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REPORT ON THE PROPOSED CHANGES TO THE FEDERAL MERCURY AND AIR TOXICS STANDARDS

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This report was produced by the External Environmental Economics Advisory Committee (E-EEAC), an independent organization dedicated to providing up-to-date, non-partisan advice on the state of economic science as it relates to regulations of the U.S. Environmental Protection Agency (EPA). The E-EEAC was established following EPA's dissolution of its own Environmental Economics Advisory Committee in 2018. That committee had provided guidance for over 25 years within the EPA's science advisory board structure.

This is the first report by the E-EEAC and it focuses on EPA's analysis that seeks to justify its proposed changes to the Mercury and Air Toxics Standards.

Specifically, the analysis was conducted by the following economists who are members of the E-EEAC's Mercury and Air Toxics Standards (MATS) Review Committee:

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EXECUTIVE SUMMARY

In 2012, the Environmental Protection Agency (EPA) promulgated the Mercury and Air Toxics Standards (MATS) to regulate the emissions of mercury and other air toxics at electricity generating units (EPA 2012). The agency argued that this rule-making is "appropriate and necessary" because: (1) electricity generating units are the largest domestic source of mercury emissions, and they emit other hazardous air pollutants; (2) these emissions pose a hazard to public health; and (3) effective emission controls are available. In 2015, the Supreme Court ruled that EPA must consider costs in making an appropriate and necessary finding and remanded the regulatory finding to EPA, but permitted implementation of the regulation to proceed (*Michigan v. EPA*). Coal- and oil-fired power plants began demonstrating compliance with the MATS in April 2016. In the same month, the agency responded to the Supreme Court decision by issuing a Supplemental Cost Finding (EPA 2016) based on several cost metrics, including the rule's original benefit-cost analysis showing the benefits far exceeding the costs. The 2016 Supplemental Cost Finding reached the same conclusion as in 2012, namely that regulating mercury and air toxics at electricity generating units is appropriate and necessary.

In February 2019, EPA published a regulatory proposal to revise the Supplemental Cost Finding for the MATS (EPA 2019). In the proposal, EPA finds that it is no longer appropriate and necessary to regulate hazardous air pollutants (HAP) from coal- and oil-fired power plants under Section 112 of the Clean Air Act (EPA 2019). EPA states that in evaluating the appropriate and necessary finding, "the most appropriate basis for comparison is the relative size of the target pollutant benefits, both quantified and unquantified, relative to the costs imposed by the rule" (EPA 2018, p. 5). While the EPA acknowledges the co-benefits associated with reductions in $PM_{2.5}$ and SO_2 emissions, it claims that co-benefits should not be given equal weight to the target pollutant benefits (HAP emissions reductions) in making the appropriate and necessary finding.

By proposing to rescind the appropriate and necessary finding that serves as the premise for the MATS, EPA sets the stage for revising a rule that the agency initially estimated would impose annual costs of $9.6 billion and yield annual benefits ranging from $33 to $90 billion.[1] Accompanying EPA's 2019 proposal, the agency issued a six-page memorandum that includes a reinterpretation of the cost and benefit estimates from the MATS regulatory impact analysis (RIA) completed in 2011 (EPA 2018). The only change between the estimates included in the RIA (EPA 2011) and the memorandum is the exclusion of co-benefits. Cost estimates and the benefits of direct mercury emission reductions remain unchanged, with the consequence being that the costs of MATS now appear to exceed the benefits.

In July 2019, the External Environmental Economics Advisory Committee[2] approved this committee's proposal to evaluate a series of economic questions raised by the EPA's 2019 proposed rulemaking on the appropriate and necessary finding. We address two major topics: the accounting of co-benefits in regulatory impact analyses, and the scope for updating the analysis to reflect the most recent data, research, and understanding of the market subject to the regulation. We include in Appendix 1 the initial proposal with questions that provide the structure of our report. Here in the executive summary, we summarize four key findings.

[1] Throughout this report, we express monetary values in 2007 dollars, consistent with EPA (2011, 2018) benefit-cost analyses of the MATS rule.

[2] The External Environmental Economics Advisory Committee (E-EEAC) is an independent organization dedicated to providing up-to-date, non-partisan advice on the state of economic science as it relates to the U.S. EPA's programs. See https://www.e-eeac.org for more information.

(1) The EPA's 2018 cost-benefit memo does not follow best practices for economic analysis with its omission of co-benefits of the MATS rule.

When determining whether a policy promotes economic efficiency, properly estimated direct benefits and co-benefits (or costs) should count on an equal footing when making benefit-cost calculations. We provide a simple conceptual framework that shows how and why accounting for co-benefits—such as those associated with human health effects from reduced exposure to particulate matter less than 2.5 micrometers in size ($PM_{2.5}$) resulting from the MATS rule—are important. We conclude as a matter of best practices for benefit-cost analysis, that the EPA's proposed revision to the supplementary finding is not consistent with the generally accepted understanding of how to quantify the net benefits of changes in co-pollutants.

We also note how the relevant government agencies themselves have already weighed in with similar answers to the question. The Office of Management and Budget (OMB) states that, when conducting a benefit-cost analysis, agencies should, "[i]dentify the expected undesirable side-effects and ancillary benefits of the proposed regulatory action and the alternatives. These should be added to the direct benefits and costs as appropriate" (OMB 2003, pp. 2-3). EPA guidance states that, "An economic analysis of regulatory or policy options should present all identifiable costs and benefits that are incremental to the regulation or policy under consideration. These should include directly intended effects and associated costs, as well as ancillary (or co-) benefits and costs" (EPA 2014, p. 11-2).

Moreover, to the specific question of health co-benefits for the MATS rule, OMB states as recently as 2017 that "particulate matter 'co-benefits,' make up the majority of the monetized benefits, even though the regulation is designed to limit emissions of mercury and other hazardous air pollutants. The consideration of co-benefits, including the co-benefits associated with reduction of particulate matter, is consistent with standard accounting practices and has long been required under OMB Circular A-4" (OMB 2017, p. 13).

(2) The 2018 EPA benefit-cost memo underestimates the public health benefits of reducing mercury emissions.

In the original RIA for MATS, the quantified target HAP benefits, which range from $4 to $6 million in the first full year of compliance, derive exclusively from one category of benefits: increased IQ among children exposed to methylmercury (MeHg) from self-caught freshwater fish. At the time, EPA acknowledged several other categories of HAP benefits, but did not quantify them due to a lack of scientific consensus, data, or methodological limitations. The same approach and estimates were carried over into the EPA's reconsideration of the benefits and costs in 2018.

We note substantive advances in the peer-reviewed research on the health impacts of mercury exposure that occurred between 2011 (the year the original RIA was released) and 2018 (Rice et al. 2010; Drevnick et al. 2012; Hutcheson et al. 2014; Cross et al. 2015; Giang and Selin 2016; and Sunderland et al. 2018). We highlight two advances in particular. First, scientists better understand the process by which mercury emissions from U.S. power plants disperse and deposit in fresh, coastal, and international waters, along with the implications of this process for exposure to MeHg through the supply of seafood in the United States. Second, recent studies that provide evidence on the health benefits in the United States of reduced MeHg exposure and incorporate cardiovascular impacts find that these effects dominate those from neurologic effects (i.e., IQ). More specifically, the monetized benefits of the MATS rule through mercury-related cardiovascular risk reduction (primarily fewer heart attacks) are estimated to be on the order of billions of dollars per year.

The EPA's decision to simply replicate 7-year-old benefit estimates in its 2018 benefit-cost memo fails to account for the latest science and economics related to the MATS. In light of the mounting scientific evidence, we believe the EPA is underestimating the quantifiable direct benefits of reduced mercury exposure, and an updating of EPA's analysis is warranted.

(3) The 2018 EPA benefit-cost memo fails to account for significant power sector changes since 2011.

During the eight years since the publication of the EPA's original RIA for MATS, the power sector has experienced significant changes. Anticipating such changes is inherently difficult in ex ante analyses, especially for an industry that is now in the midst of unprecedented transition with respect to both technological innovation and slower demand growth. While not fully anticipating these shifts in the 2011 RIA is to be expected, not acknowledging or accounting for them in a reevaluation of the benefits and costs in 2018 provides an incomplete account of the MATS impacts, which in turn might inform the reconsideration of the appropriate and necessary determination.

Shifts in the electric power sector, for reasons apart from MATS implementation, have been significant enough to materially affect the estimates of the MATS benefits and costs. For example, EPA predicted in 2011 that just under 50% of electricity generation in 2015 would come from coal and that just under 18% would come from natural gas. In fact, by 2015, coal's share of generation had declined to roughly one-third and natural gas generation had increased to approximately the same share. Underlying these differences between ex ante predictions and ex post realizations are lower natural gas prices, lower electricity demand, and greater renewable electricity generation. Recent peer-reviewed, retrospective studies have found that only a relatively small fraction of these shifts was due to the implementation of MATS. Specifically, two recent studies estimate similar impacts of MATS on coal-fired power plant retirements – about 5 GW of capacity, or 14% of the total retirements – and these estimates are approximately in line with the original EPA projection in 2011.

The more general trends that have shaped coal-fired generation mean that compared to ex ante predictions, fewer plants incurred capital expenditures associated with MATS compliance, and the cost of operations and maintenance of such equipment was lower. Indeed, coal-fired generating capacity is about one-fifth smaller today than in 2011, and output from generators still operating is significantly lower than in previous years (and significantly lower than EPA's forecast). This means that not only are the costs of MATS smaller than expected, the anticipated impacts on emissions and associated health outcomes are smaller as well.

(4) A new retrospective and prospective benefit-cost analysis could better represent the impacts of the MATS rule.

In 2019, three years after power plants began complying with MATS, considerably more information is available to understand the impacts of the MATS regulation than was available in 2011. New and updated retrospective and prospective benefit-cost analyses of MATS would provide a more accurate evaluation of the rule's economic impacts, in addition to a more fully informed basis to consider reevaluation of the EPA's appropriate and necessary finding.

A new retrospective analysis of the MATS rule could build on several recent studies to assess the costs, emissions, and monetized benefits of the regulation. These could also leverage a richer understanding of the market factors influencing coal-fired power plant retirement, generation, and pollution control investment decisions. With respect to the important $PM_{2.5}$ co-benefits of the MATS standard, such a retrospective analysis could also examine the extent to which MATS-related emission reductions induced a relaxation of other regulatory requirements on sources of $PM_{2.5}$ emissions, such as State Implementation Plans required under the Clean Air Act.

A new prospective analysis should reflect the insights gained from such a retrospective analysis. Looking forward, the analysis could incorporate the most recent epidemiology and integrated assessment modeling of the public health benefits associated with reducing power plant mercury emissions. Likewise, the analysis should include the benefits associated with co-pollutant emission reductions, reflecting an updated assessment of how the choice of pollution control technology in practice influences the emissions of $PM_{2.5}$ and SO_2. The geographic location of reductions in $PM_{2.5}$ and its precursors has important implications for public health benefits, and EPA could employ a richer approach for accounting for the regional variation in emission reductions in estimating such benefits.

SECTION 1.A.

What are the welfare consequences of ancillary reductions of air pollutant emissions, such as fine particulates? And should they count in RIAs?

The question of how to value the benefits and costs that are not directly targeted by a regulation or policy is fundamental to the practice of benefit-cost analysis (BCA). The issues are not unique to environmental management. The existing guidance from federal government agencies is clear on this question and reflects best practices.

The Office of Management and Budget (OMB) directs all regulatory agencies to account for the indirect or ancillary benefits of regulatory actions in its guidance on regulatory impact analyses:

> "To evaluate properly the benefits and costs of regulations and their alternatives, you will need to do the following:
>
> - Explain how the actions required by the rule are linked to the expected benefits. For example, indicate how additional safety equipment will reduce safety risks. A similar analysis should be done for each of the alternatives.
> - Identify a baseline. Benefits and costs are defined in comparison with a clearly stated alternative. This normally will be a 'no action' baseline: what the world will be like if the proposed rule is not adopted. Comparisons to a 'next best' alternative are also especially useful.
> - Identify the expected undesirable side-effects and ancillary benefits of the proposed regulatory action and the alternatives. These should be added to the direct benefits and costs as appropriate" (OMB 2003, pp. 2-3).

The Environmental Protection Agency's (EPA) guidance document on conducting benefit-cost analysis also calls for accounting for ancillary benefits: "An economic analysis of regulatory or policy options should present all identifiable costs and benefits that are incremental to the regulation or policy under consideration. These should include directly intended effects and associated costs, as well as ancillary (or co-) benefits and costs" (EPA 2014, p. 11-2).

The Office of Management and Budget's 2017 report to Congress on the benefits and costs of regulations also notes that the co-benefits from reducing fine particulate matter emissions should be included in an assessment of the benefits and costs of a regulation:

> "Importantly, the large estimated benefits of EPA rules issued pursuant to the CAA [Clean Air Act] are mostly attributable to the reduction in public exposure to fine particulate matter (referred to in many contexts as $PM_{2.5}$). While many of these rules monetize the estimated benefits of emissions controls designed specifically to limit particulate matter or its precursors, some rules monetize the benefits associated with the ancillary reductions in particulate matter that come from reducing emission of hazardous air pollutants which are difficult to quantify and monetize because of data limitations. For example, in the case of the Utility MACT (or MATS), particulate matter 'co-

benefits,' make up the majority of the monetized benefits, even though the regulation is designed to limit emissions of mercury and other hazardous air pollutants. The consideration of co-benefits, including the co-benefits associated with reduction of particulate matter, is consistent with standard accounting practices and has long been required under OMB Circular A-4. We will continue to work with agencies to ensure that they clearly communicate when such co-benefits constitute a significant share of the monetized benefits of a rule" (OMB 2017, p. 13).

