas plants can comply with the HCl or SO ₂ standard in Haiku. Plants cannot retrofit with dry scrubbers.
NERA Economic Consulting (NERA) , Smith, Bernstein, Bloomberg, Mankowski, and Tuladhar, 2012	NERA begins MATS compliance in 2015 instead of 2016. It also requires all plants to comply with the MATS HCl standard, whereas plants can comply with the HCl or SO ₂ standard in Haiku. NERA limits DSI installations to units that are smaller than 300 MW; Haiku does not impose this limit.
Resources for the Future (RFF) , Burtraw, Palmer, Paul, Beasley, and Woerman, 2012	RFF uses the same MATS and MATS/CSAPR scenarios as those included in the Haiku reconciliation scenarios.

5. Results

The discussion of results focuses on several important electricity market outcomes, including capacity and generation mix, pollution controls, and emissions, which constitute the primary metrics examined in the different studies. For each result, we include a table that compares results from the scenarios modeled in Haiku⁴ and the other studies. The sections on capacity and generation also include a figure that displays the results graphically. A number of the studies focus exclusively on capacity and pollution control changes, so they are not included in the other results tables.

Some of the differences among the studies stem from variations in the studies' baselines. A summary of these differences is included in Table 2. For example, some studies, such as those by BPC and CRA, relied on data about the electricity sector from the 2012 version of the AEO, whereas the other studies used the 2011 version. There are some noteworthy differences between the two AEO versions, including differences in natural gas prices. Studies that relied on 2011 data assumed higher natural gas prices than studies that relied on AEO 2012 data, which, as noted, have the potential to drive out more coal capacity that either CSAPR or MATS. It is less important, but also noteworthy, that studies differed in whether CSAPR or CAIR was included in the baseline. These differences contributed to the varying estimates of coal retirements predicted to occur in the baseline. Although differences in the baselines are important, we do not analyze them in the discussion below.

Coal Capacity

The first set of results focuses on the effects of different scenarios on coal-fired capacity retirements. The results are displayed in Table 5 as well as graphically in Figure 1. Table 5 shows coal capacity retirements in the baseline and incremental coal retirements under each of the policy scenarios. Results for the various scenarios modeled in Haiku are compared to results from the other modelers. The rows that report results from other models also identify the scenario modeled in Haiku that is the closest match. Some scenarios match loosely with multiple scenarios modeled in Haiku. For example, DOE models both CSPAR and MATS, which aligns with the MATS/CSAPR scenario in Haiku. But DOE also restricts DSI and requires SO₂ compliance, which aligns with the MATS SO₂ no DSI scenario in Haiku. Therefore, both Haiku-

⁴ Results from Haiku are presented for the year 2016, but results for 2020 are very similar except where noted.

modeled scenarios are listed in the “Closest match to Haiku-modeled scenario” column in the table below.

Table 5. Coal Capacity

Study	Closest match to Haiku-modeled scenario	Year of reported results	Incremental coal capacity predicted to retire in policy scenarios (GW)	Coal capacity predicted to retire in the baseline (GW)
Haiku reconciliation scenarios	MATS	2016	3.8	13.5
	MATS/CSAPR		3.6	
	MATS SO ₂		38.4	
	MATS HCl		3.2	
	MATS no DSI		6.7	
	MATS SCR		15.0	
	MATS CO ₂		26.7	
	MATS SO ₂ no DSI		39.9	
BPC	MATS/CSAPR	2016	16	40
CRA	MATS/CSAPR & MATS SO ₂ no DSI	2020	12.3 ^a	23.2
	MATS/CSAPR, MATS CO ₂ , & MATS SO ₂ no DSI		84.5 ^b	
	MATS/CSAPR, MATS CO ₂ , MATS SCR, & MATS SO ₂ no DSI		120.9 ^c	
DOE	MATS/CSAPR & MATS SO ₂ no DSI	2015	21	8
EEI	MATS/CSAPR, MATS SCR, & MATS SO ₂ no DSI	2020	25.6 ^d	25
	MATS/CSAPR, MATS SCR, MATS CO ₂ , & MATS SO ₂ no DSI		48.9 ^e	
EPA	MATS/CSAPR	2015	4.7	7
EPRI	MATS SO ₂ no DSI & MATS SCR	2020	57-85 ^f	5
KanORS/DecisionWare	MATS HCl	2019	50	8.5
NERA	MATS/CSAPR & MATS HCl	2015	23	15
RFF	MATS	2016	3.8	13.5
	MATS/CSAPR		3.6	

^a This reflects a scenario with MATS with a 2015 implementation date and CSAPR.

^b This reflects a scenario with MATS, CSAPR, a CO₂ price, and the Clean Water Act 316(b) rule.

^c This reflects a scenario with MATS, CSAPR, a SCR requirement, a CO₂ price, and Clean Water Act 316(b) rule.

