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ORIGINAL ARTICLE

Designing environmental policy: lessons from the regulation of mercury emissions

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Abstract In its waning days, the Clinton administration decided that it was appropriate to regulate mercury emissions from power plants. The incoming Bush administration had to decide how best to regulate these emissions. The Bush administration offered two approaches for regulating mercury emissions from power plants. The first was to establish uniform emission rates across utilities, as mandated by the 1990 Amendments. The second was to establish a cap on mercury emissions while allowing emissions trading in order to reduce the cost of achieving the goal. This paper presents the first cost-benefit analysis of this issue that takes account of IQ benefits. We find that the benefits of the mercury regulation are likely to fall short of the cost. This assessment is based

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on a number of assumptions that are highly uncertain. The finding of negative net benefits is robust to many, though not all, reasonable variations in the model assumptions. We also find that the emissions trading proposal is roughly $15 billion less expensive than the command-and-control proposal.

Keywords Regulation · Cost-benefit analysis · Environmental economics

Classifications D61 · L50 · L51 · Q52

1 Introduction

In its waning days, the Clinton administration decided that it was appropriate to regulate mercury emissions from power plants. As part of a settlement agreement, it gave the incoming Bush administration the task of designing a regulation that would meet legal requirements.

The decision to regulate mercury emissions from power plants capped the end of a long process begun with the 1990 Clean Air Act Amendments,[1] which required that the EPA evaluate mercury and other toxic emissions to determine if they required more stringent regulation. After failing to meet this obligation, the Clinton administration faced law suits from environmental groups and ultimately agreed to make a determination on mercury regulation by December 15, 2000.[2]

This created a difficult challenge for the incoming Bush administration. While there were thought to be some identifiable economic benefits from regulating mercury emissions, such as an increase in IQ in children, it was not clear that the benefits of regulation justified the cost. Moreover, any decision to move away from regulating mercury would have to reverse the Clinton administration's determination that such regulations were "appropriate and necessary."[3]

The Bush administration offered two different approaches for regulating mercury emissions from power plants. The first was to establish uniform emission performance standards across utilities, as mandated by the 1990 Amendments. The second was to establish less restrictive emission standards, but to also establish a cap on mercury emissions while allowing emissions trading in order to reduce the cost of achieving the goal.[4]

Reducing the risks posed by mercury exposure is a complex regulatory problem because mercury emissions affecting the U.S. come from a number of anthropogenic and natural sources, both inside and outside the U.S. While the

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[1] Below, we also use the term "1990 Amendments."

[2] See *Natural Resources Defense Council, Inc. v. United States Environmental Protection Agency*, et al. (1998).

[3] For a discussion of the need to reverse the "appropriate and necessary" designation, see the EPA's proposed mercury rule, Fed. Reg. 69:20, pp. 4683-4688.

[4] This second approach finds legal justification under a different part of the 1990 Amendments than offered by the Clinton administration, so the Bush administration also proposed reversing the previous determination.

U.S. regulatory proposals would address a portion of emissions coming from within the U.S. that are also deposited in the U.S., they would do nothing to address deposition coming from natural sources and from emissions coming from abroad. In fact, the sum of *all* domestic anthropogenic mercury emissions constitutes less than 3% of the global pool of emissions, and domestic utility sources account for less than 1%.[5] In assessing the benefits of regulating mercury emissions from U.S. utilities, we account for the global nature of the problem.

The basic science linking mercury emissions from power plants to impacts on humans is highly uncertain. Mercury is contained within coal and is emitted into the air when power plants burn the coal to generate electricity. The emitted mercury is then deposited on land and water. A reduction in deposition then leads to lower levels of methylmercury (an organic form) in fish.[6] Methylmercury exposure through fish consumption is the only established health pathway related to power plant mercury emissions. Furthermore, methylmercury is a known neurotoxin at high levels in humans. The theory is that low-dose exposure from fish consumption could also have damaging health effects, particularly for the developing fetus through maternal exposure. Thus, lower levels of mercury in fish, the dominant exposure pathway to humans, might provide health benefits for newborns. These benefits could include a reduction in neurological deficiencies in children that were exposed to it in the womb. The benefits could also include reduced risk of coronary heart disease in adults.[7]

The relationship between low levels of methylmercury exposure through fish consumption and health effects in children and adults is uncertain. As we discuss later, many of the possible health effects are speculative. Even though the evidence is mixed, we focus on the impact of methylmercury on IQ scores of children. We do so because the key scientific studies have examined neurodevelopmental outcomes through the administration of tests of cognitive functioning.[8] In their final rule, the EPA also focused on IQ as the endpoint of interest.[9] Another recent study also incorporates the reduced risk of coronary heart disease in adults.[10] As we discuss later, we believe that this health end

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[5] See EPA (2004) and Pacyna, Pacyna, Steenhuisen, and Wilson (2003).

[6] See EPA (1997), Florida Department of Environmental Protection (2003), and Hrabik and Watras (2002).

[7] For a discussion of the possible health effects of mercury, see the EPA's proposed mercury rule, Fed. Reg. 69:20, p. 4708. For a discussion of science linking mercury exposure to human health effects, see National Research Council (2000).

[8] According to the EPA "Participants [in EPA's 2002 workshop] were also asked about endpoints to consider for monetization and they suggested looking at neurological tests that might lead to changes in IQ or other neurodevelopmental impacts. EPA determined that IQ decrements due to mercury exposure is one endpoint that EPA should focus on for a benefit analysis, because it can be monetized" EPA (2005), pp. 180–181.

[9] EPA focuses on IQ changes, in part, because of "the availability of well-established methods and data for economic valuation of avoided IQ deficits, as applied in EPA's previous benefits analyses for childhood lead exposure" (EPA, 2005, p. 9-1).

[10] See NESCAUM (2005).

point is highly speculative and at this time does not warrant inclusion in the benefits estimate.

The economic costs of regulation are also highly uncertain, particularly for reaching stringent emission limits. Indeed, because the technology for meeting stringent emission limits is not readily available, the cost and effectiveness of meeting these limits is subject to debate.

This paper presents the first cost-benefit analysis of mercury regulation that takes account of IQ benefits. Previous analyses have not attempted to monetize benefits associated with mercury controls.[11] We consider the Bush administration's two regulatory proposals. We find that neither of these proposals is likely to pass a benefit-cost test; however, the proposal that allows for more flexibility in meeting the targets could save roughly $15 billion compared to the proposal that does not.

Section 2 provides an overview of the proposed rules for regulating mercury. Section 3 describes their likely impact on emissions and the costs of achieving the specified reductions. Section 4 provides an assessment of the benefits and net benefits of the proposals. Finally, Section 5 concludes.

2 Overview of proposed mercury rules

On December 15, 2003, the EPA proposed two mutually exclusive options for regulating mercury emissions from electric utilities.[12] The first option proposed establishing uniform limitations on mercury emission rates across utilities, based on the type of coal the utilities use. The EPA determined these emission limitations for existing utilities based on the criteria established under section 112 of the 1990 Amendments.[13] This standard is known as the "maximum achievable control technology" (MACT). This proposed rule would also set stricter emission limitations for new sources in each category.[14] While the language in the 1990 Amendments seems rather specific on how to set these standards for existing and new sources, there is some flexibility in the final determination.[15]

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[11] Schwartz (2004) estimates an upper bound on the improvement in average cognitive and neurological test scores of children who are above the EPA's reference dose that results from a 70% reduction in mercury emissions.

[12] Regulated sources include any "fossil fuel-fired combustion units of more than 25 megawatts electric that serves a generator that produces electricity for sale. A unit that cogenerates steam and electricity and supplies more than one-third of its potential electric output capacity and more than 25 MWe output to any utility power distribution system for sale is also an electric utility steam generating unit" (Fed. Reg. 69:20, p. 4662).