These clear statements in EPA and OMB documents on including ancillary benefits in the assessment of the benefits and costs of regulations build on an extensive academic literature that is unambiguous on this point. While a policy is generally focused on having a direct effect in one market (or on one pollutant), there may be spillover effects in other markets (or on other pollutants). A full accounting of the benefits and costs of the policy should account for the appropriately measured indirect effects, in addition to the direct effects.[3]

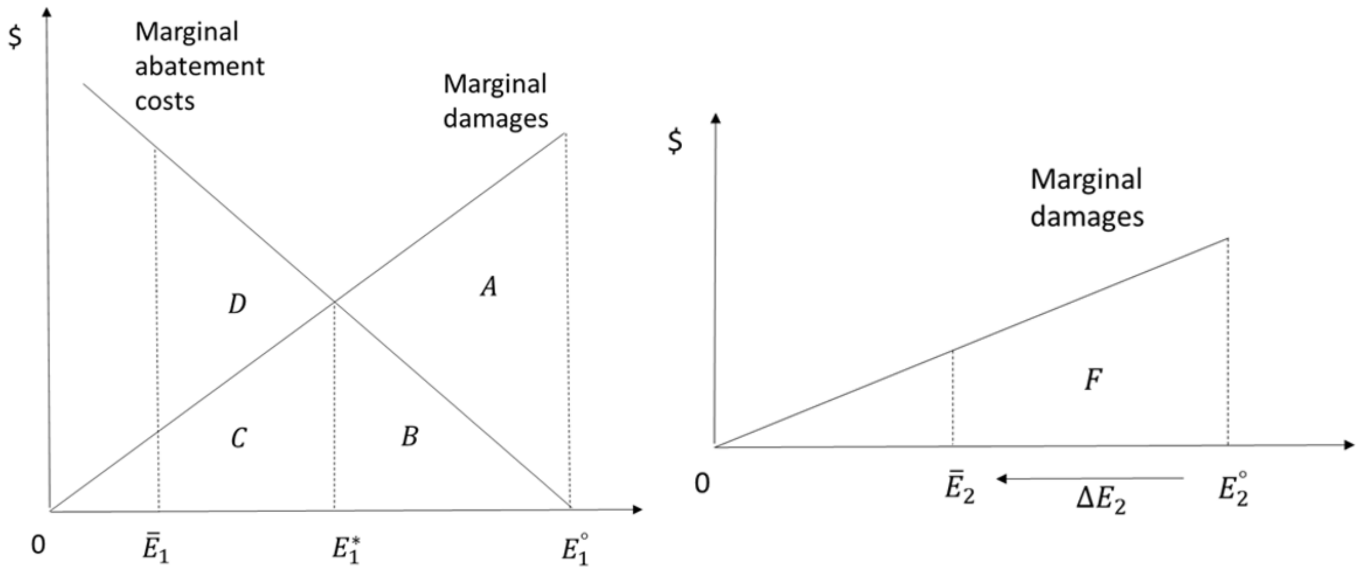
The co-benefits described by the 2011 MATS RIA represent an indirect impact—a reduction—in harmful pollutants other than those directly targeted by the policy.[4] Environmental economists have long raised concerns about ignoring such effects. For example, Sigman (1996) showed that regulations on hazardous waste disposal lead to increases in air pollution emissions, and Alberini (2001) examines how Florida's regulation of underground petroleum storage tanks led to more above-ground storage installations. Lutter and Shogren (2002) illustrate how the trading of carbon dioxide emission allowances under a cap-and-trade program would influence the location of local air quality benefits (primarily through particulate matter reductions). These papers recognize that the secondary pollutant effects could either worsen or improve as a consequence of regulating the targeted pollutant, depending on whether the indirect activity is a substitute or complement to the targeted activity. These examples illustrate the importance of accounting for both co-benefits and co-costs.

A simple model illustrates the key ideas as they relate to the categories of benefits and costs of the MATS rule. The rule targets the set of pollutants collectively referred to as "hazardous air pollutants" (HAPs). The leading one in this case is mercury, which we consider the direct pollutant for simplicity. There are social costs and benefits of reducing mercury emissions from electricity generating units (EGUs). Following a standard approach in environmental economics, we characterize these costs and benefits with functions that represent, respectively, the marginal abatement costs and marginal damages. Both curves are illustrated in the top panel of Figure 1, where the horizontal axis is emissions of the primary pollutant E_1, and the vertical axis represents the cost of each additional unit of abatement or damages in monetary units. The figure is based on the assumption that marginal damages increase as emissions increase from zero. E_1° is the level of mercury emissions without the MATS rule, and marginal abatement costs are assumed to increase as emissions are reduced from E_1°. We assume for simplicity there are no fixed damages or fixed abatement costs, so the areas under the respective curves represent the total damages and the total abatement costs.

[3] The broad concepts pertaining to when and how indirect effects are important for BCA are outlined in standard textbooks on BCA (e.g., Gramlich 1990; Boardman et al. 2018). A related area where economists have long recognized the importance of indirect effects involves calculating the deadweight loss of taxes (e.g., Harberger 1964; Auerbach and Hines 2002; Goulder and Williams 2003).

[4] Throughout this report we use the term co-benefits and indirect impacts, while recognizing that other terms are sometimes used to mean the same thing, including secondary or ancillary benefits or impacts. These should all be interpreted as having a synonymous meaning.

FIGURE 1: **Benefits and costs of the direct and indirect emission reductions**



Taking these cost and damage functions as given, E_1^* is the level of emissions that equates marginal damages with marginal abatement costs. This is the standard efficiency condition for an analysis that focuses exclusively on the targeted pollutant (and ignores indirect effects). It is efficient in the sense that it maximizes the net social benefits (area A), which are the total avoided damages (area $A+B$) minus the total abatement costs (area B). Note that any policy that requires a pollution reduction down to $\bar{E}_1$ would pass a benefit-cost test so long as total benefits $(C+B+A)$ are larger than total costs $(D+C+B)$, i.e., so long as $A>D$. Recognizing that the Clean Air Act does not direct the EPA to promulgate standards that maximize net social benefits, we illustrate the regulation in this schematic as lowering emissions to $\bar{E}_1$.

Let us now consider the consequences of indirect reductions of air pollutant emissions, such as fine particulate matter, $PM_{2.5}$. The change in emissions of an indirect pollutant may arise for several potential reasons. These include (1) a technological relationship between abatement of the targeted pollutant and emissions of the indirect pollutant, (2) a chemical (or precursor) relationship between the target and indirect pollutants, and (3) changes in prices that affect demand for related goods and emissions of the indirect pollutant. For the RIA of the MATS rule, the first two linkages apply. The projected control technologies and compliance strategies to reduce HAP emissions were expected to reduce direct emissions of $PM_{2.5}$, in addition to emissions of nitrogen oxides (NO_x) and sulfur dioxide (SO_2), which contribute to the formation of $PM_{2.5}$ in the atmosphere. The RIA also considers climate co-benefits that result from a reduction in the emissions of carbon dioxide (CO_2).

We capture these potential channels in the simplest way by assuming a linear relationship between changes in E_1 (mercury emissions) and changes in a (single) indirect pollutant E_2 ($PM_{2.5}$ for the purposes of our example). Specifically, we assume that

$$\Delta E_2 = \alpha(\Delta E_1)$$

which implies that each unit of mercury emissions reductions has the additional effect of reducing $PM_{2.5}$ emissions by $\alpha > 0$ units. While more flexible functional relationships are possible, accounting for them does not add anything to the basic insights made here. Importantly, the reduction in $PM_{2.5}$ emissions is not associated with additional costs beyond those already captured with the marginal abatement costs for mercury. The benefits of the reduction in $PM_{2.5}$ are therefore illustrated as area F in the bottom panel of Figure 1. These benefits correspond with a change in $PM_{2.5}$ from its initial level E_2° to its new level $\bar{E}_2$ according to the specified relationship

$$\bar{E}_2 = E_2^{\circ} - \alpha(E_1^{\circ} - \bar{E}_1)$$

Assuming a policy that requires reductions of E_1 from E_1° to $\bar{E}_1$, we can combine both the targeted and indirect effects into the total net benefits of the policy as follows:

$$\begin{aligned} \textit{Net Benefits} &= (A+B+C)+F-(B+C+D) \\ &= A+F-D \end{aligned}$$

This means, as shown in the first line, that the total benefits include both those based on the target pollutant $(A+B+C)$ and those based on the indirect pollutant (F).

An important result, which also follows from the first line in the equation above, is that showing $F>(B+C+D)$ is more than sufficient for the policy to pass a benefit-cost test. That is, showing that the benefits of reducing the indirect pollutant are greater than the costs of reducing the targeted pollutant is sufficient to show that the benefits of the policy exceed the costs. Indeed, the benefits arising from the reduction of the targeted pollutant can be exceedingly small or simply not quantified, and the conclusion remains the same. Although the specific areas to compare would be different for policies that regulate emissions at levels other than $\bar{E}_1$, the fundamental insight would remain: the benefits from the reduction of both the targeted and indirect pollutants should count.

The preceding analysis is, of course, simplified to elucidate the fundamental argument that BCA should account for both targeted and indirect pollution effects of a policy. In practice, however, proper accounting for these benefits and costs can be complicated by a number of factors, some of which we will refer to again below: (1) in most cases, the simple static model would need generalizing to one that accounts for multiple periods over time; (2) estimates would need to account for changes to the baseline conditions of E_1° and E_2° over time that would occur in the absence of the policy; (3) it may be important to account for changes to the baseline conditions that occur as a result of the policy, perhaps through the interaction between overlapping regulations; (4) the specific policy instrument used among overlapping regulations may affect the nature of such interactions, as would be the case with a cap-and-trade program versus a tax on the indirect pollutant; (5) nonlinearities and potential shifts in the marginal damage functions would affect benefit estimation; and, (6) there may also be shifts of the functional relationship between the target and indirect pollutants, perhaps due to changes in abatement technologies or other market adjustments.

SECTION 1.B.

Are the methods used by the EPA in its analysis of the proposed revision to the supplemental cost finding consistent with this understanding of the welfare consequences of ancillary emission reductions?

The EPA's proposed revision to the Supplemental Cost Finding (EPA 2019) focuses on the question of whether regulating HAP emissions from coal- and oil-fired EGUs is appropriate and necessary under section 112 of the CAA. In doing do so, the EPA is seeking to overturn its own previous Supplemental Cost Finding (EPA 2016) in response to the U.S. Supreme Court ruling in *Michigan v. EPA*, where the court held that that the EPA did not sufficiently consider costs when making its determination to regulate HAP emissions from EGUs. The EPA's 2016 finding included, among other arguments, an appeal to the original RIA of the MATS rule, which contained a BCA in which the estimated benefits far exceeded the costs.

Table 1 summarizes the estimated costs and benefits used to arrive at the EPA's conclusion in 2016 that the benefits of the MATS exceed the costs. Note that the benefits included in EPA's 2016 calculation include both the HAP benefits and the co-benefits. The primary HAP benefits are based on improved health from reduced exposure to methylmercury (only for children exposed to freshwater fish caught by U.S. recreational anglers), and the co-benefits are based for the most part on the avoidance of premature deaths and illness associated with reduced $PM_{2.5}$ exposure.

TABLE 1: Summary of the quantified benefits and costs in the 2011 RIA for the MATS rule

	Discount rate scenario	
	3%	7%
Costs	$9.6 billion	$9.6 billion
HAP-benefits	$4 to $6 million	$0.5 to $1 million
Co-benefits	$37 to $90 billion	$33 to $81 billion
EPA net benefits 2016	$27 to $80 billion	$24 to $71 billion
EPA net benefits 2019	– $9.6 billion	– $9.6 billion

Notes: The data reported in this table are from Table ES-1 of EPA (2011). The final row is based on the interpretation contained in Table 1 of EPA (2018).

With respect to the primary HAP benefits, we note that some important health impacts and endpoints are not reflected. Research points to two health endpoints in particular: IQ-related effects due to *in utero* exposure (Axelrad et al. 2007; NRC 2000), and heart attacks due to adult exposure (Roman et al. 2011). In the context of MATS, researchers find that more than 90% of the estimated direct benefits are associated with cardiovascular benefits (Giang and Selin 2016), and these are not quantified in the RIA and therefore not reflected in the numbers reported in Table 1. We return to this topic in greater detail in response to charge question 2.A. below.

Notwithstanding the exclusion of these and other unquantified benefits and costs, EPA (2016) finds sufficient support for the conclusion that the benefits would exceed the costs, where the estimated net benefits as evaluated in 2016 range from $24 and $80 billion annually.