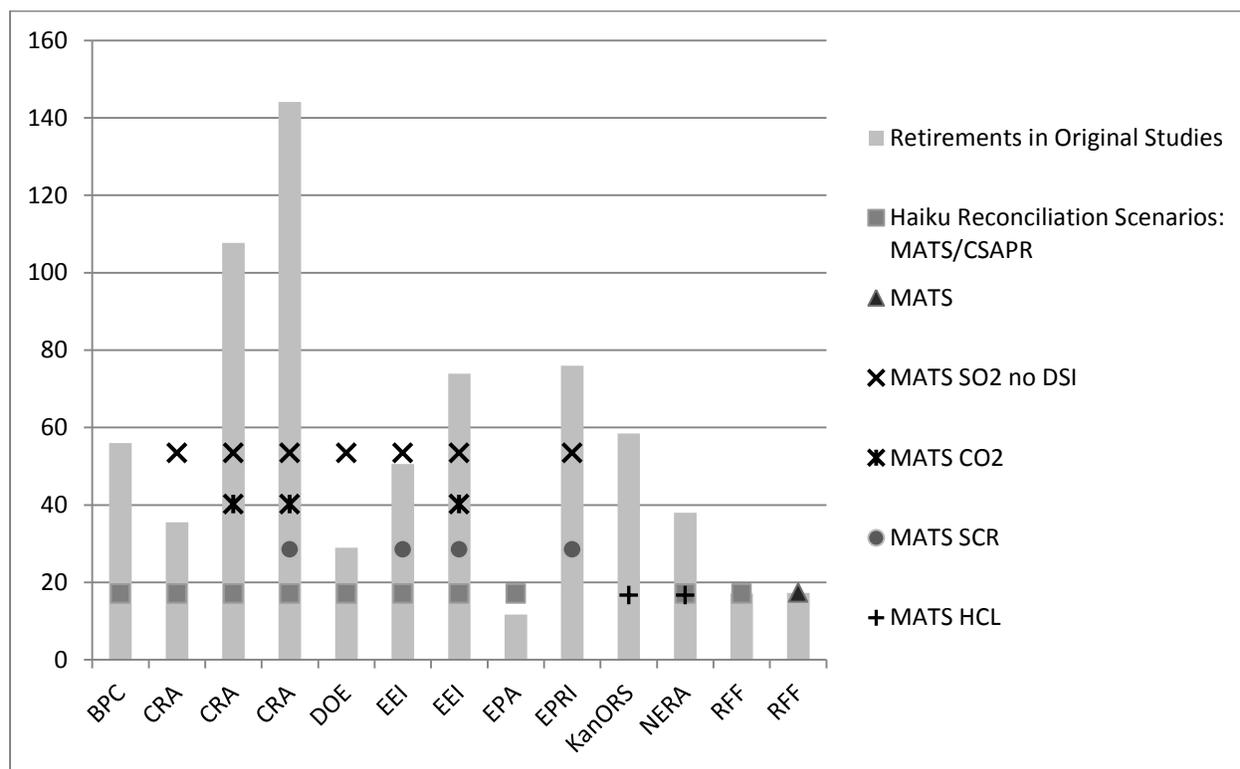
^d This reflects a scenario with MATS, CSAPR, a SCR requirement, Clean Water Act 316(b) rule, and Coal Combustion Residual rule.

^e This reflects a scenario with MATS, CSAPR, a SCR requirement, a CO₂ price, Clean Water Act 316(b) rule, and Coal Combustion Residual rule.

^f This reflects a scenario with MATS, future NAAQS requiring SCR and a more stringent SO₂ standard, Clean Water Act 316(b) rule, Coal Combustion Residual rule, and future Regional Haze rules.

The results are also displayed graphically in Figure 1. The bars represent coal retirements projected in each of the studies reviewed. The overlapping shapes represent coal retirements in the scenarios modeled in Haiku that most closely match the original studies. For example, the bar labeled BPC represents the 56 GW of coal capacity predicted to retire in the BPC study. This includes capacity that is predicted to retire in the baseline and in the policy scenario. The overlapping gray square represents the 17.1 GW of coal capacity predicted to retire in the baseline and MATS/CSAPR scenario modeled in Haiku, which is the scenario that most closely matches the assumptions made by BPC. Studies are listed more than once if multiple scenarios are analyzed. Bars with multiple overlapping shapes represent original studies that combined multiple policies and that map to more than one scenario modeled in Haiku. As discussed below, when more than one policy is modeled, its impacts are not necessarily additive. However, as seen in Figure 1, the additional costs of complying with multiple policies do have an impact on affected units, with more policy requirements or limitations in the modeling associated with more coal capacity retirements.