[13] The 1990 Amendments state that emission standards for existing sources in each subcategory must not exceed "the average emission limitation achieved by the best performing 12 percent of the existing sources... (112(d)(3)(A))."

[14] The 1990 Amendments state that emission standards for new sources in each category must be set at "the emission control that is achieved in practice by the best controlled [existing] similar source" as prescribed by section 112 of the 1990 Amendments (112(d)(3)).

[15] For example, in computing the "best performing 12 percent" and the "best controlled ... source," the EPA allowed for potential variability in the emission data, which results in higher allowable

The EPA expected that these emission rate limits would result in nationwide mercury emissions from power plants of 34 tons per year starting in 2008, which is a reduction from 48 tons estimated for 1999.

This regulatory proposal would require existing utilities to achieve the following mercury emission rate limits measured on an output basis: 21×10^{-6} pounds per MWh for bituminous coal, 61×10^{-6} pounds per MWh for sub-bituminous coal, and 98×10^{-6} pounds per MWh for lignite coal.[16] New sources would have to achieve much more restrictive mercury emission rate limits.[17] This command-and-control system does not allow utilities to trade emission reduction responsibility. Each individual unit must modify its plants to meet these emission rate limits or must shut down.

The second option proposed by EPA, which was adopted (in amended form) in the final rule, establishes emissions standards for new sources as defined under section 111 of the 1990 Amendments. These performance standards are less restrictive than MACT, but this proposal also creates an additional cap-and-trade system for mercury emissions. The cap-and-trade system applies to both new and existing electric utility sources. A cap-and-trade program establishes the annual number of allowable emission permits (the "cap"), which is set below the existing emissions level.[18] Each regulated entity must submit one permit for every ounce of mercury emissions. The cost savings come from allowing power plants to trade permits, so that an operator that finds it costly to reduce its marginal unit of mercury can instead purchase a permit from another firm that can reduce an ounce of mercury for less cost.[19]

The proposed cap-and-trade system occurs in two phases. In the first phase, which starts in 2010, utility mercury emissions are capped at approximately 34 tons per year.[20] The second phase of the mercury cap-and-trade program,

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Footnote 15 continued
emissions rates for both existing and new sources relative to using mean emissions. Consistent with the 1990 Amendments, the EPA's proposal requires that these standards are met by early 2008. However, existing sources may seek a permit granting an additional one year to comply if such time is necessary for the installation of controls" (Fed. Reg. 69:20, p. 4682).

[16] The statute also provides the following input standards: 2.0 pounds per trillion British thermal unit for bituminous coal, 5.8 pounds per trillion British thermal unit for sub-bituminous coal, and 9.2 pounds per trillion British thermal unit for lignite coal.

[17] The new source performance standards (measured on an output basis) are as follows: 6.0×10^{-6} pounds per MWh for bituminous coal, 20×10^{-6} pounds per MWh for sub-bituminous coal, and 62×10^{-6} pounds per MWh for lignite coal.

[18] The cap-and-trade rule has an additional complexity because of the 1990 Amendments. Rather than establish a national cap-and-trade market, the rule assigns an annual number of allowances to each state. The state has the choice of adopting the cap-and-trade rule, or achieving the required reduction through another EPA-approved state plan. Additionally, states could adopt the cap-and-trade rule and also set stricter standards on within-state utilities (see EPA, 2005, pp. 135–136).

[19] See, e.g., Dales (1968) and Montgomery (1972).

[20] In the proposed rule, the exact level of this first-stage cap is to be determined based on the expected level of mercury emissions reductions achieved from reductions of sulfur dioxide and nitrogen oxides resulting from a separate rule. The EPA proposal suggested that a first phase cap of 34 tons (revised to 38 tons in the final rule) would be achievable from controls installed to meet limitations on sulfur dioxide and nitrogen oxides imposed by a recent rule. Thus, they expect the

effective starting 2018, caps utility mercury emissions at 15 tons per year. While we rely on model results based on the proposal, EPA's final rule changed the first-phase cap to 38 tons. This may mean that our estimates slightly overstate the benefits as well as the costs of the final rule.[21]

The EPA's cap-and-trade system has some other features designed to reduce costs, but that also affect the distribution of mercury emission reductions over time. The cap-and-trade system will allow utilities to bank any unused permits for later use. One would expect utilities to bank permits in the first phase of the program (resulting in fewer emissions in this phase than required by the overall cap) so that they can use the permits in the more-restrictive second phase of the program (resulting in more emissions in this phase than allowed by the overall cap). Thus, banking tends to smooth out the reductions required by the two-phase program.

3 Emissions and costs under two proposals

In this section we examine emissions and costs for the two proposals that were summarized in Sect. 2. Emission reductions will be critical because we will use this estimate to derive an estimate of the monetized benefits of the different proposals. These benefits will then be compared to the monetized costs.[22]

In estimating emissions reductions, a key issue is identifying incremental emission reductions. In what follows, our baseline scenario takes into account the rule promulgated by the Administration on March 10, 2005, known as the Clean Air Interstate Rule. This rule establishes cap-and-trade programs for sulfur dioxide and nitrogen oxides emitted by electric utilities. It is important to consider this rule because the pollution control equipment that will be installed as a result of it will lead to significant reductions in mercury emissions, independent of the mercury rule.[23]

3.1 Emission scenarios

We rely on two different models of the emission scenarios that will occur from the two mercury rules. Model 1 comes from analyses by the EPA and the Clean

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Footnote 20 continued
need for additional mercury controls will not arise until the second phase cap in 2018. However, the model results we report suggest that some additional controls will be needed to meet the 34-ton first phase cap.

[21] Even though the final rule has a less restrictive first-phase cap, it also eliminated the "safety valve," which would have enabled firms to borrow future permits at a pre-established price. Eliminating this feature in the final rule could increase slightly the restrictiveness of the rule relative to the proposed rule. For an early treatment of why a mixed permit-fee scheme (such as the safety valve) might dominate a permit approach, see Roberts and Spence (1976).

[22] Below, we also consider issues related to unquantified benefits and costs.

[23] The EPA also took the Clean Air Interstate Rule as their baseline scenario when it modeled the impact of the final mercury rule (see EPA, 2005, p. 76).

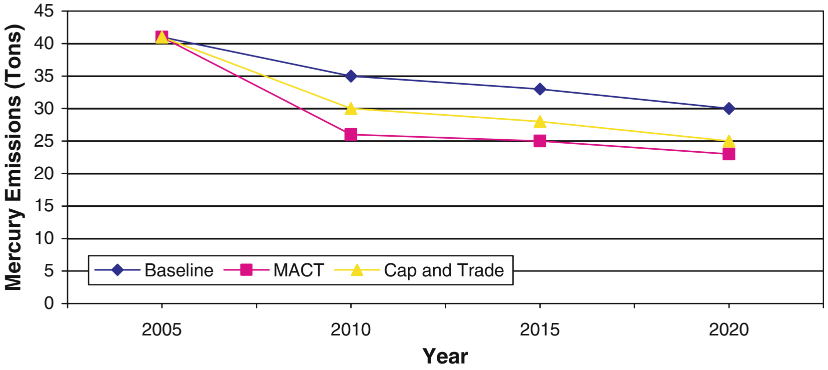

Fig. 1 Model 1 mercury emissions projections
Notes: All Model 1 projections are estimated using the Integrated Planning Model and all scenarios assume the Clean Air Interstate Rule is in effect. For baseline and MACT projections, see Clean Air Task Force public comments submitted to the EPA (Docket OAR-2002-0056-4910). For Cap and Trade projections, see EPA (Docket OAR-2002-0056-0338). The Clean Air Task Force reported that the Integrated Planning Model projected mercury emissions to be 46 tons under the MACT in 2005. This does not make sense considering their estimate for mercury emissions under the Clean Air Interstate Rule alone was 46 tons. We revised down to 41 tons, which is the same as the projected mercury emissions for our baseline. EPA's Clean Air Markets Division staff agreed this is a sensible revision