In the 2019 revision, however, the EPA seeks to narrow the scope of benefits. Referring to the earlier finding, the Agency writes that "the EPA's justification for its equal weighting on the co-benefits of non-HAP emissions when setting the MATS standards in its CAA section 112(n)(1)(A) determination was flawed" (p. 2676). Instead, the EPA argues that "in keeping with the CAA section 112(n)(1)(A) and the overall structure of the CAA, we think it is appropriate not to give equal weight to the non-HAP co-benefits in this comparison" (p. 2677). Although no further explanation is provided on what weighting approach the EPA deems suitable, an alternative interpretation of the BCA in support of the proposed revision takes a stand to fully eliminate the counting of co-benefits (EPA 2018). EPA produces revised net benefit calculations, using numbers from the original RIA, that we report in the bottom row of Table 1. All co-benefits are excluded, and the net benefits of the MATS rule are essentially equal in magnitude to the compliance costs. The finding of negative net benefits is then used to support the EPA's revised position that it is not "appropriate and necessary" to regulate HAP emissions from EGUs.

Whether co-benefits, or even BCA, provide a legal basis for making an "appropriate and necessary" determination under the CAA is beyond the scope of our review here, which aims to focus on the best practices of economic analysis.[5] From an economic perspective seeking to determine whether a policy promotes economic efficiency, properly estimated direct benefits and co-benefits should count on an equal footing. It follows that the significant co-benefits induced by the MATS rule should count in a benefit-cost analysis. We therefore conclude, as a matter of best practices for BCA, that the EPA's proposed revision to the Supplementary Cost Finding is not consistent with the generally accepted understanding of how to quantify the net social benefits of indirect emission reductions. Indeed, we would argue that the OMB and EPA guidance quoted above is the correct way to approach the question.

[5] For a review of the legal dimensions of the EPA (2019) proposal, refer to Goffman (2019).

How has EPA specified the assumptions underlying the baseline conditions with respect to the MATS rule co-benefits? Are these clear and sufficient? As part of this, how has the EPA accounted for potential changes in the baseline that may have occurred because of updates to state implementation plans for $PM_{2.5}$ since 2012?

When implementing an ex ante BCA, assumptions about the underlying baseline are always necessary. The quantification of impacts and subsequent economic valuation are then based on a comparison between the baseline and policy-induced scenarios. We find that the baseline assumptions in the original RIA for the MATs rule (EPA 2011) are quite typical and in line with other RIAs that we have reviewed. Given the EPA's use of detailed and complex models for simulating national electricity markets, emissions, and ambient air quality, we are not in a position to comment on the specific baseline assumptions in each of these models. The EPA is clear about its broad assumptions related to the development of baseline emissions and air quality scenarios. These baselines take account of assumptions related to the application of federal rules, state rules and statutes, and other binding enforceable commitments that were in place as of December 2010 and applicable to the time frame of analysis. This also includes the Cross-State Air Pollution Rule (CSAPR) as finalized in July 2011.

From the perspective of best-practices for BCA, there is no distinction between the benefits that arise from the reduction of the targeted or indirect pollutants. Both are categories of benefits that should carry equal weight when arriving at the overall net social benefit calculation, and both rely on a clear and defensible specification of the baseline conditions. We find that, in general, there are no special concerns that arise, or assumptions the EPA should have made differently, because the $PM_{2.5}$ and CO_2 co-benefits are not the primary targets of the MATS rule.

We nevertheless comment on two topics related to the specification of baselines because of their potential for the ex post realized effect on the magnitude of the co-benefit estimates.

The Potential for Regulatory Rebound

Our simple model in Figure 1 captures the baseline conditions of emission levels for E_1° and E_2°, where the latter relates to the emissions of the indirect pollutant. For example, the level of E_2° indicates the level of $PM_{2.5}$ emissions in the absence of the regulation, and because the regulation induces a change from E_2° to $\bar{E}_2$, the policy induced co-benefits are the area F.[6] If, however, the baseline condition itself responds to implementation of the policy, the preceding description is no longer correct.

This additional complexity is potentially relevant to the MATS RIA, and especially the estimation of co-benefits, because of overlapping requirements on ambient $PM_{2.5}$ through implementation of the National Ambient Air Quality Standards (NAAQS). The EPA acknowledges the potential concern when it states that the MATS rule might "lead to reductions in ambient $PM_{2.5}$ below the NAAQS for PM in some areas and assist other areas with attaining the PM NAAQS" (EPA 2011, p. 5-2). A further consequence

[6] One could also consider $\bar{E}_2$ as the emissions of $PM_{2.5}$ and other pollutants, such as SO_2, that contribute to the formation of $PM_{2.5}$ in the atmosphere.

might then be that $PM_{2.5}$ reductions from electricity generating units due to the MATS rule allow state and local governments to relax pre-existing $PM_{2.5}$ regulations on other sources as a part of their State Implementation Plans under the Clean Air Act.

We call this potential response "regulatory rebound." In such cases, we might be concerned about overestimation of the emission reduction health co-benefits, a failure to account for avoided compliance costs or economic benefits due to regulatory rebound (a different kind of co-benefit), and double counting of estimates across different BCAs.

While the EPA acknowledges the potential for double counting in the RIA, the discussion and justification described is not convincing, with the argument that, "[t]he setting of a NAAQS does not directly result in costs or benefits, and as such, the NAAQS RIAs are merely illustrative and are not intended to be added to the costs and benefits of other regulations that result in specific costs of control and emission reductions. However, some costs and benefits estimated in this RIA account for the same air quality improvements as estimated in the illustrative $PM_{2.5}$ NAAQS RIA" (p. 5-2). In effect, the argument here is that the BCAs for the NAAQS should only be interpreted as illustrative, yet we do not believe this is how the results are generally understood, meaning that at the very least the NAAQS RIAs should include greater qualification about their intended interpretation.

Moreover, the EPA's mention of the NAAQS does not directly address concerns about regulatory rebound. Even in a world with no federal $PM_{2.5}$ standards, where every state sets its own $PM_{2.5}$ standard (E_2° in Figure 1), a new federal rule that indirectly reduces $PM_{2.5}$ emissions from EGUs might lead states to relax their existing local regulations on $PM_{2.5}$ emissions from other sources. The NAAQS only make regulatory rebound more likely, because if they are binding then they require states to regulate existing $PM_{2.5}$ sources more stringently than they would otherwise. E_2° in Figure 1 then represents a legally binding "corner solution," where left on its own the state would have more pollution. If the MATS rule reduces $PM_{2.5}$ from electricity generating units so that air quality is cleaner than the NAAQS requires, a state could relax regulations on $PM_{2.5}$ from other sources to return to E_2°. To the extent states have flexibility in how they design and update their State Implementation Plans for $PM_{2.5}$, such a rebound could occur.

To be clear, our view is not that the EPA should have done anything different with respect to accounting for a potential regulatory rebound. In fact, it is not clear that regulatory rebound represents a net cost, because the compliance savings a state realizes from relaxed regulations on non-electricity generating units could conceivably offset the foregone health benefits. Our intent in raising the issue is to point out that regulatory rebound could cause co-benefits to be realized quite differently than the EPA (2011) ex ante analysis projects. Some of the co-benefits identified by the EPA might not be realized in the form of $PM_{2.5}$ reductions, and instead be realized as compliance cost savings.

Accurately forecasting any such responses is inherently difficult, and we are not aware of any existing research on regulatory rebound that could have informed the EPA on alternative baselines. One recommendation for future analyses, however, is to report the estimated benefits broken out by regions that are near versus far from NAAQS compliance, as this would help to show whether and where regulatory rebound effects might be a large concern and/or whether alternative assumptions might be worth considering. A further recommendation is that the EPA consider evaluating the question of whether regulatory rebound is in fact quantitatively important, and MATS may provide a leading example for such retrospective analysis, given that the rule has been in effect for more than 3 years.

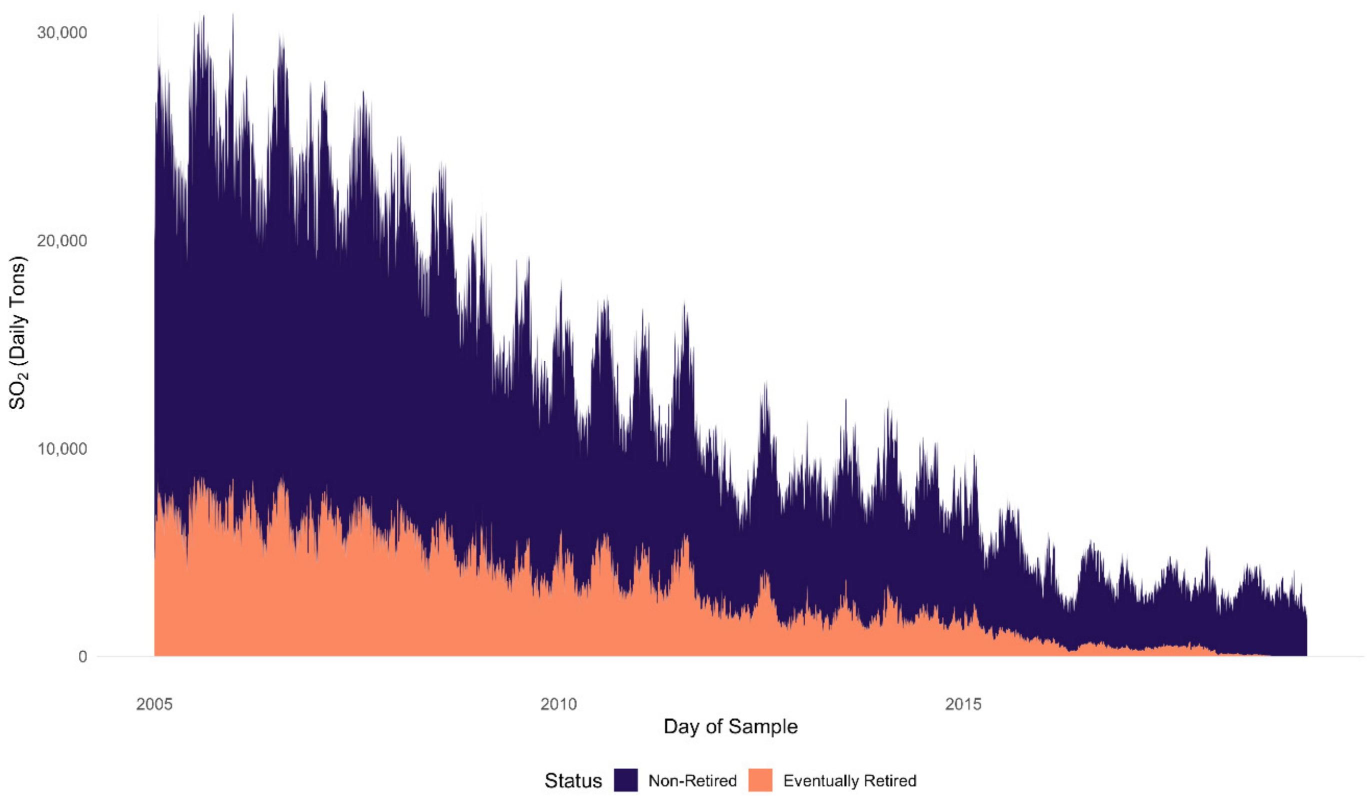
Baseline Emissions

The EPA's 2019 revision does not update any of the analysis related to estimation of co-benefits (or, as we describe in detail later, any of the benefits and costs). Instead, the revision argues in favor of fully eliminating the inclusion of co-benefits. As discussed previously, we disagree with this argument on the basis of best-practices for BCA. As Table 1 illustrates, the co-benefits are economically significant, and these benefits merit the same degree of consideration as the benefits that arise from reductions in the targeted pollutant.

In reviewing the 2011 RIA with the benefit of hindsight, however, it is important to acknowledge how different the electricity sector looks today vis-a-vis the original baseline projections. Although the EPA could not have anticipated all the developments that have transformed the domestic electricity sector in recent years, it is worth noting these developments ex post because they have significant implications for the realized benefits and costs induced by MATS.

The baseline scenario was intended to represent emissions absent MATS. These baseline projections were based on plant-level data in 2005. Figure 2 shows how daily SO_2 emissions have evolved over time since 2005. Baseline emissions in 2017 were projected to be 8,990 tons per day, and MATS was projected to reduce SO_2 emissions by 43%, to 5,113 tons per day in that year. The extended MATS compliance deadline was April 2016, and in the years prior, daily SO_2 emissions had already dropped to 6,000 tons per day. In other words, fundamental changes in the electricity markets (including low natural gas prices, declining electricity demand, and the rise of renewables) pushed the "business as usual" SO_2 emissions well below the projected baseline.