Figure 1. Projected Coal Capacity Retirements (GW) in Original Models and Corresponding Scenarios Modeled in Haiku



Findings Using the Haiku Model

The scenarios modeled in Haiku focus on different assumptions about compliance options with MATS or single policy add-ons to MATS. Other than under the MATS SO₂ no DSI

scenario, we did not use the Haiku model to evaluate combinations of assumptions or policies, such as modeling MATS along with an SCR requirement and a CO₂ price. Thus it is unclear what level of coal retirements would result in the Haiku model under a combination of assumptions. Two policies may negatively affect the same set of coal units, in which case coal retirements would not increase beyond that seen in one of the policies alone, so the combination would be less than additive. On the other hand, the combined effect of the two policies may cause additional coal capacity to retire that would have survived under a single policy, in which case the combination would be more than additive. It is not known which effect would be seen under any given combination of assumptions, and it is likely that the effect would change depending on which assumptions are combined. Consequently, the level of retirements observed in Haiku should not be directly compared to those in other studies that combine multiple assumptions in addition to MATS, but rather one may compare the general qualitative trends observed in the different studies. For example, as seen in Figure 1, studies that include more restrictions, and thus map to more of the scenarios modeled in Haiku, tend to predict more severe impacts, such as more coal capacity retirements. Studies by CRA, DOE, EEI, EPRI, and NERA all include multiple policy assumptions in addition to MATS.

Among the scenarios modeled in Haiku, the largest retirement of coal capacity occurs when plants are forced to comply with the MATS SO₂ standard without the option to meet the alternative HCl standard; this occurs in two scenarios: the MATS SO₂ and MATS SO₂ no DSI cases. A number of coal plants are able to meet the HCl standard by simply switching to a coal type with a low HCl content. When this option is removed, as in the studies by CRA, DOE, EEI, and EPRI, many of these plants must instead install new SO₂ controls to meet the SO₂ standard. The costs of these additional controls are prohibitive for some plants leading this capacity to retire. In both of these scenarios, natural gas capacity increases slightly to help fill in the void from the retired coal plants.

The second-largest retirement of coal capacity occurs in MATS CO₂, the scenario that includes a tax on CO₂. This outcome reflects the fact that coal is the most carbon-intensive fuel modeled, and therefore, a tax on CO₂ penalizes coal and incentivizes a switch to lower-carbon sources of generation, including natural gas and renewables. The third-largest amount of coal capacity retires under MATS SCR, where all coal units are required to install SCR for compliance with a future tightening of the NO_x NAAQS. In all of the other scenarios modeled, such as MATS and MATS/CSAPR, substantially less coal capacity is expected to retire as a result of the introduction of new environmental policies than are projected to retire in the baseline due to changes in secular trends between 2009 and 2011. This trend was highlighted in the RFF paper as an indication that MATS is unlikely to harm coal capacity to the point of causing reliability problems.

Findings of the Original Studies

The other studies show a wide variation in projected coal retirements, but they generally follow the same trends as the corresponding scenarios evaluated in the Haiku model. That is, the most coal capacity retires when SO₂ compliance is required for MATS, when a price is put on CO₂ emissions, or when additional controls are required to meet future regulations included in the analysis. It is important to note that several of the studies, including CRA, DOE, and EEI, require all or most of the coal fleet to install wet scrubbers. This can be viewed as not only requiring these units to comply with the MATS SO₂ standard, but actually forcing them to overcomply with the standard, similar to the MATS SO₂ no DSI scenario modeled using Haiku.

For example, CRA models three policy scenarios: one that includes MATS and CSAPR, a second that adds the Clean Water Act 316(b) rule and a \$10 per ton tax on CO₂ beginning in 2020 that rises at 5 percent annually in real dollars, and a third that adds a SCR requirement to simulate future NO_x NAAQS. The last two simulations yield the largest amount of coal retirements of all the studies examined, 84.5 GW and 120.9 GW, respectively. This can be expected due to the compounding effect of requiring scrubbers for MATS compliance, imposing a price on emissions of CO₂, and requiring SCR for NAAQS compliance, which conforms to the pattern of higher retirements with more regulations seen in the scenarios modeled in Haiku.

The EEI simulations also result in a substantial amount of coal retirements. Although this study includes many modeling scenarios, we chose to highlight two. The first includes MATS, CSAPR, a SCR requirement, the Clean Water Act 316(b) rule, and the Coal Combustion Residual rule, while the second adds to this a CO₂ price starting at \$10/ton in 2017. As noted above, all coal plants in the EEI simulations are required to install scrubbers for MATS compliance. These two scenarios yield 25.6 GW and 48.9 GW of coal retirements, respectively. These results also agree with the findings using Haiku that requiring compliance with the MATS SO₂ standard, requiring additional controls, or imposing a CO₂ price would greatly increase the retirements of coal units.