Air Task Force.[24] Model 2 comes from Charles River Associates.[25] Figures 1 and 2 show each model's projected trends in national mercury emissions for the two mercury proposals.[26]

Both models predict that the baseline scenario will reduce mercury emissions, which is expected because the control technologies stemming from the sulfur dioxide and nitrogen oxides rule are likely to yield reductions of mercury emissions. Model 1 predicts steady declines in mercury over time with the MACT standard, which is surprising since the MACT standard does not change over time. The model also predicts that cap-and-trade will yield smaller reductions than MACT. The reason that it shows smaller emission reductions for cap-and-trade is likely because it assumed that firms could borrow future allowances

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[24] We combine EPA and Clean Air Task Force model estimates because the former did not model mercury emissions given the MACT scenario and the sulfur dioxide and nitrogen oxides rule. Both EPA and the Clean Air Task Force use the same Integrated Planning Model to derive their estimates. The Clean Air Task Force estimates are meant to use the same assumptions as the EPA estimates in order to make their numbers comparable. We obtained the Clean Air Task Force forecasts and cost analyses from their public comments submitted to EPA (Docket OAR-2002-0056-4910 and Docket OAR-2002-0056-0338).

[25] Charles River Associates uses the Electric Power Market Model to derive their estimates. We obtained Charles River Associates forecasts and cost analyses from the public comments submitted to EPA (Docket OAR-2002-0056-2578) by the Electric Power Research Institute, which hired Charles River Associates.

[26] These emission scenarios in Model 1 allow for indefinite borrowing of future permits at the safety valve price, which is not allowed in the final rule.

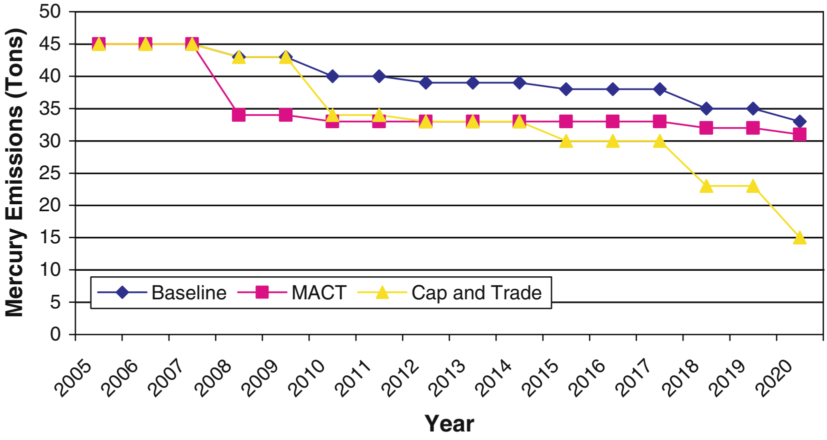

Fig. 2 Model 2 mercury emissions projections
Notes: Model 2 projections were estimated by Charles River Associates using the Electric Power Market Model. We obtained Charles River Associates forecasts from the public comments submitted to EPA (Docket OAR-2002-0056-2578) by the Electric Power Research Institute (EPRI), which hired CRA. All scenarios assume the Clean Air Interstate Rule is in effect

indefinitely and never achieve the 15-ton goal. However, in the final rule EPA eliminated the borrowing option. While we use both models in our analysis of costs and benefits, we have greater confidence in the pattern of emissions that are projected under Model 2 because it is unaffected by the existence of the borrowing provision.

According to Model 2, the MACT will lead to a reduction of mercury to 34 tons (in 2008), and this level will hold relatively constant, declining to 31 tons by 2020. Model 2 also predicts that the cap-and-trade scenario will lead to a reduction in mercury to 34 tons in 2010, and that mercury will then steadily decline through the second phase of the cap-and-trade proposal, reaching the 15-ton cap in 2020, which is substantially below the MACT scenario.

In summary, both sets of emission projections forecast declines in emissions, but under Model 1, cap-and-trade appears to result in higher emissions over time as a result of the borrowing provision (which is not part of the final rule), whereas in Model 2, cap-and-trade results in higher emissions in the short term, but lower emissions over the longer term. The timing of the reductions is important because the benefits of emission reductions are discounted over time.

3.2 Estimated cost of the two mercury proposals

We rely on the same models as above for our estimates of the costs of the two mercury rules. These cost estimates are highly uncertain because they involve many assumptions based on limited data. For example, projected costs will depend on assumptions about future electricity demand, natural gas prices,

Table 1 Model 1 Incremental cost estimates for MACT and cap and trade (in billions of 1999 dollars)

Year	MACT costs	Cap and trade costs
2005–2007	$0.0	$0.0
2008–2012	$2.3	$0.2
2013–2017	$2.0	$0.5
2018–2020	$1.7	$0.1

Notes: These costs derive from the Integrated Planning Model used by the EPA and others. The Integrated Planning Model reports total annual production costs for the electricity industry for three scenarios: MACT and the Clean Air Interstate rule are enacted, Cap and Trade and the Clean Air Interstate Rule are enacted, and only the Clean Air Interstate Rule is enacted. We compute incremental costs for both the MACT and Cap and Trade scenarios by subtracting the costs of the Clean Air Interstate Rule only scenario. These costs are understated because they do not include transaction costs, paperwork for the rule, and some small compliance costs like monitoring the mercury level at each plant. The source for the Clean Air Interstate Rule only scenario and the Clean Air Interstate Rule plus MACT scenario is EPA (Docket OAR-2002-0056-4910). The source for the Clean Air Interstate Rule plus cap & trade scenario is EPA (Docket OAR-2002-0056-0338)

coal production and usage, and the effectiveness of largely un-tested control technologies.[27]

Tables 1 and 2 show annual cost estimates for the MACT and cap-and-trade scenarios from both models. These estimates are the incremental costs relative to a baseline that includes the sulfur dioxide and nitrogen oxides cap-and-trade rule. The highest costs for MACT occur in the early years of the rule (which starts in 2008), when firms retrofit their plants to meet the strict emission standards. The MACT rule does not provide flexibility in meeting the targets across time, so sources must meet the emissions rate limitation each year.[28]

Unlike the MACT proposal, the cap-and-trade proposal does allow flexibility across sources through trading and across time through banking. With the cap-and-trade proposal, Model 2 predicts relatively low costs in the early years, slightly increasing over time largely due to the need to install more experimental control technologies[29] in order to meet the stricter phase two standards. Model 1 predicts relatively constant incremental costs for cap-and-trade over time.[30] Since the cap-and-trade approach allows firms to gradually adopt the control

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[27] The most critical assumption in the cost models is the cost of the control technology (known as Activated Carbon Injection). Changes in the cost of this technology will have little impact in the early years of the cap-and-trade proposal, but by 2020, they could have significant impacts. Technology costs are more certain for the case in which all the MACT controls must be installed by 2008.

[28] Both models suggest that the costs of MACT actually decline in later years. This is because the baseline sulfur dioxide and nitrogen oxides rule becomes more restrictive over time, thus increasing the amount of mercury reductions associated with the rule.

[29] Known as Activated Carbon Injection.

[30] Model 1 predicts constant costs because it assumes indefinite borrowing due to the safety valve. Thus, in this model, firms do not install control technology if the marginal cost of reducing emissions exceeds the safety valve price. This assumption is not valid for the final EPA rule that eliminated the safety valve.