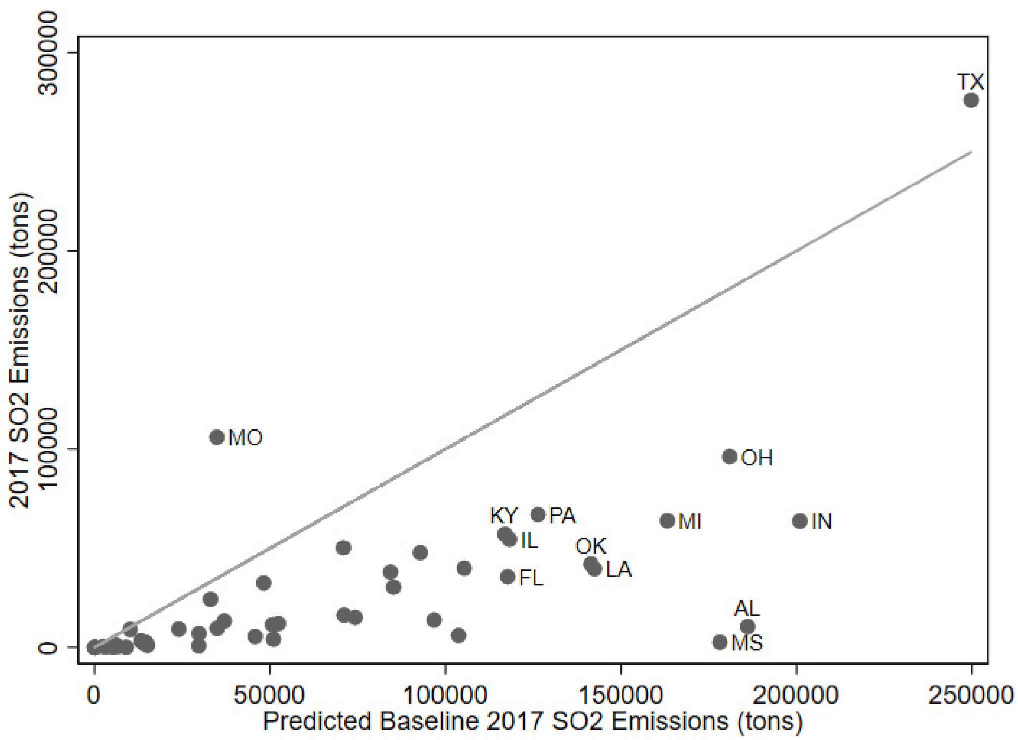
FIGURE 2. Changes in SO_2 emissions from EGUs since 2005, including non-retired and eventually retired units



Notes: Constructed by Edward Rubin (personal communication, 2019) based on EPA CEMS data.

We provide an additional illustration of how the projected baseline differed from the ex post realization. Figure 3 plots the realized 2017 SO_2 emissions by state against the forecasted baseline for 2017, the first full calendar year of MATS compliance. The figure shows how forecast errors, based on a comparison of these years, were not uniform across states. Some states (e.g., Texas) had realized annual emissions in 2017 in excess of the forecasted 2017 baseline. But most states had emissions well below their forecast levels. The EPA analysis projected that MATS would be largely met by investments in costly pollution abatement (e.g., activated carbon injection or flue-gas desulfurization). However, a remarkable number of coal plant retirements—far more than could have been anticipated back in 2005—obviated the need for many of these investments.

FIGURE 3. Comparison between predicted and realized SO_2 emissions from EGUs by state, with selected states labeled



Notes: The 2017 emissions data are drawn from the EPA CEMS database. The predicted baseline 2017 emissions data are drawn from EPA (2011).

The difference between the forecasted and realized baselines ex post, of course, creates significant differences between the forecasted and realized net benefit of MATS. Because the baseline level of emissions would have been lower, the co-benefits of MATS reductions would be lower. At the same time, the costs of compliance would be lower. If nothing else, this observation emphasizes the importance of conducting ex post analysis of significant environmental regulations to understand realized net benefits and to help inform better methods of ex ante analysis. It also underscores the potential value of considering alternative baseline projections ex ante. We recommend that the EPA pay greater attention to the possibility of conducting such sensitivity analyses of the baseline scenarios in future RIAs. In section 2.C., we address the further questions about how and why the power sector, independent of the MATS, evolved in a fundamentally different way than projected in the EPA (2011) baseline.

SECTION 1.D.

EPA translates changes in emissions into changes in ambient air quality, and these procedures have potential implications for the regional and temporal variation in co-benefits. Are EPA's methods appropriate, especially with respect to the economic issues that might arise?

In responding to this question, we provide an overview of (i) the process that EPA used to construct estimates of exposure and impacts, (ii) the EPA's use of the benefit per ton approach for valuing impacts in the final RIA, and (iii) the sources of spatial variation in impacts, only some of which are captured in the EPA's analysis. We conclude with observations about opportunities for improvement both in terms of damage assessment and the characterization of distributional impacts.

As we noted above, EPA (2011) quantifies the benefits of $PM_{2.5}$ in a manner that is generally consistent with other RIAs we have reviewed. The analysis proceeds in several steps.

First, the EPA uses emissions inventories and existing models to construct a baseline $PM_{2.5}$ emission level for the year 2005, for both energy and non-energy sources. EPA then forecasts future year emissions trajectories under "business as usual" (BAU) assumptions, which reflect, among other considerations, the effects of existing federal rules, such as the Cross-State Air Pollution Rule, state rules, consent decrees, etc. This provides the baseline case (reference case) without the MATS rule (see Appendix 5A of EPA [2011]).

Second, the EPA projects emissions trajectories under MATS, which represent the policy case (control case). The analysis assumes that MATS will have no impact on non-EGU emissions vis-a-vis the baseline case. EGU emissions under MATS are forecasted using the Integrated Planning Model, which identifies the least-cost approach to complying with MATS (and associated emissions reductions) conditional on a series of assumptions about technology costs, fuel prices, and other economic considerations. The difference between the baseline case and the policy case yields the predicted effect of the MATS rule on emissions (see Appendix 5A of EPA [2011]).

Third, the EPA translates the predicted change in EGU-level emissions into predicted changes in air quality (see Appendix 5B of EPA [2011]). The EPA uses the Community Multi-scale Air Quality (CMAQ) model, with 2005 baseline conditions for the continental United States, to predict daily and annual $PM_{2.5}$ concentrations under the baseline and policy cases.

Finally, the EPA monetizes damages associated with the projected air quality improvements. The EPA uses the Environmental Benefits Mapping Analysis Program (BenMAP) that is based on peer-reviewed estimates of the pollution concentration-response relationships and a value of a statistical life (VSL) parameter (see Appendix 5C of EPA [2011]).

These last two steps of the MATS analysis were complicated by the fact that EPA initially carried out its analysis based on the proposed (rather than the final) rule, which differed somewhat from the final rule and therefore had different projections of the emissions with MATS in the second step described above. The EPA did not, however, re-simulate the air quality impacts associated with the spatial distribution of emissions changes under the final rule. The rationale was that CMAQ modeling of pollutant fate and transport is very time- and resource-intensive, and that the proposed and final rules were projected to have roughly similar impacts on SO_2 emissions at power plants (1.42 million tons and 1.33 million tons for the proposed and final rules, respectively).

The EPA's approach was to use the analysis of the proposed rule to derive regional, benefit per ton (BPT) estimates that could be employed in the analysis of the final rule. In particular, the health benefits (adult mortality, infant mortality, etc.) resulting from the air quality changes projected under the proposed rule were aggregated regionally and divided by the corresponding regional reductions in emissions. The approach is captured with the following equation:

$$\mathrm{BPT}_{i,j,k} = \frac{TotalBenefits_{i,j,k}}{\Delta Emissions_{i,j,1}}$$

where i is a pollutant (SO_2, $PM_{2.5}$), j is a region (eastern or western states), k is a health outcome, and the subscript '1' in the denominator refers to the estimate of emissions reductions from the proposed rule. In EPA's analysis of the proposed MATS rule, adult mortality accounts for 93-97% of the total health benefits related to the emission reductions of SO_2 and $PM_{2.5}$, which are the indirect pollutants included in the analysis of the final rule.[7]

Specifically, the EPA applies the BPT estimates to the analysis of the final rule using the following approach:

$$TotalBenefits_{i,j,k} = \Delta Emissions_{i,j,2} \times \mathrm{BPT}_{\mathrm{i,j,k}}$$

where $\mathrm{BPT}_{i,j,k}$ is from the previous equation, and the change in estimated emissions is for the corresponding pollutant i in region j (eastern or western states) for the final rule as referenced by the subscript '2'. We make some comments below about the EPA's use of the BPT approach, but first provide some context for the potential importance of regional variation for estimating such health benefits, regardless of whether they are for the target pollutant or co-benefits.

These mortality-related co-benefits are not evenly distributed across regions or individuals because the regulation impacts ambient concentrations and health outcomes differently in different locations. The following equation extends the health impact function for $PM_{2.5}$ in the MATS RIA (page 5-10) in order to highlight some potentially important sources of spatial variation:

$$Avoided\ mortality\ benefits = VSL \sum_{l} \left(y_{ol}\left(\mathrm{e}^{\beta(X_l)\Delta PM_l} - 1\right) pop_l\right)$$

where VSL is an estimate of the value of a statistical life, l indicates a particular location, y_{ol} is the baseline mortality rate, $\beta(X_l)$ is the concentration-response relationship that depends on a set of locational characteristics X_l, ΔPM_l is the change in the ambient concentration of $PM_{2.5}$, and pop_l is population. With this framework in hand, we make several observations about the potential importance of regional heterogeneity, before returning to the BPT approach below.

Variation in concentration-response (C-R) relationships: The co-benefits from an incremental reduction in $PM_{2.5}$ concentrations can differ significantly across locations and sub-populations due to underlying differences in demographics, health stock, and/or differences in defensive investments. $\beta(X_l)$ is the

[7] Of these mortality-related benefits, 95% are associated with reduced exposure to indirect sulfate particulate matter associated with SO_2 emissions from EGUs regulated under MATS (the remaining 5% comes from direct $PM_{2.5}$ reductions).

coefficient that summarizes the relationship between a change in the PM concentration and the mortality rate within a sub-population characterized by X_l. Studies such as Krewski et al. (2009) have documented striking differences in associations between exposure and mortality across different locations.

Baseline mortality rates and population size: Both y_{ol} and pop_l can also differ significantly across locations. To assess the potential implications of this variation, we estimate the changes in lung cancer, cardiovascular and lung disease mortality associated with a $1\ \mu g/m_3$ decrease in $PM_{2.5}$ across 2,500 counties using C-R parameters from Krewski et al. (2009).[8] We find that the average reduction in mortality across all counties is 6.3 deaths, and the standard deviation is 16.8.

Spatial distribution of changes in emissions and concentrations: MATS-induced changes in plant-level emissions will be unevenly distributed across space depending on the location of power plants and the specific compliance choices made at each plant. Because power plants had many compliance options to choose from, and because compliance choices will be determined in part by dynamic electricity market conditions, projecting how each power plant will respond under MATS is complicated. EPA (2011) correctly notes that any uncertainty surrounding these projected emissions impacts "will be propagated throughout the entire analysis … small uncertainties in emission levels can lead to large impacts on total monetized co-benefits" (p. 5-16). One important link in the chain is pollution transport. Once the impacts of MATS on plant-level emissions has been established, complicated interactions between atmospheric chemistry, meteorology, and pre-existing levels of $PM_{2.5}$ and precursors will determine how changes in plant-level emissions at one location translate into changes in ambient $PM_{2.5}$ concentrations at other locations.[9]

Accounting for these different sources of heterogeneity in the estimation of MATS co-benefits is potentially important. EPA modeling explicitly accounts for differences in baseline mortality rates, population size, and the distribution of concentrations in the modeling of the proposed rule. The EPA chose not to model any systematic variation in the β estimates – representing the concentration-response function in the avoided mortality benefits equation – across impacted locations. Simulated changes in $PM_{2.5}$ concentrations across all locations were evaluated using the same C-R parameters. While we are not in a position to comment on how taking account of such heterogeneity would have affected the results, more discussion on the topic by the EPA seems warranted in the RIA. We do acknowledge, however, that the EPA has been careful to incorporate sensitivity analysis with respect to the C-R parameters, using a wide range of estimates from the literature.

We have described above how the BPT approach extrapolates from a detailed analysis of benefits under the proposed rule to estimate benefits from reduced $PM_{2.5}$ exposure for the final rule. A key feature of the analysis is the division of the United States into two regions: the eastern and western states. Table 2 (based on Table 5C-3 in EPA [2011]) shows the difference in the BPT estimates between the east and west, across pollutants, and between different C-R assumptions based on estimates in the literature. We note the wide variation in BPT estimates within the east and west regions, based on the 95% confidence intervals in parentheses. The within-region variation in BPT values means that estimates generated using a BPT approach could potentially be misleading, to the extent that that the geographic distribution of emissions differs between the proposed and final rule.

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[8] We confined our analysis to those counties for which 2016 baseline mortality rates and population are readily available.

[9] See Muller and Mendelsohn (2009) for an important application that takes account of such regional variation.

TABLE 2: Heterogeneity in regional BPT estimates

	Eastern US	Western US
BPT SO2	$29	$8.3
Pope *et al.* (2002)	($2.3-$87)	($0.1-$25)
BPT SO2	$73	$21
Laden *et al*. (2006)	($6.4-$210)	($1.9-$62)
BPT Carbonaceous PM	$220	-$66
Pope *et al.* (2002)	($17-$670)	(-$450-$210)
BPT Carbonaceous PM	$560	-$170
Laden *et al.* (2006)	($49-$670)	(-$960-$350)

Notes: The data reported in this table are from Table 5C-3 in EPA (2011).