EPRI also finds large retirements of coal capacity by 2020, ranging from 57 GW to 85 GW. Its model includes MATS, the Clean Water Act 316(b) rule, and the Coal Combustion Residual rule, and it imposes additional emissions limits to simulate future changes to SO₂, NO_x, ozone, and particulate matter NAAQS and Regional Haze rules. Additionally, this model forces coal plants to comply with the SO₂ standard in MATS without the option to meet the alternative HCl standard or install DSI. These results fit with the trends discussed previously that increase the retirement of coal units.

The EPA, BPC, and RFF models result in some of the fewest coal retirements, 4.7 GW, 16 GW, and 3.6 to 3.8 GW, respectively. These are also the models with assumptions closest to

those in the MATS/CSAPR and MATS scenarios modeled in Haiku, with no additional policies in place and no restrictions on how plants can comply with MATS. The findings from the EPA, BPC, and RFF studies are again in agreement with the results observed in the scenarios modeled in Haiku, where the fewest coal retirements occur when no restrictions are imposed on MATS compliance and no future policies are simulated. The difference between modeling CSAPR, as in the MATS/CSAPR scenario, and CAIR, as in the MATS scenario, has little impact on coal retirements.

These results suggest that the wide variation in coal retirements among models and scenarios can be largely attributed to the way MATS is represented by the different modelers as well as the accompanying policies that are included in the analysis. One exception to these trends found in Haiku is the KanORS/DecisionWare model, which results in 50 GW of coal retirements despite modeling a scenario very similar to the Haiku MATS HCl scenario, which yielded very little retirement. The cause of this discrepancy is unclear, but it is likely due to model-specific characteristics.

Coal and Natural Gas Generation

The next set of results focuses on coal and natural gas generation. Table 6 presents changes in each compared to the baseline scenario for Haiku results and for those scenarios from the other modelers where these variables are reported.

The results are also displayed graphically in Figures 2 and 3. The graphs highlight that generation, like capacity, is affected more when the scenarios deviate from the parameters of the final version of MATS.

Table 6. Coal and Natural Gas Generation

Study	Closest match to Haiku-modeled scenario	Year	Change in coal generation from the baseline	Change in natural gas generation from the baseline
Haiku reconciliation scenarios	MATS	2016	-3.7%	2.3%
	MATS/CSAPR		-1.2%	-2.4%
	MATS SO ₂		-8.5%	6.8%
	MATS HCl		-3.0%	2.8%
	MATS no DSI		-4.7%	3.1%
	MATS SCR		-8.1%	8.5%
	MATS CO ₂		-13.0%	13.1%
	MATS SO ₂ no DSI		-9.3%	8.1%
BPC	MATS/CSAPR	2020	-3%	5%
CRA*	MATS/CSAPR & MATS SO ₂ no DSI	2020	-4.3%	5.9%
	MATS/CSAPR, MATS CO ₂ , & MATS SO ₂ no DSI		-29%	39.7%
	MATS/CSAPR, MATS CO ₂ , MATS SCR, & MATS SO ₂ no DSI		-41.2%	56.4%
EEI	MATS/CSAPR, MATS SCR, & MATS SO ₂ no DSI	2020	-7.9%	12.9%
	MATS/CSAPR, MATS SCR, MATS CO ₂ , & MATS SO ₂ no DSI		-16.2%	19.4%
EPA	MATS/CSAPR	2015	-1.3%	3.1%
KanORS/DecisionWare	MATS HCl	2019	-15.8%	14.2%
RFF	MATS	2016	-3.7%	2.3%
	MATS/CSAPR		-1.2%	-2.4%

*The CRA report does not include the total baseline generation in TWh. The percentages above are based on a Haiku-modeled scenario with CSAPR and no MATS in 2020, which closely matches the CRA baseline. The total generation from the scenario modeled in Haiku is 21,930 TWh.