Table 2 Model 2 Incremental cost estimates for MACT and cap and trade (billions of 1999 dollars)

Year	MACT costs	Cap and trade costs
2004–2007	−\$0.1	−\$0.1
2008–2009	\$3.2	−\$0.4
2010–2011	\$2.3	\$0.4
2012–2014	\$1.8	\$0.7
2015–2017	\$1.7	\$0.7
2018–2019	\$0.8	\$0.8
2020	−\$0.2	\$1.1

Notes: These costs derive from the Electric Power Market Model used by Charles River Associates. It reports the incremental annual costs required to comply with the proposed rules. Charles River Associates cost estimates are provided by the Electric Power Research Institute in their public comments to EPA (Docket OAR-2002-0056-2578). Cost figures represent incremental costs compared to a baseline scenario that assumes the Clean Air Interstate Rule is in effect

Table 3 Present value costs for 2005–2020 of MACT and cap and trade (billions of 2004 dollars)

Discount rate (%)	Using Model 1 estimates		Using Model 2 estimates	
	MACT costs	CAP and trade costs	MACT costs	Cap and trade costs
3	\$23.2	\$3.3	\$20.7	\$5.5
5	\$19.5	\$2.7	\$17.8	\$4.3
7	\$16.5	\$2.3	\$15.4	\$3.4

Notes: These costs are computed by using the cost estimates from Charles River Associates, EPA, and the Clean Air Task Force listed in Tables 1 and 2. Cost figures represent incremental costs compared to a baseline scenario that assumes the Clean Air Interstate Rule is in effect. We computed the present value of the sum of these annual costs, summing from 2005 to 2020, and we converted to 2004 dollars

technologies over time rather than the one-time massive installation that must occur in order to meet the MACT requirements in 2008, the greater flexibility results in lower costs relative to the MACT proposal.

Table 3 contains the estimated present value costs of each proposal based on the two models.[31] The table presents three different discount rates—3%, 5%, and 7%.[32] In all cases, the table reveals that cap-and-trade is approximately 15 billion dollars less expensive than MACT for the period from 2005–2020.

The cost estimates in Table 3 assume that any technological retrofits will be commercially available as demanded and that there will be no price increases due to an increase in demand, both of which are highly unlikely assumptions. In order to meet the regulatory standards, firms will need to increase their use of certain control technologies. For example, Table 4 shows a forecast of

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[31] In order to compare the two models, and because Model 1 begins its estimates in 2005, we remove the cost estimates for 2004 (which were negligible) for Model 2 and assume that the costs of both proposals are zero in 2005.

[32] The Office of Management and Budget recommends to agencies that "For regulatory analysis, you should provide estimates of net benefits using both 3 percent and 7 percent [discount rates]" OMB (2003).

Table 4 Model 2 estimates of retrofits (in Megawatts)

Year	MACT Scrubbers	Selective catalytic Reduction	Activated carbon Injection and Fabric filters	Cap and trade Scrubbers	Selective catalytic Reduction	Activated carbon Injection and Fabric filters
2004	1,309	18,508	1,072	1,315	18,508	1,050
2008	67,430	25,957	64,039	8,159	3,005	1
2010	1,488	2,207	1,623	35,421	11,341	14,675
2012	2,661	3,061	74	11,289	11,065	3,085
2015	2,090	3,336	21	3,361	1,994	12,270
2018	4,212	2,422	0	15,975	7,704	25,202
2020	18,211	10,139	0	33,662	7,031	50,562
Total	94,700	65,630	66,829	109,181	60,648	106,844

Notes: This table combines Table VI-6 and VI-9 from Electric Power Research Institute public comments submitted to EPA (Docket OAR-2002-0056-2578). Scrubbers, also called flue gas desulphurization units, are primarily used to reduce sulfur dioxide emissions. Selective catalytic reduction systems are primarily used to reduce nitrogen oxide emissions. Activated carbon injection systems require the installation of fabric filters, which together are called compact hybrid particulate collectors. This technology is relatively new and there is much uncertainty about both its cost and effectiveness

64 gigawatts of Activated Carbon Injection retrofits (the technology for mercury reduction) by 2008 in order to meet the MACT regulation.[33] This technology is barely used today, so this large projected increase in its demand would likely raise its price. This suggests that the models underestimate the cost of meeting the regulations, perhaps by a substantial amount. This underestimation of costs is much more likely for the MACT scenario because it requires installation of a substantial amount of control technology over a very short timeframe.[34]

The large $15 billion difference in costs between MACT and cap-and-trade is not too surprising. The MACT standard sets a rigid emissions rate limit on each unit. So no matter how much a unit operates, or how many total tons it emits, it still must achieve the assigned emissions rate through early capital investments. Thus, large plants that operate much of the time will emit much more than small plants that only run during peak periods because they must achieve the same emission rate. Under the cap-and-trade proposal, the larger plants will achieve much greater reductions than smaller peak-load plants, so there are much lower capital expenditures needed under the cap-and-trade proposal to achieve an identical emission level achieved by the MACT standard.[35]

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[33] Sixty-four gigawatts constitutes approximately 20% of all coal plant capacity.

[34] While we contend that optimistic assessments of commercial availability of technological retrofits may lead to overestimates of MACT costs, it is important to note that some studies have found that EPA tends to overestimate the cost of regulations (see Harrington, Morgenstern, & Nelson, 2000). However, this same study finds evidence that benefits may also be overestimated.

[35] Even though MACT is much costlier than cap-and-trade, both Model 1 and Model 2 predict very few power plants exiting the market as a result of the MACT regulation. This is because the proposed MACT is technologically achievable with the current control technology. Few plants will exit rather than bearing the cost because existing coal plants are much less expensive to operate

4 Benefits

In this section, we derive estimates of benefits, taking careful account of the key steps in the pathway from emissions to human health impacts.

4.1 Mercury emissions pathway: an overview

To evaluate the benefits of reducing mercury emissions from power plants, the relevant measure is the incremental benefit that accrues from a reduction in power plant mercury emissions. This estimate of the additional benefit of a reduction of mercury emissions from power plants is especially important because it accounts for the global nature of emissions and deposition. The EPA estimates that annual total global mercury emissions from all sources are about 5,000–5,500 tons per year.[36] Approximately 20% of these emissions are from natural sources, and approximately 40% are from re-cycling of mercury associated with past emissions. That leaves approximately 2,000 tons of mercury emissions per year attributable to current anthropogenic activities. As of 1999, mercury emissions from U.S. power plants accounted for only 48 tons per year (EPA, 1999).[37] Thus, a regulation that would completely eliminate mercury emissions from U.S. power plants would reduce the global mercury pool by *less* than 1%. Completely eliminating all anthropogenic mercury emissions in the U.S. (approximately 115 tons per year) would lead to a reduction in the global mercury pool of less than 3%.[38]

In order to estimate the benefits of reducing U.S. power plant mercury emissions, we must consider each link in the pathway from emissions to health outcome, which is shown in Fig. 3. Since this is a U.S. regulation, our concern is with methylmercury exposure for U.S. citizens. A reduction of U.S. power plant mercury emissions leads to an associated reduction in mercury deposition in the U.S. This reduction in U.S. deposition leads to an associated reduction in methylmercury levels in U.S. freshwater and marine fish. This reduction in methylmercury levels in U.S. fish is then weighted by the proportion of domestic fish consumption that is caught domestically. We use estimates of the mean level of methylmercury for each fish type consumed by U.S. residents, so by assum-

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Footnote 35 continued
compared to existing gas plants. Thus, even marginal coal plants have large enough operating margins to be able to pay for the capital equipment imposed by MACT.

[36] See EPA (2004).

[37] U.S. total annual anthropogenic mercury emissions have declined significantly over the past 15 years due to regulations of mercury use in goods, regulations on incineration of mercury-containing wastes, and mercury reductions from power plants stemming from regulations on sulfur dioxide and nitrogen oxides.