However, a crude calculation using the available data suggests this extrapolation exercise is unlikely to have had a large impact on co-benefit estimates. Consider the eastern region, where most of the benefits are concentrated. In states such as Michigan and Alabama, emissions reductions of SO_2 under the proposed rule are much larger than the emissions reductions projected under the final rule. See Figure 5C-1 of EPA (2011), which shows that simulated reductions fall by more than 60,000 tons and 30,000 tons in Michigan and Alabama, respectively. In contrast, we see higher emissions for the final rule (compared to the proposed rule) in several large-population states such as Florida, Ohio, and Pennsylvania, where the difference ranges from about 10,000 to 25,000 tons. To get a sense for how such magnitudes might matter, we consider the range of Laden et al. (2006) estimates from high and low damage locations in the east with a shift of 50,000 tons. This would alter damage estimates by approximately $10 million (50,000×[$210 – $6.4]), or less than 1% of the total co-benefits estimates.

Overall, the errors in benefits assessment stemming from differences between the proposed versus final rule emissions projections appear small relative to those stemming from differences between ex ante projected versus ex post realized emissions impacts. Differences across rules and across states do, however, raise questions about the reliability of EPA's (2011) breakdown of benefits-by-state for the final rule in Appendix 5D. Overall, the extent to which benefits from reduced $PM_{2.5}$ exposure can vary across space underscores the importance of sensitivity analysis that considers a range of possible market conditions and associated compliance outcomes, along with the degree of spatial aggregation. EPA should seek to incorporate these approaches in future analyses.

How can the EPA improve the quality of its estimated benefits and cost of the MATS rule by leveraging the most recent data and analysis?

Since publication of EPA's original RIA for MATS (EPA 2011), the power sector has experienced significant changes. At the same time, scientists have continued to study the relationship between emissions of HAPs and human health endpoints. By leveraging data and analyses that have become available since publication of the RIA, EPA can update and improve the quality of its estimated benefits and costs of the MATS rule. We see value in both a revisiting of the estimated costs and benefits of MATS (a retrospective analysis) and a more prospective consideration of MATS impacts going forward. We comment on benefits and costs in separate sub-sections that follow.

Benefits

Table 1 of EPA's Cost-Benefit Memo (EPA 2018) calculates the net benefits of MATS as the difference between the estimated costs and benefits of HAPs, thereby excluding the co-benefits (see also our Table 1 in this report). Our responses to questions 1.A. and 1.B. address the issue of co-benefits, so we focus on HAP benefits in this section. The quantified target HAP benefits, which range from $4 to $6 million in the first full year of MATS compliance, derive exclusively from one benefits category: increased IQ among children in households exposed to less methylmercury (MeHg) from consumption of self-caught freshwater fish. EPA (2011) mentions, but fails to quantify, several other potential HAP benefit categories due to a lack of scientific consensus, data, and methodological limitations. EPA's treatment of unquantified HAP benefits in the 2011 RIA and 2018 Cost-Benefit Memo is not unique to the evaluation of MATS; unquantified benefits and costs are common in regulatory impact analyses of environmental rules.[10]

However, given advances in the science since publication of the RIA (EPA 2011), EPA should reconsider the unquantified HAP benefits, specifically those related to MeHg exposure. We summarize two discoveries relevant to the estimated benefits of reduced mercury emissions from U.S. EGUs.[11]

First, scientists better understand the process by which mercury emissions from U.S. EGUs disperse and deposit in fresh, coastal, and international waters, along with the implications of this process for exposure to MeHg through the supply of seafood in the United States. EPA (2011) focuses exclusively on reductions in MeHg exposure from the consumption of self-caught freshwater fish. In doing so, the analysis fails to account for other potentially-exposed populations (e.g., households that do not engage in fishing) and for other exposure pathways, e.g., the consumption of seafood commercially caught in domestic coastal waters.[12] Recent research elucidates this exposure pathway. Sunderland et al. (2018) estimate that domestic coastal regions accounted for 37% of U.S. MeHg exposure from seafood for the years 2010–2012; freshwater fisheries accounted for only 9% of U.S. MeHg exposure from seafood during

[10] For example, unquantified benefits are included in the regulatory impact analyses of the five economically significant final rules reviewed by OMB in fiscal year 2016 for which EPA estimated benefits and costs (OMB 2017).

[11] See also the related discussion in Sunderland et al. (2016).

[12] EPA acknowledges this limitation in the MATS RIA: "Exclusion of these commercial pathways means that this benefits analysis, although covering an important source of exposure to domestic mercury emissions (recreational freshwater anglers), excludes a large and potentially important group of individuals. Recreational freshwater consumption accounts for approximately 10 to 17% of total U.S. fish consumption, and 90% is derived from commercial sources (domestic seafood, aquaculture, and imports) (EPA, 2005)" (EPA 2011, p. 66).

this period.[13] Other recent analyses shed light on the relationship between mercury emissions from U.S. EGUs and mercury deposition to U.S. ecosystems (Drevnick et al. 2012; Hutcheson et al. 2014; Cross et al. 2015). Together, these findings underscore the importance of revisiting the potential mechanisms by which changes in mercury emissions from U.S. EGUs influence exposure to MeHg.

Second, the 2011 RIA and 2018 Memo include uncertain cardiovascular impacts of reductions in MeHg exposure among the unquantified HAP benefits, citing a lack of scientific consensus and inconsistency across studies. EPA (2011) notes that: "EPA did not develop a quantitative dose-response assessment for cardiovascular effects associated with MeHg exposures, as EPA finds there is no consensus among scientists on the dose-response function for these effects. In addition, there is inconsistency among available studies as to the association between MeHg exposure and various cardiovascular system effects" (p. 4-4, 4-5). A year prior to the publication of the RIA, the EPA convened a workshop to summarize the state of the science on this relationship as of 2010. The panel of experts published their findings and concluded: "We found the body of evidence exploring the link between MeHg and acute myocardial infarction (MI) to be sufficiently strong to support its inclusion in future benefits analyses…" (Roman et al. 2011, p. 607). However, a highly-cited study published that same year by Mozaffarian et al. (2011) finds no significant relationship between MeHg exposure and adverse cardiovascular effects. There are several potential explanations for the divergent findings from this literature including the confounding positive effects of fish consumption arising from their fatty acid content (Mahaffey et al. 2011). As economists, we are ill-suited to assess the scientific evidence on the relationship between MeHg exposure and cardiovascular effects, but in our opinion the relationship merits a re-examination by experts from appropriate fields including epidemiology, clinical medicine, and toxicology.

Indeed, two recent analyses of the health benefits in the United States of reduced MeHg exposure incorporate cardiovascular effects (Giang and Selin 2016; Rice et al. 2010). In these analyses, the estimated benefits associated with cardiovascular effects dominate those from neurologic effects (i.e., IQ). Results from these studies suggest that if a robust relationship between MeHg exposures and risk of acute myocardial infarction is confirmed, then the estimated benefits from reduced MeHg exposure under MATS may be orders of magnitude larger than those reported in EPA (2011) and EPA (2018).

To illustrate the consequence of including potential cardiovascular effects of MeHg, Table 3 summarizes the estimated benefits of reduced MeHg exposure from Rice et al. (2010) and Giang and Selin (2016) for two scenarios. The estimates are not comparable between the two studies as they consider different exposure reduction scenarios and employ different modeling techniques and parameter assumptions. (See the supporting information available in the papers' appendices for details.) In addition, neither study is directly comparable to the estimated benefits included in the RIA and 2018 Memo. Estimates in the table from Rice et al. (2010) reflect the expected monetary value of the annual health benefits generated by a 10% reduction in U.S. population exposure to MeHg for one year. Estimates from Giang and Selin (2016) reflect the cumulative lifetime benefits of MATS to the United States by 2050. For both studies, the base case estimates reported in the fourth column account for potential cardiovascular impacts of MeHg exposure while the estimates in the final column of the table assume no relationship between MeHg exposure and the risk of acute MI. In the case of Rice et al. (2010), accounting for potential cardiovascular impacts leads to a five-fold increase in estimated benefits. For Giang and Selin (2016), benefits increase by more than ten-fold when cardiovascular impacts are considered.

[13] Because Sunderland et al.'s (2018) data comes from domestic fisheries landings, seafood imports and exports reported by the National Marine Fisheries Service, their estimates of exposure attributed to freshwater fisheries are not directly comparable to the estimates of exposure from consumption of self-caught fish among households included in EPA (2011).

TABLE 3: The effect of incorporating cardiovascular impacts on the estimated health benefits to the U.S. of reduced MeHg exposure

Study	Policy scenario	Time frame	Base case estimate	Estimate when cardiovascular impacts are excluded
Rice *et al*. (2010)	10% reduction in U.S. population exposure to MeHg	One year	$1.0 billion	$200 million
Giang and Selin (2016)	MATS	Cumulative to 2050	$156 billion	$15 billion

Notes: The table reports the estimated benefits of reductions in exposure to MeHg (methylmercury) based on two studies, which employ different modeling techniques and parameter assumptions (see the supporting information available in the papers' appendices for details). Estimates in the table from Rice et al. (2010) reflect the expected monetary value of the annual health benefits generated by a 10% reduction in U.S. population exposure to MeHg for one year. Estimates from Giang and Selin (2016) reflect the cumulative lifetime benefits of MATS to the U.S. by 2050. For both studies, base case estimates account for potential cardiovascular impacts of MeHg exposure while estimates in the final column of the table assume no relationship between MeHg exposure and the risk of acute myocardial infarctions (heart attacks). Both estimates from Rice et al. and the base case estimate from Giang and Selin are reported in the published papers. The final estimate in the table is based on unpublished results provided by Amanda Giang on October 11, 2019. All values have been converted to 2007 dollars based on the GDP implicit price deflator (US BEA 2019).

Given the likely magnitude of the unquantified benefits associated with potential cardiovascular impacts, and the advancements that have been made, we believe an updating of EPA's analysis is warranted. At a minimum, EPA should follow federal guidelines for the treatment of significant, unquantified benefits:

> "If the non-quantified benefits and costs are likely to be important, you should carry out a 'threshold' analysis to evaluate their significance. Threshold or 'break-even' analysis answers the question, 'How small could the value of the non-quantified benefits be (or how large would the value of the non-quantified costs need to be) before the rule would yield zero net benefits?' In addition to threshold analysis you should indicate, where possible, which non-quantified effects are most important and why" (OMB 2003, p. 2).

While this would provide a more complete analysis of the direct benefits versus costs of mercury emission reductions, it should also be noted that with inclusion of the co-benefits, the overall BCA that EPA conducted in the original RIA indicated overall benefits that were far away from the overall cost threshold.

Costs

EPA (2011) projects about $9.4 billion in costs in 2015 based on its IPM modeling analyses, with modestly declining annual costs thereafter (e.g., 2030 costs were projected to be $7.4 billion). The 2015 estimate reflects four major categories of cost: variable operations and maintenance (O&M) at $2.4 billion, fixed O&M at $1.8 billion, fuel at $2.7 billion, and capital at $2.4 billion. The agency also estimates another $200 million of compliance costs, three-quarters of which resulted from monitoring and recordkeeping. Oil-fired power plant compliance costs represent the balance of the costs. As noted in EPA (2018), EPA applies the 2015 estimates as a proxy for the compliance costs in 2016 to reflect the one-year extension for compliance purposes granted to regulated entities from April 2015 to April 2016.

Realized costs in 2015 and 2016 likely were, however, lower than those projected in EPA (2011), and updated estimates suggest that future compliance costs will be lower as well. In practice, several factors contribute to these differences. As of June 2019, 237 GW of coal-fired generating capacity operate in the United States (EIA 2019), representing a more than 20% decline from the capacity projected in EPA (2011). As we describe elsewhere in our responses, the vast majority of these retirements reflect non-regulatory factors, such as lower-than-expected natural gas prices, lower-than-expected electricity demand, and higher-than-expected renewable power investment. The lower coal-fired capacity should result in lower operating costs and record-keeping costs, as well as lower capital costs, although these are a sunk cost (as we describe below in our response to 2.B.) and thus merit exclusion from a BCA undertaken after those investments had been made.

Consider how new information about actual pollution control technology adoption and natural gas prices could be used to update the cost analysis of the MATS rule. EPA (2011) states that "by 2015, the final rule will drive the installation of an additional 20 GW of dry flue-gas desulfurization (dry scrubbers), 44 GW of dry sorbent injection, 99 GW of additional activated carbon injection, 102 GW of fabric filters, 63 GW of scrubber upgrades, and 34 GW of electrostatic precipitator upgrades" (EPA, 2011, p. 3-15; note: we have spelled out all acronyms that were reported in the original text). The Energy Information Administration (2017) reports significantly less pollution control capital investment as a part of MATS compliance strategies over the period from December 2014 through April 2016.[14] For example, EIA reports 73 GW of activated carbon injection (26% less than EPA's projection under MATS), 15 GW of sorbent systems (66% less), 14 GW of fabric filters (86% less), and 12 GW of scrubbers (40% less). EIA (2017) reports an additional 14 GW arising from "other compliance strategies." For these leading strategies of projected pollution control investment, realized investment was less than half of what EPA (2011) projected: 128 GW actual vs. 265 GW projected.[15]

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[14] EIA examined a period through April 2016 to account for the one-year extension to the compliance period from 2015 into 2016 under the MATS rule.