Figure 2. Change in Coal Generation from the Baseline

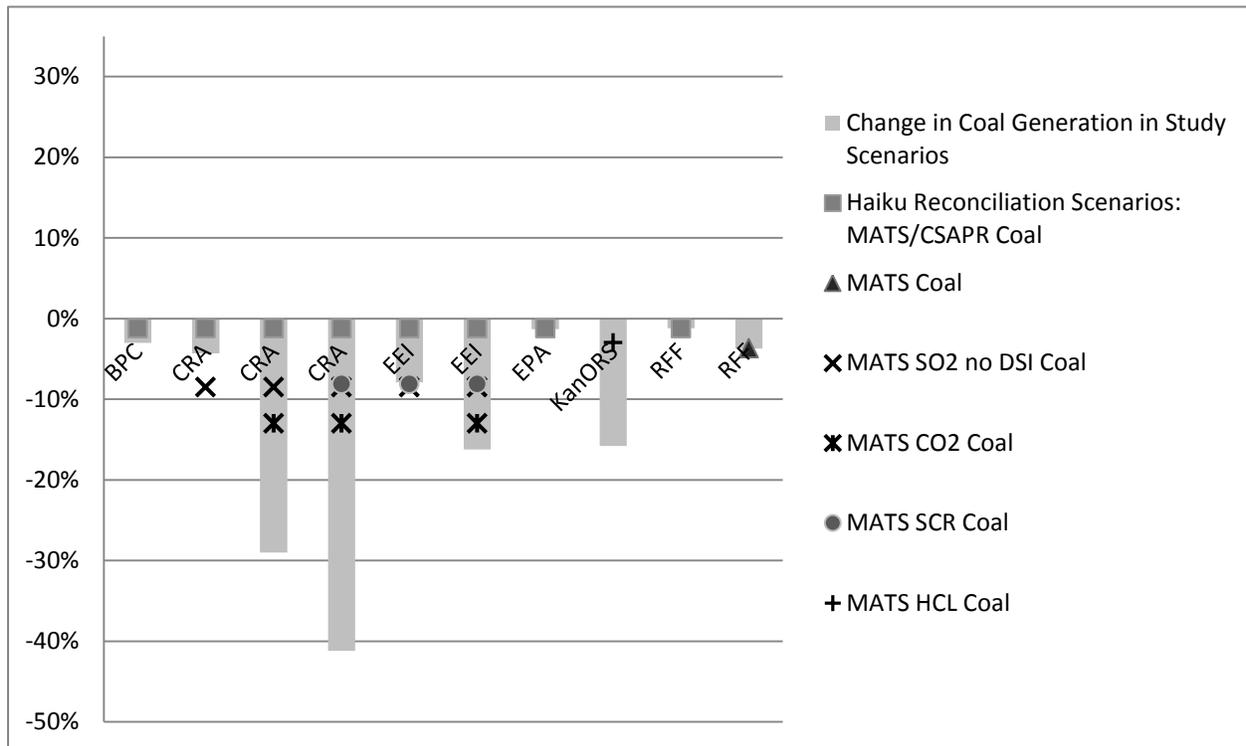
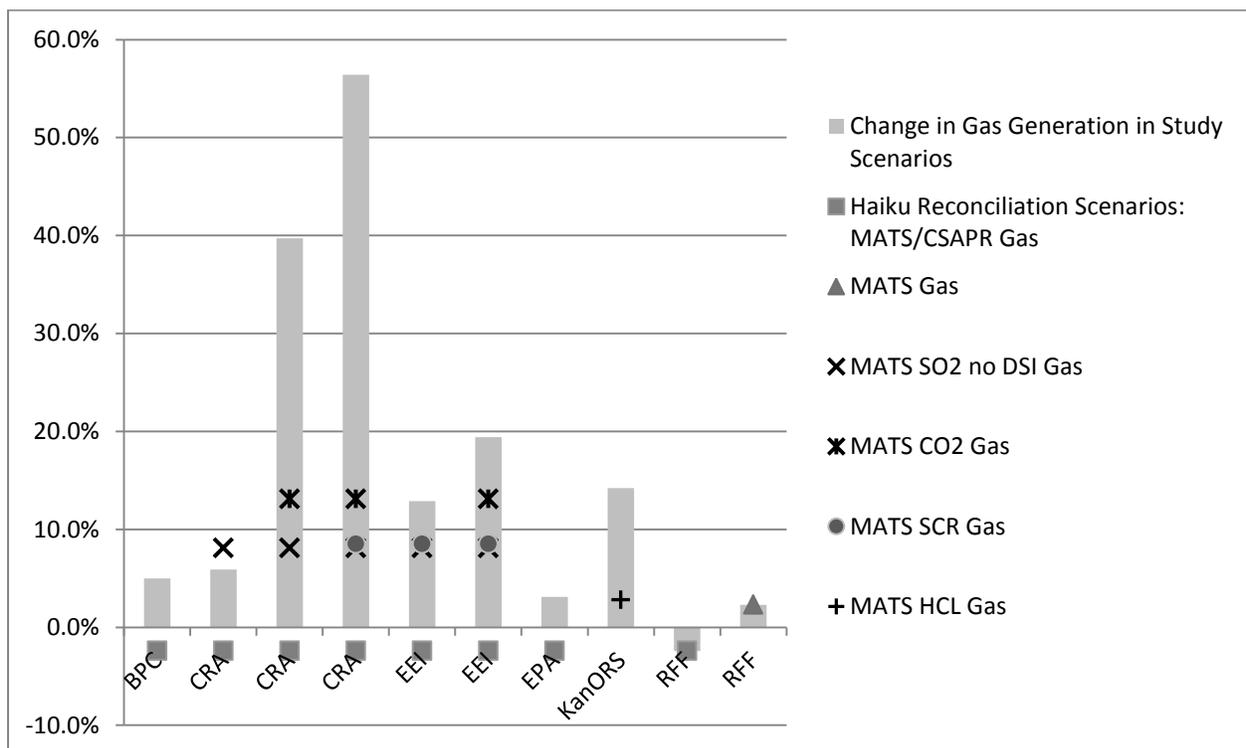