[38] See EPA (2004) and Pacyna et al. (2003). This highlights one of the main difficulties with the regulatory approach to mercury reductions. Part of the mercury emissions from electric utilities deposit locally, but a larger part enters the pool of emissions that deposit globally. Thus, elimination of mercury emissions is both a local and global public good, and any domestic regulation will incur costs without addressing the mercury transported from abroad.

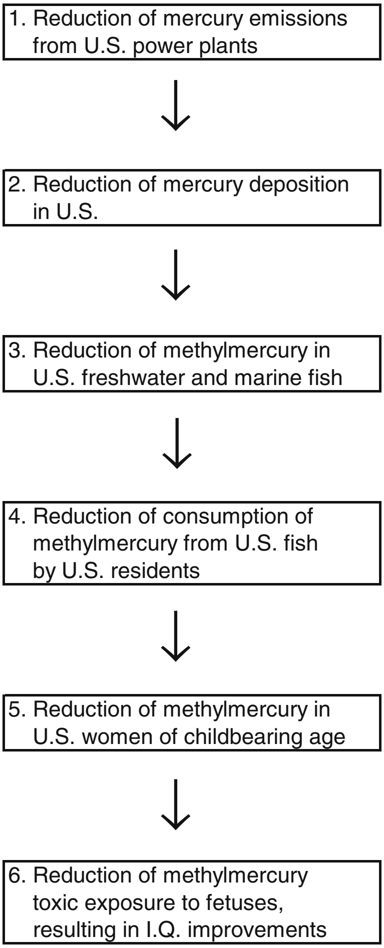

Fig. 3 Pathway from mercury to emissions to health outcome

ing that blood mercury levels are determined strictly from fish consumption, we can compute the change in methylmercury blood levels given the change in methylmercury consumption from domestic fish. We then combine this measure of exposure with toxicological evidence of the effect on health outcomes. For this study, we focus on changes in IQ scores in children as the primary health outcome of mercury exposure.[39] The final step of the benefits assessment is to monetize the improvement in children's IQ scores stemming from the reduction in power plant mercury emissions.[40]

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[39] As we mentioned before and throughout, we agree with EPA that IQ changes represent the clearest measure of the neurological outcomes examined in studies using tests of cognitive functioning. As we will discuss later, we believe the impacts on coronary heart disease are highly speculative and do not warrant monetization within the analysis.

[40] We rely on point estimates of the relationship between blood mercury levels and IQ scores even though most analyses find that the relationship is not statistically different from zero.

For our analysis, we assume that methylmercury levels in farm-raised U.S. fish are not affected by any changes in power plant mercury emissions because these are not predatory fish that gain nourishment from the top of the food chain, a condition for methylmercury accumulation. For the analysis we present below, we also assume that mercury levels of U.S. residents stemming from fish caught in non-U.S. waters will be negligibly affected by reductions in U.S. mercury emissions. The reason is that we include all marine fish caught in U.S. waters in our analysis. This leaves approximately 50% of fish consumption by U.S. citizens stemming from fish caught overseas. While our analysis may not include some fish caught overseas and eaten domestically, it also treats some U.S.-caught fish from the Pacific Ocean as domestic fish, even though they would be unaffected by a regulation of domestic power plant mercury emissions. More importantly, given that U.S. power plant emissions make up less than 1% of global emissions, the impact of the regulation will have a minimal impact on methylmercury levels on overseas fish. While we do not present them in our tables, our estimates suggest that including the effect of the regulation on domestically consumed international fish leads to only a \$2–\$5 million increase in benefits.

4.2 Mercury emissions pathway: emissions to deposition

An annual reduction in U.S. mercury emissions leads to a less than proportionate reduction of mercury deposited in the U.S. The reduction is not one-to-one because most U.S. mercury emissions are not deposited within the U.S., and U.S. deposition also stems from other sources.[41] Figure 4 shows estimates of existing U.S. mercury deposition.[42] For most of the country, over 60% of the deposition comes from other countries, showing that a significant amount of mercury is transported across national boundaries.

While there is a limited understanding of the transport of both types of mercury, the EPA's Mercury Report to Congress[43] on the mercury emissions from all domestic sources estimates that approximately 34% of domestic mercury emissions are deposited locally.[44] The other 66% contributes to the global pool of (elemental) mercury. In the same report, the EPA estimates that approximately 80 tons of mercury are deposited annually within the U.S. Thus, reducing all 48 tons of mercury emissions from U.S. power plants will result in a reduc-

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[41] Power plants emit only inorganic forms of mercury, both in a soluble divalent (ionic) form and in an insoluble elemental form. The elemental form, because it is insoluble, tends not to be deposited locally.

[42] Source: Vijayaraghavan et al. (2004).

[43] See EPA (1997).

[44] This means the mercury deposits somewhere in the continental United States, including parts of the ocean near the coastline and parts of the Gulf of Mexico. See EPA (1997), Fig. 3-3, for a depiction of the area covered.

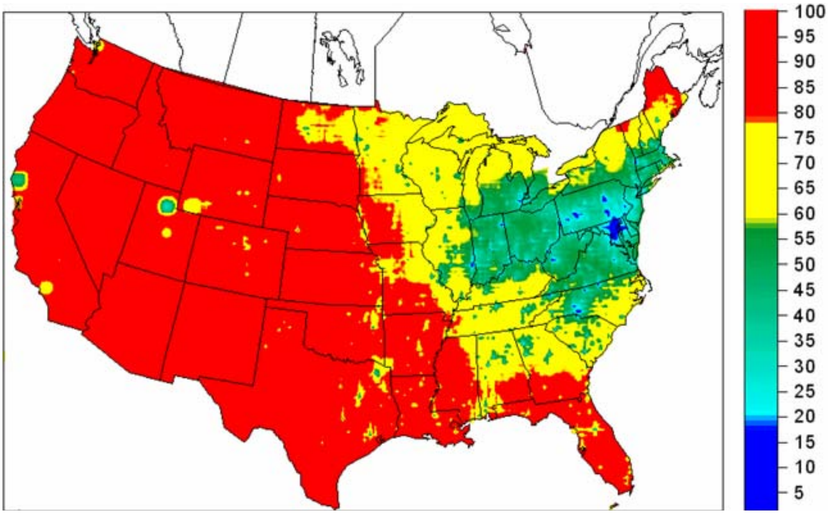

Fig. 4 Contribution of sources other than U.S. anthropogenic sources to mercury deposition *Notes.* See Vijayaraghavan et al. (2004)

tion of 16 tons of mercury emissions, which is a 20% reduction in U.S. annual deposition.[45]

4.3 Mercury emissions pathway: deposition to methylmercury in U.S. fish

Mercury deposition is converted by bacteria into methylmercury, which is believed to be toxic to humans because it is relatively easily absorbed into the blood through fish consumption (EPA, 2004). Methylmercury exposure through fish consumption is the main route of exposure.[46] Methylation occurs through biological processes and the methylmercury then can accumulate in fish tissue. Fish at the top of the food chain, such as bass and swordfish, therefore tend to have higher methylmercury concentrations in their tissues. However, the methylation process depends on many factors, including water chemistry, oxygen conditions, acidity, and water circulation. Deposition directly to a water body or into a watershed is only one component of mercury addition, further modified by methylation of the oxidized component of that deposition. This explains why there is no clear scientific evidence of a correlation between mercury deposition in a given location and resulting methylmercury in fish tissues within

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[45] This 20% is computed as the total reduction in U.S. emissions (48 tons) multiplied by the percent of emissions deposited locally (34%), divided by the total U.S. deposition (80 tons). The 20% estimate is likely a high-end estimate. A recent study by Seigneur, Vijayaraghavan, Lohman, Karamchandani, and Scott (2004) suggests that reducing all 48 tons of mercury emissions from U.S. power plants will result in an 8.6% reduction in U.S. annual depositions (see Schwartz, 2004).