[15] Note that in both the EPA (2011) projection and the EIA (2017) analysis of actual investments some generating units employed more than one pollution control technology. For example, EIA reports that the pollution control technology adoption, summing to 128 GW, occurred at 87.4 GW of capacity.

Activated carbon injection (ACI) and sorbent technologies represent about three-fourths of the installed GW of pollution control technologies; these are also the two lowest capital cost technologies, with ACI estimated to cost $10 per kilowatt (EIA 2017). The technologies with much lower installation rates than projected by EPA (2011) – such as scrubbers and fabric filters – have capital costs an order of magnitude higher. This difference among technologies suggests that the coal-fired power plants that continue operating may have incurred lower capital costs than what was projected by EPA in 2011. These capital costs are sunk, however, and should be excluded from a 2019 BCA that seeks to re-evaluate the rule.

The estimated fuel costs of MATS primarily reflect the higher projected fuel expenditures for natural gas. EPA (2011) estimates that natural gas consumption would increase by 3.3% under MATS and that the price of natural gas would increase by 4.9%. This estimated price effect likely overestimates the fuel expenditure impacts in light of changes in U.S. natural gas production. The continued expansion of and innovation in shale gas production technology has contributed to a more elastic supply of natural gas. U.S. natural gas production has increased 30% and power sector consumption of gas has increased 40% since 2011, but natural gas prices have been consistently lower over 2012-2019 than they were in 2011 and lower than EPA's (2011) baseline projection.

Summary

In sum, the 2011 RIA understated benefits by only examining neurological effects on children exposed to recreational freshwater fish consumption. This could be corrected with new science on cardiovascular consequences of MeHg exposure, and by application to other exposed populations. Furthermore, both costs and benefits were overstated because actual power sector particulate matter and mercury emissions were lower than baseline projections. This too could be corrected with retrospective analysis of the three years of actual MATS compliance.

SECTION 2.B.

Given the capital costs associated with pollution abatement investment already incurred by some facilities, how should EPA treat such capital in its analysis of the proposed rule?

Compliance with MATS requires coal-fired EGUs to incur two general categories of costs, the initial capital investment in pollution control technology and O&M costs of using the equipment. Once a firm has incurred the former, these costs become sunk as they represent resources allocated in the past that cannot now be allocated to some alternative use in the future.[16] In contrast, O&M costs reflect opportunity costs; if a firm no longer has to run its pollution control equipment, then the resources that would have been allocated to pollution abatement can be reallocated to some alternative use.

Numerous government documents, reflecting first principles in economics, provide guidance on the appropriate treatment of opportunity and sunk costs in regulatory impact analyses. For example, the OMB (2003) guidance to regulatory agencies states that "'[o]pportunity cost' is the appropriate concept for valuing both benefits and cost" (p. 18). EPA's (2014) guidelines for BCA state that "[a]ssessing opportunity costs is fundamental to assessing the true cost of any course of action" (p. xiv).

In contrast, sunk costs should not be included in an assessment of the costs of a regulatory action. We describe the reasoning above—because there is generally no opportunity cost—a further discussion on the topic can be found in standard textbooks on benefit-cost analysis (e.g., Boardman et al. 2018).

In the case of MATS, EPA's initial RIA (EPA 2011) appropriately includes both categories of costs as, at the time, both costs were incremental to the proposed regulation. EPA's recent benefit-cost memorandum (EPA 2018), which serves as a supporting document for its proposal to reverse its appropriate and necessary determination, also includes both categories of costs. Nevertheless, while O&M costs do remain incremental in 2018, capital costs do not. Firms have already incurred the sunk costs of installing their pollution control equipment. A revised BCA in 2018 should therefore treat these costs differently.

The owners and operators of the electricity generating units covered by the 2012 MATS regulation initially had three years, before EPA granted a one-year extension, to come into compliance with the rule. Starting in late 2014 through early 2016, a significant number of power plants undertook investment in pollution control equipment (EIA 2017; we elaborate further on this investment in the response to 2.A.). EPA (2011) estimated that the annualized capital costs for compliance would be about $2.5 billion in each of 2015, 2020, and 2030. The 2018 EPA Memo includes these capital costs among the costs of controlling emissions from EGUs under MATS (see Tables 1, 2, and 3 of the Memo). However, based on recent estimates, a large fraction of these costs has already been incurred by EGUs. For example, the Edison Electric Institute, representing the electric power generating industry, reported that the owners and operators of coal- and oil-fired power plants have already spent $18 billion to comply with the 2012 MATS rule (EEI 2019).[17] While EEI does not distinguish between capital costs and O&M costs, this estimate likely includes significant investments in capital equipment.

In sum, by including both operating and sunk capital cost in its evaluation of the MATS rule, the EPA's BCA memo significantly overstates the cost of continuing to enforce the MATS rule as finalized in 2012.

[16] The sole exception is in the case that a firm could uninstall pollution abatement equipment and sell the equipment to other potential users. In this case, the initial capital costs are at least partially sunk given the inability to capture the full value of capital equipment in used equipment markets. More importantly in the context of the MATS rule, the absence of an active market in used power plant mercury emissions control technology suggests that capital investments to date are sunk.

[17] We interpret this $18 billion estimate as a cumulative, nominal measure and have not deflated it to 2007 dollars.

SECTION 2.C.

How have changes to the power sector unrelated to the MATS rule influenced the realized costs and benefits of the regulation to date, and how could this understanding inform the prospective analysis of the 2019 proposal?

As discussed previously, prospective analysis of a regulation—such as the 2012 MATS rule in EPA (2011)—requires a wide array of assumptions. In the context of an environmental regulation on the power sector, assumptions are necessary to define the baselines for electricity demand, fuel supply and prices, technology costs, power plant operator decisions, and other public policies. Identifying appropriate, forward-looking assumptions over a time horizon of at least two decades is challenging. This is especially true for an industry experiencing significant technological innovation and unpredictable changes in demand, much of which has occurred since the EPA promulgated the MATS in 2012.[18]

The dramatic change in the power sector over the past decade illustrates how a market may evolve in ways that depart substantively from what an ex ante analysis assumes. Understanding the significant changes in the power sector—especially the extensive retirement of coal-fired power plants and the lower levels of generation at those units still operating—provides important context for an assessment of the benefits and costs of the MATS rule in 2019.

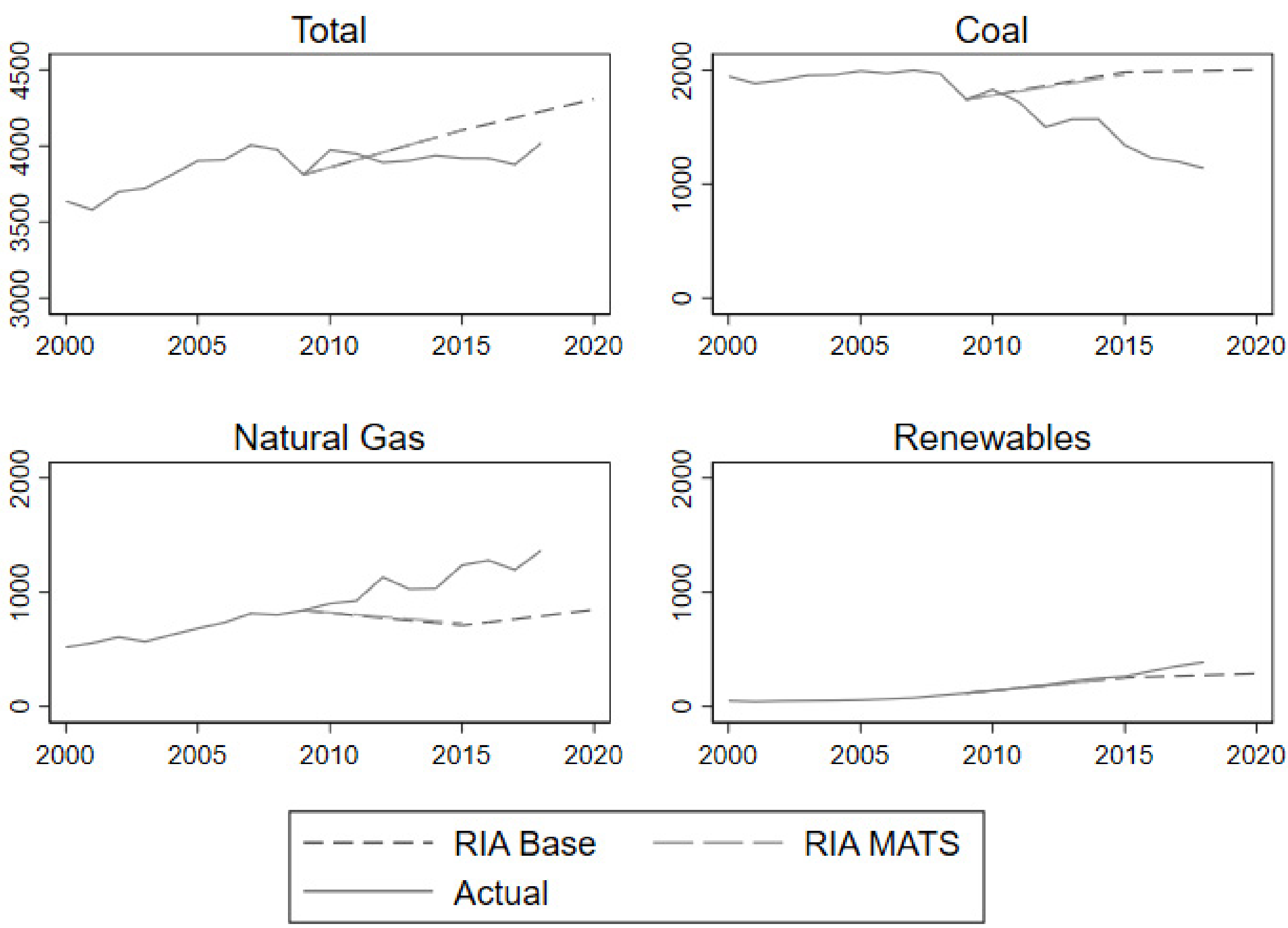
We have already shown some comparisons in our response to question 1.C., where we discuss the baselines used in the original RIA. Here we compare the baseline and policy scenarios in the MATS RIA using more aggregated data along several dimensions, including power market demand, output by type of generator, and fuel prices. These comparisons illustrate how the dramatic increase in the supply of natural gas, the expansion of renewable power generating capacity, and flat power demand over the past decade have collectively contributed to the decline in coal generation since 2008. We also summarize the results of two recent retrospective studies on the estimated impact of the MATS rule on coal-fired power plants. All of these trends have had a substantial effect on the realized benefits and costs of the MATS rule. Understanding them can help guide more complete retrospective analyses and inform the assumptions for prospective analysis of the MATS rule.

[18] In an independent prospective analysis of the rule, Burtraw et al. (2012) use the Haiku electricity market simulation model to show how assumptions about future fuel price and electricity demand growth can affect generator plant profitability and compare the effects of potential future market trends with the modeled effects of the MATs rule. They find that the market factors have a bigger effect than the MATS rule on plant retirements and investments, on the mix of fuels, and on electricity prices. In a second independent prospective analysis of MATS and other Clean Air Act regulations (the Clean Air Interstate Rule and CSAPR), Pratson et al. (2013) estimate engineering-based costs of electricity based on data through February 2012 and find that environmental regulations play a larger role in increasing the cost of electricity from coal-fired power plants above the median cost of electricity from natural gas power plants than do projected natural gas prices. The differences between these studies reflect both differences in methods and differences in forecasting future economic, energy, and technology characteristics of the power sector. This provides more motivation for rigorous retrospective analysis, which we address below.

Changes in the U.S. Power Sector, 2000-2018

Both the baseline and policy scenarios in the RIA draw assumptions about future growth in electricity demand from the 2010 Annual Energy Outlook (AEO2010). Between 2010 and 2016 electricity demand growth was lower than anticipated (see Figure 4).[19] According to EIA's most recent comparison of actual electricity consumption to past AEO projections (EIA 2018), the AEO2010 overpredicted annual electricity consumption from 2012 through 2016 by 2-4% depending on the year. The predicted average annual growth rate in electricity consumption from 2008 (the last year of actual data available in the AEO2010) through 2016 in the AEO2010 was close to 1.2%, but the actual annual average growth rate in consumption over that time period was closer to 0.6%.[20]

FIGURE 4: U.S. Net Generation (billion KWh)



Notes: Constructed from generation data provided in EIA (2019) and EPA (2011).