Figure 3. Change in Natural Gas Generation from the Baseline



Findings Using the Haiku Model

As seen in Table 6 and Figure 2, coal generation, like coal capacity, decreases most in the scenarios modeled in Haiku where units must comply with the MATS SO₂ standard, there is a price on CO₂, or SCR is required to simulate a future change in the NO_x NAAQS. These scenarios also yield a commensurate increase in natural gas generation to make up for the reduced generation from coal.

The largest change to coal generation, a decrease of 13 percent, occurs in the MATS CO₂ scenario, where the introduction of a price on CO₂ provides a disincentive for generation from coal units. The next largest changes, decreases of roughly 9 percent, result from the MATS SO₂ no DSI and MATS SO₂ scenarios, respectively, both of which require coal units to comply with the MATS SO₂ standard without the option to instead comply with the HCl standard. The MATS SCR scenario results in coal generation decreasing by 8.1 percent. In the last three scenarios, coal generation decreases because of coal capacity retirements, and the extent of the changes in these two variables is roughly proportional.

Findings of the Original Studies

As in the Haiku-modeled scenarios, the studies that included a price on CO₂, required compliance with the MATS SO₂ standard, and required SCR retrofits resulted in the largest reductions in coal generation. The CRA study, for example, predicted a 41.2 percent decrease in coal generation in its most stringent case. Much of this lost coal generation was replaced by natural gas generation, which increased by 56.4 percent. EEI's study also predicted large decreases in coal capacity. In its most stringent case, coal generation decreases by 16.2 percent, while natural gas increases by 19.4 percent. Natural gas also increases in the scenarios modeled in Haiku to make up for lost coal generation. For example, in the MATS CO₂ scenario, coal generation decreases by 13 percent, while natural gas generation increases by 13.1 percent.

Conversely, the modeling by EPA, BPC, and RFF projects small changes in coal generation. RFF predicts decreases of 3.7 to 1.2 percent, EPA predicts decreases of 1.3 percent, and BPC predicts decreases of 3 percent. As mentioned above, these are the scenarios that most closely duplicate the assumptions in the MATS/CSAPR scenario modeled in Haiku and in the study by RFF, which yield very little change in the electricity generation mix. As with coal retirements, this suggests that differences in coal generation can be attributed primarily to differences in the assumptions used to model MATS and the inclusion of additional policies.

Pollution Control Retrofits

The third set of results is the change in the amount of capacity retrofitted with different types of pollution controls. Aggregate results are reported in Table 7 for Haiku and for each of the other models that report this information.

Table 7. Pollution Control Retrofits

Study	Closest match to Haiku-modeled scenario	Year	Change in wet FGD from the baseline (GW)	Change in dry FGD from the baseline (GW)	Change in DSI from baseline (GW)	Change in SCR from baseline (GW)	Change in ACI from baseline (GW)	Change in FF from baseline (GW)
Haiku reconciliation scenarios	MATS	2016	10	-1	62	8	139	53
	MATS/CSAPR		20	-1	66	4	134	53
	MATS SO ₂		29	94	-4	3	105	36
	MATS HCl		12	-1	62	8	137	53
	MATS no DSI		16	30	-4	1	135	52
	MATS SCR		-1	-1	68	150*	117	51
	MATS CO ₂		4	-4	54	0	124	43
	MATS SO ₂ no DSI		30	92	-4	2	101	36
BPC	MATS/CSAPR	2016	16	11	65	4	131	165
EEI	MATS/CSAPR, MATS SCR, & MATS SO ₂ no DSI	2020	-4	~55	Not modeled	88	~200	160
	MATS/CSAPR, MATS SCR, MATS CO ₂ , & MATS SO ₂ no DSI		-5	~45	Not modeled	69	~185	146
EPA	MATS/CSAPR	2015	-6	22	43	0	141	101
KanORS/DecisionWare	MATS HCl	2017	77	Not modeled	11	0	54	Not reported
NERA	MATS/CSAPR & MATS HCl	2015	1	47	22	1	71	124
RFF	MATS	2016	10	-1	62	8	139	53
	MATS/CSAPR		20	-1	66	4	134	53

*This result is for 2020, the first year of the SCR requirement in Haiku modeling

Findings Using the Haiku Model

In the scenarios using the Haiku model, the modeling assumptions have an important effect on the retrofit of SO₂ and HCl controls. In many of the scenarios, approximately 60 GW of DSI are installed to comply with the HCl or SO₂ standard imposed by MATS. When units are required to comply with the SO₂ standard, however, DSI is not a sufficient control strategy and is not used. Instead, approximately 120 GW of wet and dry FGD controls are installed, which would raise the cost of compliance. Under the MATS no DSI scenario, which still allows for compliance with the HCl standard but does not allow for the use of DSI, 46 GW of wet and dry FGD are installed.