[46] See Mahaffey, Clickner, and Bodurow (2004).

the corresponding watershed(s), with some studies finding no correlation, some finding a positive correlation, and one even finding a negative correlation.[47]

The EPA's Mercury Study Report to Congress[48] stated, "Because of the current scientific understanding of the environmental fate and transport of [mercury], it is not possible to quantify the contribution of U.S. anthropogenic emissions relative to other sources of mercury. . .on methylmercury levels in seafood consumed by the U.S. population." There is, thus, great uncertainty about the relationship between mercury deposition and the level of methylmercury in fish.

For our assessment, we assume a proportionate change in methylmercury in fish resulting from the change in mercury deposition.[49] That is, given that we assume that eliminating mercury emissions of U.S. power plants will reduce total deposition in the U.S. by 20%, we likewise assume that this will reduce methylmercury in U.S. fish by 20%. We assume this relationship holds for both freshwater and marine fish in U.S. waters.[50]

4.4 Mercury emissions pathway: methylmercury in U.S. fish to methylmercury in U.S. women of child-bearing age

In order to estimate the effect of methylmercury levels in fish on blood mercury levels, we assume that blood mercury levels in women of child-bearing age are entirely a function of fish consumption. Using 1999–2001 data on the amount of fish caught in the U.S., imported into the U.S., and exported out of the U.S., we compute the average annual proportion of fish (by tons of each fish commodity) consumed in the U.S. that was caught in U.S. waters.[51] This includes freshwater fish and marine fish, both commercially and recreationally caught. That is, for each type of fish eaten within the U.S., we estimate the average annual proportion that was caught within U.S. waters and would thus be affected by the proposed regulation. We link these data with FDA estimates of the mean concentration of mercury in each type of fish.[52] We then compute the amount of mercury people in the U.S. consume from U.S.-caught fish as a

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[47] See Miller et al. (1972), Carrington, Cramer, and Bolger (1997), Lutter (2000), Hrabik and Watras (2002).

[48] See EPA (1997).

[49] Hrabik and Watras (2002) found that a 10% reduction in annual mercury deposition led to a 5% reduction in fish mercury. The authors note that "they know of no other ecosystem where such a rapid response has been observed, with the possible exception of some highly contaminated sites following remediation."

[50] We also assume that the change in deposition leads to an immediate change in methylmercury in fish tissue. This is a very conservative assumption, because according to EPA, "the lag period changes in fish tissue (and hence changes in IQ) can range from less than 5 years to more than 50 years, with an average time span of one to three decades" (EPA 2005, p. 184).

[51] Our definition of fish caught in U.S. waters includes all U.S.-landed fish. This includes freshwater fish, recreational fish, and marine fish in U.S. waters. The data are from the National Marine Fisheries (see http://www.st.nmfs.gov/st1/trade/).

[52] The FDA data are available at http://www.cfsan.fda.gov/~frf/sea-mehg.html

proportion of the amount of mercury people in the U.S. consume from all fish. We aggregate across all fish commodities and find that 46% of U.S. mercury ingestion comes from fish caught within U.S. waters. We further assume that this estimate for the U.S. population holds for women of child-bearing age.[53] Thus, a reduction in methylmercury in U.S. fish leads to an associated 46% reduction of methylmercury blood levels in U.S. women of child-bearing age.

4.5 Mercury emissions pathway: from methylmercury in U.S. women of child-bearing age to toxicity

Perhaps the most difficult assessment is to estimate the dose–response relationship between mercury exposure and children's cognitive skills. The three main epidemiological studies on this relationship examine populations in the Republic of the Seychelles,[54] the Faroe Islands in the North Sea,[55] and New Zealand.[56] These populations all have diets that rely heavily on fish consumption, and thus have much higher mercury exposure than in the U.S. Because we are interested in measuring the impact of mercury exposure on children's IQ, we focus on the endpoint of the Wechsler Intelligence Scale for Children full-scale IQ.[57] Both the Seychelles and New Zealand studies used this measure as an endpoint; however, the Faroe Islands relied on three sub-tests of the Wechsler scale, which allows one to infer the full-scale IQ effects.[58]

Table 5 shows the linear coefficient estimates (of the relationship between mercury in either maternal hair or cord blood and various scores) for the three studies. The Seychelles study finds that a unit (1 ppm) increase in maternal hair mercury levels is associated with a 0.13 point decline in the Wechsler score. This relationship is not statistically different from zero. The New Zealand study (after dropping the one child with high mercury levels but test scores within the normal range and after controlling for education and age of the

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[53] This might be a conservative assumption, because Oken et al. (2003) found evidence that pregnant women reduced their consumption of fish as a response to the EPA's fish advisory.

[54] See Myers et al. (2003).

[55] See Grandjean et al. (1997) and Budtz-Jorgensen, Debes, Weihe, and Grandjean (2004). One potential concern with the Faroe Islands study is that this population was exposed to high levels of polychlorinated biphenyls (PCBs) via pilot whale meat. The study could not completely control for PCB exposure because only half of the newborns were tested for PCBs, and cord-tissue PCB concentrations are not known to be reliable indicators of PCB blood levels.

[56] See Kjellstrom et al. (1989) and Crump, Kjellstrom, Shipp, Silvers, and Stewart (1998).

[57] Below, we refer to this IQ measure as the Wechsler score.

[58] Also, while the Faroe Islands study uses cord-blood mercury levels as their primary exposure measure, the Seychelles and New Zealand studies use maternal hair mercury measures. According to Grandjean et al. (1997), 1 ppm of mercury in maternal hair is roughly equal to 5 ppb of mercury in cord blood. For our benefit estimates, we adjust the coefficient estimates accordingly. We also present standardized coefficient estimates, which are unaffected by the conversion between the maternal hair and cord blood measures. Finally, because we assume a linear relationship between methylmercury exposure and IQ scores in order to compute the IQ effects, we rely on the linear estimates of the Faroe Island study computed in Budtz-Jorgensen et al. (2004).

Table 5 Estimated linear and standardized coefficients of relationship between mercury and IQ

Study sample	Mercury measure	Outcome measure	Linear coefficient estimate
Seychelles	Maternal hair	WISC full scale IQ	−0.13 (0.10)
New Zealand	Maternal hair	WISC full scale IQ	−0.42 (0.31)
Faroe Islands	Cord blood	WISC digit spans	−0.0025 (0.0018)
Faroe Islands	Cord blood	WISC similarities	−0.0039 (0.0050)
Faroe Islands	Cord blood	WISC block designs	−0.0175 (0.0098)

Notes: WISC refers to Wechsler Intelligence Scale for Children. For Seychelles results see Myers et al. (2003), for New Zealand results see Kjellstrom et al. (1989) and Crump et al. (1998), and for Faroe Islands results see Grandjean et al. (1997) and Budtz-Jorgensen et al. (2004). Standard errors are in parentheses

child) finds that a unit increase in maternal hair mercury levels is associated with a 0.42 point decline in the Wechsler score. This relationship is also not statistically different from zero. Finally, for the three Wechsler scale outcome variables used in the Faroe Islands study—Digit Spans, Similarities, and Block Designs—the authors find that a unit increase in cord blood mercury levels is associated with a 0.0025, 0.0039, and 0.0175 decline in the three test scores, respectively. Of these three coefficient estimates, none are significantly different from zero at the 5% level, yet the Block Designs coefficient is statistically significant at the 10% level. While most of the estimated coefficients in Table 5 are not statistically significant, they all have the expected sign. We adopt the approach implicit in NRC (2000) of relying on point estimates with large standard errors, even though they are not within conventional ranges of statistical significance.