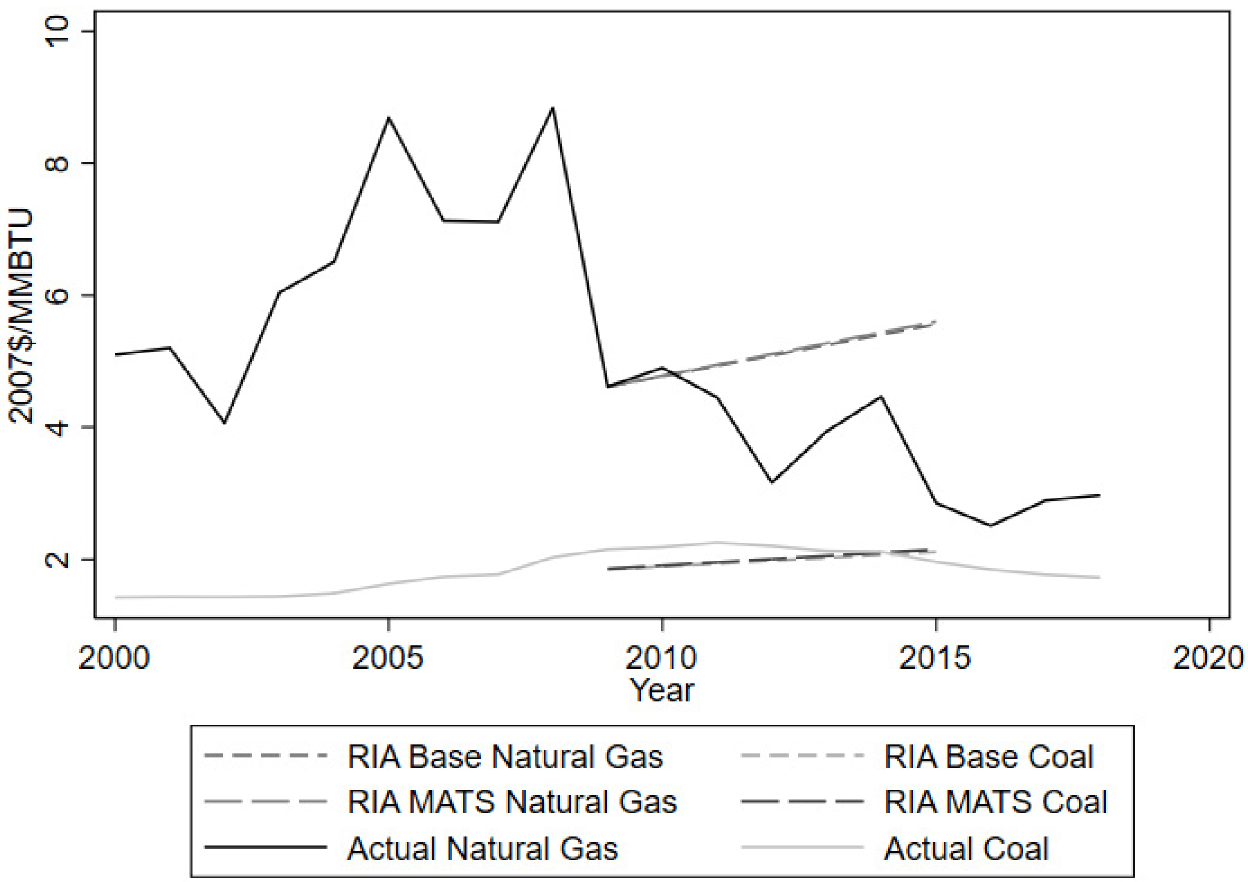
[19] Figure 4 displays trends in electricity generation. Generation and consumption differ due to transmission and distribution losses (which create a negative wedge between consumption and generation) and net imports of power (which create a positive wedge between consumption and generation). In general, transmission losses dominate imports, which constituted roughly 1 percent of consumption in recent years, although imports of power from Canada have increased since 2010 (EIA 2015).

[20] The RIA was written after the release of AEO2011, which had significantly lower estimates of electricity consumption growth and EPA acknowledged the potential effects of assuming a higher consumption growth rate in a footnote to the RIA (see footnote 7 on p. 3-6 in EPA 2011).

In the RIA, EPA predicted that about 50% of electricity generation in 2015 would come from coal and less than 18% would come from natural gas. In fact, by 2015 coal's share of generation had declined to roughly one third and natural gas's share had increased to be similarly sized. The significant investment in wind and solar generating capacity over the past decade resulted in faster-than-projected growth in renewable power generation.

In terms of prices, EPA (2011) projected the price of natural gas supplied to the power sector in 2015 to be 14% higher than it was in 2010. The agency estimated gas prices to be 1% higher under the MATS rule than its baseline. In contrast, delivered gas prices in 2015 and 2016 were more than 40% below their 2010 level (Figure 5).

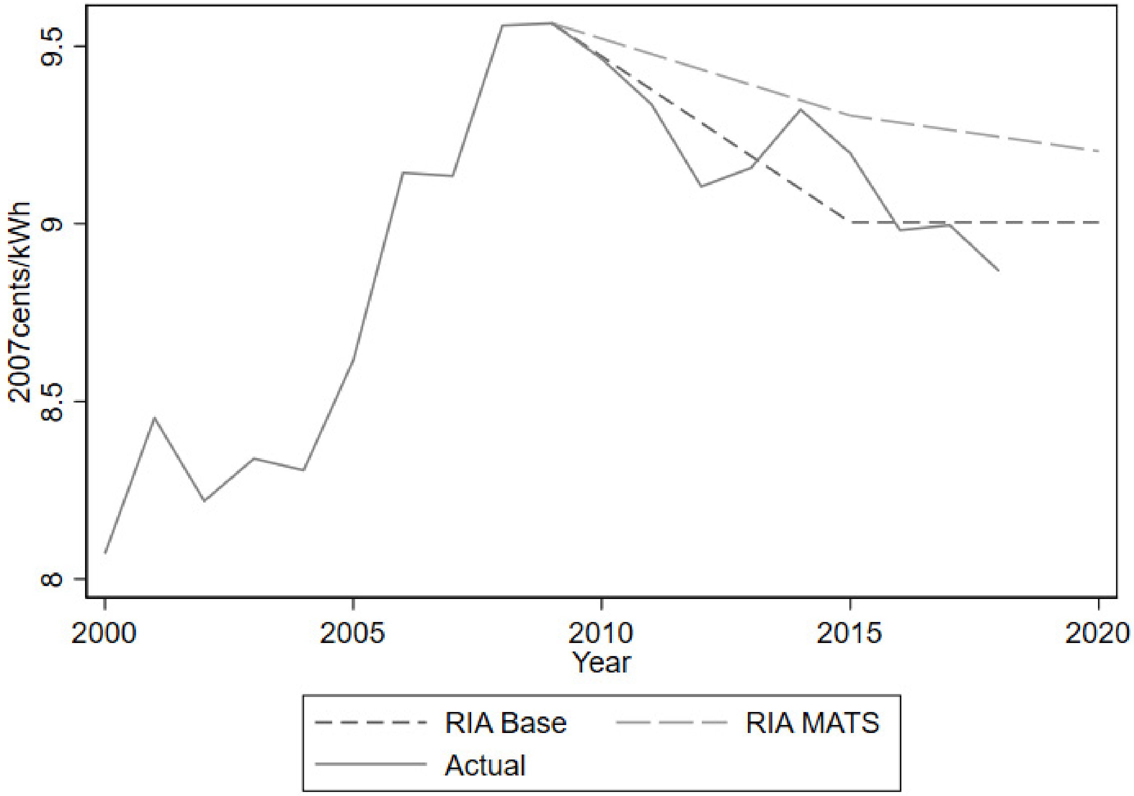
FIGURE 5: Prices of Fuels Delivered to Power Sector, 2000-2020



Notes: Actual annual fuel prices from EIA (2019) and RIA fuel prices from EPA (2011). All series are converted to 2007 dollars based on the GDP implicit price deflator (US BEA 2019).

Similarly, EPA estimated higher coal prices under the MATS and its baseline in 2015 than in 2010, but since 2015 delivered coal prices have been 10% or more below their 2010 level. The combination of positive supply shocks in natural gas and renewable power coupled with the negative demand shock for power have contributed to lower-than-forecasted retail electricity prices (see Figure 6).

FIGURE 6: **Average U.S. Electricity Prices, 2000-2020**



Notes: Actual annual electricity prices from EIA (2019) and RIA electricity prices from EPA (2011). All series are converted to 2007 dollars based on the GDP implicit price deflator (US BEA 2019).

To illustrate how the changes in the power sector have influenced emissions of sulfur dioxide and mercury, we have compiled relevant installed capacity, power generation, and emissions data for coal-fired power plants in 2017, the first full year of MATS compliance.[21]

We compare the observed 2017 characteristics of coal-fired power plants to the baseline in EPA (2011). We contrast these comparisons with the differences between the policy case (MATS) and baseline in EPA (2011).[22]

More specifically, we present the percentage changes in installed capacity, generation conditional on operating, the emissions intensity of generation, and overall emissions. This decomposition can illustrate how the changes in power plant retirements and capacity factors have contributed to emissions changes. The decline in emissions intensity of output can illustrate the effectiveness of control technologies in reducing SO_2 and mercury emissions at plants during their operations. These analyses do not present evidence of the causal impacts of MATS in practice, but can illustrate important evidence to inform future analysis of the regulation.

[21] Given the one-year extension granted to regulated entities, the MATS compliance obligations began on April 2016.

[22] For the plant-level data underlying EPA (2011), refer to: USEPA. 2010. IPM Parsed File – 2010 Base Case. Docket ID: EPA-HQ-OAR-2009-0234-19982 Available at: https://www.regulations.gov/document?D=EPA-HQ-OAR-2009-0234-19982.

The first row of each panel of Table 4 presents the comparison of the policy and the base cases in EPA (2011). Panel A presents the results for mercury and panel B for SO_2. We employ a unique sample of power plants for each pollutant comparison. In Panel A for mercury, we limit our evaluations – in both the policy case vs. base case and 2017 vs. base case comparisons – to power plants reporting mercury emissions through the EPA Air Markets Program MATS rule database in 2017 that we can match to EIA data on capacity and generation. This sample corresponds to about 93% of the installed generating capacity in 2017. The sample for sulfur dioxide corresponds to all installed generating capacity in 2017 and includes emissions data from the EPA Continuous Emissions Monitoring Database. Appendix 2 provides details on the construction of our datasets.

TABLE 4. Changes in Power Sector Capacity, Generation, and Emissions Intensity (Percentage Changes)

	A. Mercury			
	Δ Capacity	Δ Generation	Δ Emissions Intensity	Δ Emissions
Policy Case vs. Base Case	-2.5%	+0.3%	-74.8%	-75.2%
2017 vs. Base Case	-18.5%	-30.9%	-72.3%	-81.0%
	B. Sulfur Dioxide			
	Δ Capacity	Δ Generation	Δ Emission Intensity	Δ Emissions
Policy Case vs. Base Case	-2.5%	+0.3%	-39.6%	-41%
2017 vs. Base Case	-20.6%	-39.8%	-33.4%	-60.9%

Notes: The policy case and base case refer to the projections by EPA (2011) for the first full year of MATS compliance. The 2017 case refers to power sector data compiled from the Energy Information Administration and Environmental Protection Agency (refer to Appendix 2 for details). The 2017 sample for panel A on Mercury is comprised of the power plants that we could match to EIA power sector data and EPA Air Markets Program data for the MATS rule for 2017 and correspond to 93% of EIA-reported installed coal-fired power plant capacity in 2017. The 2017 sample for panel B on Sulfur Dioxide is comprised of power plants that in aggregate correspond to 100% of EIA-reported installed coal-fired power plant capacity in 2017. The differences in samples explain the differences in the changes in capacity and generation reported on the second row between the two panels.

As clear in the first row of panel A, the vast majority of projected mercury emission reductions under MATS occur as a result of reducing the emission intensity of generation (attributed to the adoption of pollution control technologies in EPA [2011]). EPA (2011) projects about 2.5% of coal-fired power plant capacity retirements in the policy case relative to the base case. Yet, conditional on operating, EPA projects coal-fired generation to increase modestly under MATS. EPA (2011) estimates a 74.8% reduction in the mercury emission intensity of generation under MATS and a similar 75.2% reduction in mercury emissions overall. The second row of Panel A compares the observed data in 2017 to the EPA projected base case. Installed capacity fell by 18.5% and generation, conditional on operating, fell by 30.9%. While the EPA projections for capacity and generation well exceeded what coal-fired power plants delivered in 2017, the emission intensity of operating power plants was down by 72.3%, quite close to the EPA projection. Overall, mercury emissions in 2017 were 81% lower than the EPA (2011) baseline.

The EPA (2011) projections for SO_2, shown in the first row of panel B, reflect a similar pattern to that of mercury. The installed capacity and generation estimates are the same as for mercury, and the significant reduction in SO_2 emissions occurs in the EPA analysis primarily through the 39.6% reduction in the emission intensity of generation. Overall, EPA (2011) projects that that the MATS rule would reduce SO_2 emissions by nearly 41%. In 2017, installed capacity in our sulfur dioxide sample was about 20% below the baseline while generation conditional on operating was nearly 40% below the baseline. The sulfur dioxide emission intensity in 2017 was about one-third below the base case, realizing about 85% of the projected improvement in SO_2 emissions intensity of the policy case. The combination of lower capacity, lower generation conditional on operating, and lower emission intensity all contributed to SO_2 emissions being 60% below the base case projection in EPA (2011). The realized improvement in SO_2 emissions intensity and SO_2 emissions overall may have reflected other market and regulatory factors, and it is beyond the scope of this illustrative analysis to make a causal claim. We note that the less-than-forecast improvement in SO_2 emission intensity could reflect how adoption of mercury and air toxics pollution control technology differed from the EPA (2011) policy case projection, as described in section 2.A. above.