These changes in SO₂ and HCl controls, or an SCR requirement, have a small effect on the use of ACI to control mercury emissions. The combination of an FGD and SCR is able to control some emissions of mercury, although the exact rate of emissions reductions depends on unit-specific characteristics. Thus, installing FGD to comply with the SO₂ or HCl standard in MATS, or the requirement to install SCR to simulate future NO_x NAAQS, may also bring the unit into compliance with the MATS mercury standard. We find that the scenarios that require SO₂ compliance under MATS or require an SCR yield the lowest retrofits of ACI, approximately 105 GW and 117 GW, respectively. Most of the other scenarios result in roughly 135 GW of new ACI.

The amount of fabric filter retrofits required for MATS compliance is directly related to retirements of coal plants. When minimal coal units retire, 53 GW of fabric filter are installed. Under the scenarios that result in larger retirements, however, this capacity falls to only 36 GW. This suggests that the additional costs of these modeling assumptions, including the requirement to comply with the MATS SO₂ standard or imposing a price on CO₂ emissions, fall primarily on units that already have to bear the cost of retrofitting with fabric filters in order to comply with the MATS rule.

The addition of SCR at coal units occurs in a substantial amount only under the scenario where such retrofits are required. In the other modeling scenarios, there is little change in the amount of SCR.

Findings of the Original Studies

In the other studies, ACI and fabric filters are retrofit in large quantities, as much as 200 GW of ACI in the EEI study and 165 GW of fabric filters in the BPC study. This conforms to the trend seen in the modeling scenarios using Haiku, where, although modeling assumptions can cause small changes in the amount of ACI and fabric filter retrofits, the overall trend is that large capacities of both controls are required regardless of the scenario modeled.

Controls for SO₂ and HCl, however, vary greatly among these different studies. In fact, most studies project that the largest change will occur for a different control type. The EPA and BPC studies find 43 GW and 65 GW of DSI, respectively; the KanORS/DecisionWare study finds 77 GW of wet FGD; and the EEI and NERA studies find roughly 45 to 55 GW and 47 GW of dry FGD, respectively. This also agrees with the patterns seen in the Haiku modeling, where SO₂ and HCl controls appear to be the most sensitive to modeling assumptions.

Emissions

The last modeling outcome that we compare is the effects of different scenarios on emissions of a host of different gases, including SO₂, NO_x, CO₂, and mercury. The results are presented in Table 8.

Table 8. Pollution Emissions

Study	Closest match to Haiku-modeled scenario	Year	Change in SO ₂ emissions from the baseline (million tons)	Change in NO _x emissions from the baseline (million tons)	Change in CO ₂ emissions from baseline (million tons)	Change in mercury emissions from baseline (tons)
Haiku reconciliation scenarios	MATS	2016	-1.3	-0.1	-61	-20.5
	MATS/CSAPR		-1.4	0.2	-13	-20.4
	MATS SO ₂		-3.0	-0.1	-123	-21.3
	MATS HCl		-1.3	-0.1	-45	-20.5
	MATS no DSI		-1.5	-0.1	-73	-20.6
	MATS SCR		-1.2	-0.6 ^a	-110	-19.9
	MATS CO ₂		-1.5	-0.1	-202	-21.0
	MATS SO ₂ no DSI		-3.0	-0.1	-133	-21.3
BPC	MATS/CSAPR	2016	-2.0	-0.1	-71	-20.9
EPA ^b	MATS/CSAPR	2015	-1.3	0.0	-15	-19.9
EPRI	MATS SO ₂ no DSI & MATS SCR	2020	-2.4	-0.8	-110	Not reported
KanORS/ DecisionWare	MATS HCl	2019	-5.7 ^c	-0.3	Not reported	-36.2
RFF	MATS	2016	-1.3	-0.1	-61	-20.5
	MATS/CSAPR		-1.4	0.2	-13	-20.4

^aThis result is for 2020, the first year of the SCR requirement in Haiku modeling.

^bThese results are for all EGUs, not just EGUs covered by the regulations.

^cDoes not include CAIR in the baseline, so SO₂ reductions appear much larger than in other models. If CSAPR is included in the baseline, then SO₂ reductions from MATS are comparable to those observed in the BPC and EPA models.