4.6 Monetizing benefits

As discussed earlier, the latest Center for Disease Control study on mercury found that the geometric mean of blood mercury levels for 2001–2002 was 0.83 ppb (95% confidence interval = 0.73–0.93). Using the data from 1999 to 2002 of pregnant women, we fit a log normal curve through the percentile distribution in order to estimate an arithmetic mean of blood mercury concentrations. We find that the mean blood mercury concentration for pregnant women is approximately 1.4 ppb (with a standard deviation of approximately 2.4). Using this estimate, and given the assumptions on exposure, we estimate that a complete elimination of U.S. power plant emissions (48 tons) would result in a decrease in mean maternal blood mercury levels of 0.13 ppb.[59]

Our focus, nonetheless, is on estimating the change in methylmercury levels for developing fetuses. There is some evidence that the ratio of methylmercury levels in fetal cord blood to methylmercury levels in maternal blood is greater than one. The NRC report concludes that the central tendency for

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[59] This estimate derives from the product of each parameter estimate in the benefit pathway; i.e., $0.13 = 0.20 \times 0.46 \times 1.4$.

this ratio is 1.2–1.3.[60] The EPA[61] estimated a ratio of 1.7. A recent study by Stern and Smith (2003) also recommends an estimate of 1.7. Using the 1.7 estimate, we therefore estimate that eliminating U.S. power plant mercury emissions would result in a decrease in mean fetal cord blood mercury levels of 0.22 ppb (0.13 × 1.7). By linking this with the estimates in Table 5 (and by assuming a conversion factor of 5 ppb of cord blood per 1 ppm of hair[62]), we find that the reduction of 0.22 ppb in fetal cord blood mercury levels leads to an increase in Wechsler scores of 0.00572 for the Seychelles study and an increase in Wechsler scores of 0.01848 for the New Zealand study. For the Faroe Islands study, we convert the increases in each of the listed sub-tests into an increase in Wechsler scores.[63] We find a Wechsler score increase of 0.01156. Averaging the three expected score increases yields an expected increase of 0.012 points given a complete elimination of mercury emissions from U.S. power plants.

In order to monetize the benefits of this increase in IQ stemming from the mercury reduction, we rely on estimates by Agee and Crocker (1996), in which they examine parental decisions in purchasing chelation therapy for their children. Chelation therapy reduces the lead in children's bodies. Lutter (2000) then links this estimate of the willingness to pay for lead reduction in children to an estimate of the relationship between lead and IQ scores. He finds that parental choices on chelation therapy suggest a willingness to pay between $1,295 and $2,236 per IQ point for their children (updated to 2004 dollars).

Above we estimated that there is a 0.012 point expected increase in the Wechsler score given the *complete* elimination of the 48 tons of annual mercury emissions from U.S. utilities. In order to monetize the benefits of the proposed regulations, we multiply this estimate by the proportional decrease in annual emissions. We then multiply by the expected number of newborns each year in the U.S. to get the annual increase in IQ points from the proposed regulations from 2005 through 2020.[64] Using the low-end estimate of $1,295 per IQ point, we find the estimated total benefits of the MACT proposal is $82 million using a 3% discount rate, $70 million using a 5% discount rate, and $63 million using a 7% discount rate. For the cap-and-trade rule, the estimated total benefits are $86 million, $68 million, and $58 million using a 3%, 5%, and 7% discount rate, respectively. Using the high-end estimate of $2,236 per IQ point, we find the estimated total benefits of the MACT proposal is $142 million using a 3% discount rate, $120 million using a 5% discount rate, and $109 million using a 7% discount rate. For the cap-and-trade rule, the estimated total benefits are

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[60] See NRC (2000).

[61] See EPA (2001, 2003).

[62] See Grandjean et al. (1997).

[63] See Sattler (1988) and Tellegen and Briggs (1967).

[64] Estimates of future births come from U.S. Census, National Population Projections: Summary Files, "Components of Change for the Total Resident Population: Middle Series, 1999 to 2100 (NP-T6-A)."

$149 million, $118 million, and $100 million using a 3%, 5%, and 7% discount rate, respectively.[65]

Our estimates can be subjected to a sensitivity analysis. As mentioned previously, if we consider the reduction in U.S. mercury consumption stemming from the reduced contribution of U.S. emissions to global deposition, then the regulation will include an additional $2–$5 million in benefits. If we estimate benefits using the 95th upper confidence interval of the toxicity point estimates, the benefits increase by a factor of 2.5.

Perhaps the one assumption that we should be most cautious about is our estimate of the value of an IQ point. We rely on Lutter (2000) and Agee and Crocker (1996) because they derive the only willingness-to-pay estimate, which is an appropriate measure to use for estimating benefits. However, there are some potential problems with using chelation therapy in order to infer the value of an IQ point. First, chelation therapy is inconvenient and by some accounts painful, which would lead to an underestimate of willingness to pay for IQ increases. Second, the magnitude of the long-term effect of chelation therapy on IQ is unclear. What matters for the willingness-to-pay measure is parental perceptions of this effect. This last point is essential, as there is mixed evidence of the effectiveness of chelation therapy. Presumably, parents must believe it has at least limited effectiveness, or else the implied willingness-to-pay estimate would be zero. If parents think it is more effective than it really is, then the implied willingness-to-pay would be an underestimate. If they think it is less effective than it really is, then the implied willingness-to-pay would be an overestimate.

Our assumption for the values of an IQ point of $1,295 to $2,236 does, however, seem consistent with the estimates in the literature of the effect of IQ on earnings.[66] Admittedly, there is no clear consensus on the impact of IQ on earnings. Some studies (such as Bound, Griliches, & Hall, 1986) claim that there is no significant impact of IQ on earnings. Others, such as Zax and Rees (2002) estimate that a one standard deviation increase in IQ score leads to a 5.85% increase in earnings. Given the estimates of lifetime earnings used by

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[65] These benefits are derived using Model 2. Although not reported in the tables, we also computed the total discounted benefits for both rules using Model 1's forecasts of emissions. We find virtually identical results for the MACT scenario, but due to the binding safety valve assumed in Model 1 (which no longer applies), this model estimates lower benefits from the cap-and-trade rule. EPA presents benefits for the cap-and-trade rule that are about one order of magnitude smaller than those presented here even though EPA uses a value for IQ points that is more than four times higher than the value we use. Accounting for part of this difference is the slope of our linear IQ dose–response curve, which is more than double EPA's slope in absolute value. Additionally, EPA assumes that benefits will not occur until 5–50 years in the future. If we were to assume a time lag of 25 years and EPA's assumptions regarding the IQ dose–response curve and the value of an IQ point, our benefits would decrease by about half. The remaining discrepancy between EPA's benefits and our benefits is primarily the result of our conservative assumption that all fish from boats coming to U.S. ports, including freshwater and marine fish, are affected the same by reductions in mercury emissions from U.S. coal-fired power plants. EPA assumes that only freshwater, recreational fish are significantly affected by the cap-and-trade rule because the relationship between mercury deposition in oceans and methylmercury concentrations in marine fish is uncertain and U.S. coal-fired power plants account for a lower percentage of mercury deposition in the ocean.

[66] All estimates of the value of an IQ point are presented in 2004 dollars.

Trasande, Landrigan, and Schechter (2005), this would mean an increase of approximately $3,300 for girls and $4,400 for boys per IQ point. Cameron and Heckman (1993) estimate that a standard deviation increase in IQ score leads to a 7%–10% increase in earnings. This translates into a gain of approximately $5,300 to $7,500 for boys and a gain of approximately $3,900 to $5,600 for girls. On the high end, a study by Neal and Johnson (1996) finds a 17% increase given a standard deviation increase in IQ. This translates into a gain of approximately $13,700 for boys and $9,500 for girls. Thus, the estimates of lost earnings due to an IQ decrement range from 0 to $13,700 for boys and from 0 to $9,500 for girls. Using the high-end value of an IQ point from Neal and Johnson (1996) increases our benefit estimates by a factor of approximately 5.2, which is not enough for the benefits of either regulation to outweigh the estimated costs.