The changes in composition of generation illustrated in Figure 4 and the decline in the output from coal-fired power plants presented in Table 4 have contributed to important changes in emissions of SO_2 and mercury emissions from the sector that differ from what was predicted to happen under MATS in EPA (2011). Importantly, many of these changes in emissions arguably would have occurred in the absence of the MATS regulation, and therefore are expected to have had significant effects on the realized benefits and costs of the rule.

Retrospective Analysis of Power Market Shocks and Regulations

Two recent papers have employed distinct empirical strategies to estimate (a) the impacts of non-regulatory factors on coal-fired power production, and (b) the role of MATS in the decline of coal. Interestingly, they both reach very similar conclusions. One of these papers also decomposes the effects on emissions of key pollutants that contribute to the benefits of MATS. We describe their methods and key findings to update the current understanding of the realized benefits and costs of MATS.

Linn and McCormack (2019) use a newly constructed combination structural and reduced-form computational model of fossil fuel generators in the eastern half of the United States to decompose the contributions of changes in electricity demand growth, environmental regulations and relative fuel prices on coal plant profitability, generation and retirement between 2005 and 2015. The model consists of three components: (1) an investment and retirement module that predicts plant retirement and investment by type based on expected future profits, (2) a pollution abatement module that makes investments that minimize the cost of meeting emissions caps under Clean Air Act regulations, and (3) an operations module that employs a simplified unit commitment model with minimum load and inter-hour operating constraints. The model is parameterized using data for all the units in EPA's CEMS database from 2005 and units that were subsequently added with information on pollution control costs from EPA and fuel price information from EIA. The three phases of the model are solved in reverse order such that choices about operations and associated market equilibria inform plant-level investments in pollution control and decisions about retirement. Retirements lead to adjustments in the capital stock that affect market equilibria in subsequent executions of the operations module and the pollution control module, and each is solved in turn iteratively until the results converge. The authors test the model against existing annual data between 2005 and 2015 and find that it performs well.

The authors use the model to analyze differences between actual outcomes and projections of outcomes that were made in 2005 for a range of variables including coal plant profitability and coal retirements. By changing input assumptions of key variables, the model seeks to explain the relative contributions of shocks to electricity demand, natural gas prices, and wind generator production as well as environmental regulations on the role of coal in electricity generation. They find that market shocks explained 80% of the retirements of coal plants and that in the presence of these market shocks and the Cross-State Air Pollution Regulation (CSAPR), MATS was responsible for about 5.6 GW of retirements, or approximately 14% of total retirements, by 2015.

Coglianese, Gerarden, and Stock (2019) take a different approach that focuses on decomposing the impacts of market trends and environmental regulations on changes in coal production in the United States since 2008. They use a combination of methods in their decomposition, but the bulk of their analysis relies on econometric modeling, as distinct from the computational model employed by Linn and McCormack. They adopt three separate approaches to address different components: (1) econometric modeling of the market (primarily fuel price) and regulatory determinants of coal's share of electricity generation by state (primarily state renewable portfolio standard policies), exploiting state-level differences in fuel prices, renewables requirements, and monthly state-level panel data; (2) empirical modeling of MATS impacts on coal plant retirements by exploiting differences between planned retirements announced before and after promulgation of the MATS regulation; and (3) accounting techniques to capture the effects of changes in electricity demand and demand for coal exports as well as metallurgical coal. In their analysis of the impacts of MATS on power plant retirements, they control for changes in fuel prices relative to fuel price expectations prior to the rule being announced.

They find that declines in the price of natural gas explain about 92% of the drop in coal production between 2008 and 2016. They estimate that the CSAPR and MATS regulations caused about 6% of the fall in coal production, and the remaining 2% is attributable to a combination of other factors including the slowdown in electricity demand. They estimate about 5.2 GW of retirements induced by the MATS regulation, quite similar to Linn and McCormack and EPA (2011).

Linn and McCormack also explore the effects of non-regulatory factors on emissions of key pollutants from the electricity sector; though they do not examine the effects on mercury. They find that changes in demand growth, gas supply and renewables generation contributed to a roughly 49% reduction in SO_2 emissions. Moreover, the incremental reductions in those emissions due to CSAPR were only 5% of the decline attributed to non-regulatory factors, and those due to MATS were only 1.3%. It is important to acknowledge that the SO_2 emission levels reported in their CSAPR and MATS cases are about three times greater than observed coal-fired power plant SO_2 emissions in 2015. Thus, there are several million tons of SO_2 emission reductions unaccounted for in their analysis.

The reductions in NOx emissions from non-regulatory changes were slightly less at 46%, and the additional reductions from the MATS and CSAPR were only 11 percentage points from the baseline assumptions consistent with EPA's RIA. Indeed, the MATS rule leads to a very slight increase in NOx emissions above what resulted with just the Cross-State Air Pollution Rule in place in their analysis. Observed NOx emissions in 2015 were about 10% lower than what Linn and McCormack estimate with and without the MATS rule.

These two retrospective analyses provide alternative empirical strategies for evaluating the impacts of market shocks and environmental regulations on coal-fired power plant capacity and generation. They provide compelling evidence about retirements and illustrate how competition from low-cost natural gas and renewable power in the presence of lower-than-expected demand can reduce coal-fired power plant generation. Neither study explicitly addresses the change in mercury emissions and emission intensity (tons per megawatt-hour) resulting from the MATS. The focus on market investment, retirement, and power output decisions reduces emphasis on the emissions and emissions intensity of other pollutants as well. Further ex post review of the performance of the MATS rule could shed light on the impacts of the policy on mercury, air toxics, SO_2, and NOx emissions.

Informing New Prospective Analysis of the Benefits and Costs of MATS

A new prospective analysis of the MATS could reflect the insights gained from retrospective analyses, both from the academic literature and new work undertaken by EPA. Such a prospective analysis could incorporate the most recent epidemiology and integrated assessment modeling of the public health benefits associated with reducing power plant mercury emissions. Likewise, such an analysis could include the benefits associated with indirect emission reductions, reflecting an updated assessment of how the choice of pollution control technology in practice influences the emissions of $PM_{2.5}$ and SO_2. The geographic location of reductions in $PM_{2.5}$ and its precursors has important implications for public health benefits, and EPA could employ a richer approach for accounting for the regional variation in emission reductions in estimating such benefits.

Any prospective cost analysis should also distinguish between the sunk costs of past capital investments – which do not merit inclusion in a 2019 BCA because those resources have already been expended and have no alternative use in the economy – and O&M ongoing costs associated with implementation of MATS – which represent the ongoing opportunity costs of the MATS regulation. Ongoing operation of mercury and air toxics pollution control equipment will impose costs on EGUs and deliver pollution reduction public health benefits.

A critical element of any economic analysis of a regulatory action is the choice of baseline. In 2011, EPA chose a baseline scenario that represented its best understanding of how the power sector would evolve without the MATS standard – a status quo regulatory setting. The MATS regulation was then evaluated in comparison to this no-new-policy base case. In 2019, more than three years into power plant compliance with MATS, the regulation has become the status quo. If there are no regulatory changes, then the MATS is the baseline going forward. Any regulatory action that could reduce the probability of continued implementation of MATS – either through this regulatory action or in future actions that could be precipitated by this action or legal decisions in response to this regulatory action – should be considered the new regulatory alternative. In this context, the baseline is effectively switched from what it was in 2011, and the social costs of regulatory actions that undermine MATS would include foregone mercury, air toxics, and $PM_{2.5}$ public health benefits and the social benefits would include cost-savings at power plants that do not have to operate and maintain existing pollution control equipment required under the regulation.

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APPENDIX 1

E-EEAC Review Questions

Question 1: Accounting of Co-benefits in Regulatory Impact Analysis. Because air pollutants result from complex processes, the abatement of one pollutant frequently affects the levels of other pollutants. The interconnections can occur though chemical processes and/or byproducts of abatement technologies. Thus, when a regulation is targeted to reduce a particular pollutant, the costly compliance strategies adopted by regulated entities will often lead to reductions in other pollutants. In some cases, the emission of a molecule of a specific aerosol can simultaneously count as two pollutants under the Clean Air Act, such as a hazardous air pollutant (due to its chemical properties) and a fine particulate (due to its physical properties). This means that the linkages among different air pollutants may connect different regulations that seek to improve air quality. This is incorporated into the rulemaking process in two ways: the accounting for indirect benefits (co-benefits), and the establishment of a baseline from which to estimate the incremental costs and benefits of a given rule. As an example of the latter, the RIA for the 2012 $PM_{2.5}$ NAAQS accounted for the pollutant reductions achieved as a result of compliance with MATS (EPA, 2012). Moreover, for MATS itself, EPA's baseline accounts for pollutant reductions achieved under the Cross-State Air Pollution Rule, among other regulations. Specific questions we intend to address include:

1.A. What are the welfare consequences of ancillary reductions of air pollutant emissions, such as fine particulates? And should they count in RIAs?

1.B. Are the methods used by EPA in its analysis of the proposed revision to the supplemental cost finding consistent with this understanding of the welfare consequences of ancillary emission reductions?

1.C. How has EPA specified the assumptions underlying the baseline conditions with respect to the MATS rule co-benefits? Are these assumptions clear and sufficient? As part of this, how has EPA accounted for potential changes in the baseline that may have occurred because of updates to state implementation plans for $PM_{2.5}$ since 2012?

1.D. EPA translates changes in emissions into changes in ambient air quality, and these procedures have potential implications for the regional and temporal variation in co-benefits. Are EPA's methods appropriate, especially with respect to the economic issues that might arise?

Question 2: Applying Retrospective Review of the 2012 MATS Rule to Inform the 2019 Proposal. The final MATS rule became effective on April 16th, 2012 and power plants' compliance obligations under MATS started four years later in April of 2016. In the seven years since publication of the MATS RIA, the electricity sector has experienced rapid and significant changes. For example, the 2011 MATS RIA projected electricity generating capacity from coal of 304 GW in 2030 – a 4 GW reduction from the no-MATS baseline scenario. Since 2010, however, U.S. coal-fired capacity has already fallen 70 GW, and the most recent 2030 projection from the U.S. Energy Information Administration estimates 161.8 GW of capacity. While some of the observed changes in the utility sector could reflect the (expected) regulatory costs imposed by the MATS, the significant increases in low-cost power generation from natural gas and renewable energy during a period of zero electricity demand growth are likely to be larger drivers of the sector's transformation. Thus, MATS provides an example of a regulatory setting in which retrospective analysis can provide important information for improving public policymaking. It would also illustrate the value of updating the analysis to reflect rapidly changing market conditions. The specific questions we intend to address on this topic include:

2.A. How can the EPA improve the quality of its estimated benefits and costs of the MATS rule by leveraging the most recent data and analysis?

2.B. Given the capital costs associated with pollution abatement investment already incurred by some facilities, how should EPA treat such capital in its analysis of the proposed rule?

2.C. How have changes to the power sector unrelated to the MATS rule influenced the realized costs and benefits of the regulation to date, and how could this understanding inform the prospective analysis of the 2019 proposal?

APPENDIX 2

Data Appendix

We have compiled data from a variety of EIA and EPA sources to produce the analysis, tables, and figures in this report. The following lists the sources, with a URL for accessing the data:

- 2011 Regulatory Impact Analysis Data: Regulatory Impact Analysis for the Final Mercury and Air Toxics Standards, EPA-452/R-11-011, December
https://www3.epa.gov/ttnecas1/regdata/RIAs/matsriafinal.pdf

- Generation data: EIA 923, Schedules 2,3,4,5
https://www.eia.gov/electricity/data/eia923/

- Capacity data: EIA 860, 3-Generator_Y spreadsheets
https://www.eia.gov/electricity/data/eia860/

- SO_2, NO_x emissions data: EPA FTP (see below for download method)
ftp://newftp.epa.gov/DMDnLoad/emissions/daily/quarterly/

- Mercury emissions data: EPA FTP (see below for download method)
ftp://newftp.epa.gov/DMDnLoad/emissions/mats/

- Pollution Control Equipment data: EIA 860, 6_1_EnviroAssoc & 6_2_EnviroEquip sheet,
https://www.eia.gov/electricity/data/eia860/

- Plant Closures and Retirements [includes retirement date by month-year]: NEEDS,
https://www.epa.gov/airmarkets/national-electric-energy-data-system-needs-v6

- Plant-specific capacity, generation, emissions, and pollution control equipment under baseline and policy cases in the MATS RIA
USEPA. 2010. IPM Parsed File – 2010 Base Case. Docket ID: EPA-HQ-OAR-2009-0234-19982:
https://www.regulations.gov/document?D=EPA-HQ-OAR-2009-0234-19982

We used a python script to download the emissions data from the EPA FTP at the state-month year before appending each individual month-state dataset together by year and then finally we appended all years together. We merged data sets at the generator-plant level. For each of these data sources, generator IDs occasionally differed, requiring some modest data cleaning, including the adjustment of strings added to some generators identification codes in some datasets. In some cases, where generator ID's do not match but there is only one generator per plant, we match on the plant ID.

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