MATS is intended to reduce emissions of mercury and SO₂, and that is what we find in the scenarios using the Haiku model. Mercury emissions are reduced by roughly 80 percent, regardless of the assumptions used in the modeling scenario, and comparable reductions are observed in the other studies. Emissions of SO₂ are reduced most under the Haiku modeling of the MATS policy that forces plants to comply with an SO₂ standard rather than giving them the

option to instead comply with an HCl standard, with reductions of 3 M tons compared to at most 1.5 M tons in the other scenarios. This trend is also seen in the other studies. The EPRI study, which requires compliance with the MATS SO₂ standard, yields reductions of 2.4 M tons, which is larger than the reductions observed in the BPC and EPA models.

The MATS rule, as well as the additional policies that some modelers included in their analyses, also affects emissions of CO₂ and NO_x. In the Haiku modeling, CO₂ reductions are largest when a price is imposed on CO₂, as would be expected. The next largest reductions of CO₂ emissions occur in those scenarios with the largest retirements of coal units and reductions in coal generation. The remaining scenarios result in only small reductions of CO₂ emissions. This is also observed in the BPC and EPA models, which yield small reductions in CO₂ under assumptions that most closely replicate the assumptions of the MATS/CSAPR scenario in Haiku. Emissions of NO_x fall by the most in the MATS SCR scenario in Haiku, 0.6 M tons in 2020, the first year of the SCR requirement. This trend is seen in the other studies as well. The EPRI study, which also includes an SCR requirement, yields NO_x reductions of 0.8 M tons, which is much larger than the reductions observed in the other models.

6. Conclusion

Several recent studies have used economic simulation models to attempt to quantify and explain the potential effects of EPA's MATS rule. These studies, however, have tended to produce inconsistent results, making it difficult to draw general conclusions about the effect the rule will have on the electricity sector, especially the capacity of coal-fired units that will be forced to retire as a consequence of the new regulation. We attempt to reconcile these differences and extract the effect of MATS from the important differences in the modeling assumptions used and the policies modeled.

We conclude that studies that most closely match the regulatory requirements as laid out in the final MATS rule and do not include other proposed EPA regulations in their analyses find MATS to have less severe impacts on the electricity market. This includes the studies that map closest to the MATS and MATS/CSAPR scenarios modeled in Haiku, such as scenarios modeled by BPC, EPA, and RFF. All of the other scenarios modeled in the studies we reviewed include at least one additional policy requirement that differentiates it from the final MATS rule and makes compliance more difficult for coal-fired units.

In particular, the way researchers modeled the acid gas requirements under MATS had a substantial impact on the amount of coal-fired capacity projected to retire. Those studies that allowed plants to meet either a SO₂ or HCl emissions standard, as laid out in the final MATS rule, tended to find less of an impact on coal-fired plants than those studies that forced plants to

comply with the SO₂ standard. The inclusion of additional policies, such as a price on CO₂ or a requirement of SCR to simulate a future tightening of the NO_x NAAQS, also cause more coal-fired capacity to retire than under modeling of the MATS rule alone.

These same factors are also important for projections of the generation mix. Consideration of the potential cascade of additional policies may have value, but unfortunately the effect of the additional policies has been conflated with the effects of MATS per se, leading to confusion, which this paper helps resolve. Coal-fired generation is most negatively affected when a price is put on CO₂, directly introducing a disincentive to generation from coal. Forcing coal units to comply with the MATS SO₂ standard or requiring SCR retrofits also decreases coal generation because of the retirement of coal-fired capacity. In these cases, the reduced generation from coal is made up almost entirely by higher natural gas generation.

Controls for SO₂ and HCl emissions are the most sensitive to changes in modeling assumptions. The modeling of the MATS acid gas requirements and the inclusion of additional policies appear to affect the amount of SO₂ and HCl controls required and what types of controls are selected by coal-fired units. Conversely, retrofits of ACI to control mercury and fabric filters to control particulate matter are required in large amounts for compliance with MATS, regardless of the various scenarios modeled.

Due to changes in SO₂ controls, emissions of SO₂ are also highly dependent on modeling assumptions. Forcing coal units to comply with the MATS SO₂ standard approximately doubles the reductions of SO₂ emissions. Emissions of CO₂ also vary with modeling scenarios, often commensurate with the amount of coal-fired generation. Emissions of mercury, however, are reduced by roughly 80 percent regardless of modeling assumptions or policies, and emissions of NO_x change substantially only when SCR is required for compliance with a future NO_x NAAQS.

Although we have identified these general trends in studies of EPA's MATS rule, differences still remain among studies that cannot be easily explained. This suggests that the effects of MATS are still uncertain. However, this reconciliation analysis narrows that uncertainty significantly by identifying and explaining some of the largest differences among the existing studies, making it easier to compare these studies and better understand how the MATS rule will impact the electricity sector.

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