We acknowledge that there are many uncertainties in our estimates of costs and benefits. We should note that EPA's benefit estimate of the cap-and-trade rule is about one order of magnitude smaller than our estimate. The only way we think our conclusions would change dramatically would be if there were *substantial* benefits that could result from reducing mercury that we have not quantified.

One such potential benefit is the reduced risk of cardiovascular health in adults due to a reduction in mercury exposure. We believe that the link between methylmercury and cardiovascular health is not strong enough to warrant inclusion in the benefits analysis, especially given two recent studies that find no association between mercury exposure and coronary heart disease.[67] In their proposed rule, the EPA agreed with this assessment, stating that "it has been hypothesized that there is an association between methylmercury exposure and an increased risk of coronary disease in adults; however, this hypothesis warrants further study as the few studies currently available present conflicting results."[68] In EPA's Regulatory Impact Analysis of the final rule, they conclude that "[s]tudies investigating the relationship between methylmercury and cardiovascular impacts have reached different conclusions. The findings to date and the plausible biological mechanisms warrant additional research in this arena."[69]

NESCAUM (2005), however, does estimate the benefits from reduced myocardial infarctions.[70] However, they base this health effect on only one study

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[67] See Hallgren, Hallmans, and Jansson (2001) and Yoshizawa, Rimm, and Morris (2002).

[68] See Fed. Reg. 69:20, p. 4658.

[69] See EPA (2005).

[70] Even if we include the NESCAUM (2005) estimated benefits of reduced myocardial infarctions for males, the net benefits of the mercury MACT regulation are still negative. NESCAUM (2005) finds that net benefits are positive when including these benefits, but this is because they assume a baseline scenario in which there was no new rule for sulfur dioxide and nitrogen oxides. Given that this rule is already in place and will lead to reductions in mercury emissions, an assessment of the mercury rule should account for these reductions in the baseline. If we accept all of NESCAUM's (2005) bounding assumptions and include their estimated benefits of reduced myocardial infarctions for males and females, then the net benefits of the cap-and-trade regulation do indeed become positive. However, NESCAUM (2005) conducts a separate analysis assuming only cardiovascular benefits to males, since "only one study evaluated cardiovascular disease and mercury exposure in women (Ahlqwist, Bengtsson, Lapidus, Bergdahl, & Shutz, 1999) and this study did not report

(Salonen et al., 1995) and acknowledge that "the epidemiologic studies showing an association between methylmercury exposures and cardiovascular effects are comprised of a relatively small number of subjects..." (p. 47) and that "the predicted myocardial risks ... should be interpreted with caution. Most of the evidence of such risks is based on observations from a single cohort. Additionally, a great deal of evidence indicates that fish consumption in general protects individuals from incurring adverse cardiac events" (p. 69).[71]

Some critics of the administration's mercury proposals argue for reducing annual power plant emissions to 5 tons.[72] We did not examine this proposal because there is no reliable modeling information on its costs. However, given that it is likely that the costs of removing mercury increase more than proportionately for greater reductions, while the benefits increase roughly proportionately, any alternative plan to further reduce mercury would likely impose greater net costs than the ones already proposed.

One issue that some proponents of regulation have raised is that mercury regulation could also result in benefits from reductions in particulate matter. While some of the technologies used to reduce mercury could also reduce particulate matter, this is not likely to have an impact on the overall level of particulate matter.[73] The reason is that current regulations already impose caps on sulfur dioxides and nitrogen oxides, which are the primary pollutants that affect the level of particulate matter. Thus, mercury regulation is not likely to have any significant independent impact on the overall level of particulate matter, and is an expensive way to achieve them.

This step-by-step analysis of the benefits of mercury reduction demonstrates that there are likely to be relatively small health improvements stemming from reductions of mercury emissions from domestic utilities. This is because the path linking domestic utility emissions to impacts on human health is tenuous, long, complex, and highly uncertain.

5 Conclusion

We can combine the previous analysis of costs and benefits to obtain a measure of net benefits. Table 6 summarizes the information on benefits and costs, and

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Footnote 70 continued
a statistically significant association" (p. 47). Using only the estimated cardiovascular benefits to males, the MACT and the cap-and-trade regulation both have negative net benefits in our model.

[71] NESCAUM (2005) acknowledges that their estimated benefits of reduced myocardial infarctions are based on the assumption that the Salonen et al. (1995) sample of Finnish men "can be externally generalized to the U.S. population despite differences between these populations and the types of fish consumed" (p. 92). In their computation of lost life years, NESCAUM (2005) also assumes that the age of death coincides with the average age of the first myocardial infarct, which they acknowledge is "extremely uncertain and conducted as a bounding exercise" (p. 95). See Stern and Smith (2003) and Lutter and Irwin (2002) for critiques of the Salonen et al. (1995) study.

[72] See Clean Power Act S.150 (2005).

[73] The analysis used to justify the EPA's proposal discusses particulate matter benefits. See Schwartz (2004) for a discussion of the relationship between particulate matter reduction and the mercury rule.

Table 6 Present value of net benefits using Model 2 (billions of 2004 dollars)

Discount rate (%)	MACT Benefits	Cost	Net benefits	Cap and trade Benefits	Cost	Net benefits
3	\$0.08–\$0.14	\$20.7	(\$20.62) – (\$20.56)	\$0.09–\$0.15	\$5.5	(\$5.41) – (\$5.35)
5	\$0.07–\$0.12	\$17.8	(\$17.73) – (\$17.68)	\$0.07–\$0.12	\$4.3	(\$4.23) – (\$4.18)
7	\$0.06–\$0.11	\$15.4	(\$15.34) – (\$15.29)	\$0.06–\$0.10	\$3.4	(\$3.34) – (\$3.3)

Notes: Computed from Charles River Associates estimates of costs and emissions. Parentheses indicate negative values. Net benefits equal benefits minus costs. Parenthetical values indicate negative numbers

shows the net benefits of the two different policy options using different discount rates. No matter which of the three discount rates is used, the net benefits of both proposed regulations are far below zero. Indeed, costs are larger than benefits by well over two orders of magnitude for the MACT proposal and well over one order of magnitude for the cap and trade proposal. Net present value costs of the cap-and-trade proposal are around \$3–\$5 billion dollars. The net present value costs of the MACT proposal are about \$15–\$21 billion dollars.

Although neither proposal yields positive net benefits, the gap between costs and benefits is lower for the cap-and-trade proposal. One concern about the cap-and-trade approach is that it will result in *hot spots*, which are localized concentrations of emissions stemming from plants in a small area garnering a substantial number of permits to pollute. With respect to the mercury risk pathway, a hot spot would be an identifiable peak in mercury deposition into a water body that has consumable fish. This is not likely to be a concern with the mercury cap-and-trade approach for three reasons. First, as previously discussed, most mercury emissions are not deposited locally, so a local spike in emissions may not result in a localized hot spot. Second, even if emissions did not disperse, hot spots would only present a health risk if the deposition affected a local stock of fish that are caught and consumed. Third, model estimates by the Electric Power Research Institute indicate that neither the cap-and-trade approach nor the MACT approach will lead to hot spots. They also find that the cap-and-trade approach is less likely to lead to hot spots than the MACT proposal because the former requires larger cuts in emissions.[74] Finally, given the minimal benefits of mercury reduction, it is highly unlikely that the issue of hot spots would warrant taking on the greater costs of the MACT proposal.

The bottom line is that the regulation of utility emissions does not appear to be worth the costs. Given the uncertain nature of many of the assumptions that go into the cost-benefit analysis, there is room to debate this conclusion. As more evidence is brought forth on the exposure and toxicity of mercury stemming from power plants, the assessment of benefits and costs can change. But given the current state of understanding, our findings suggest that the cost of regulating power plant emissions of mercury is not justified by the benefits.

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[74] See EPRI (2004, 2005).

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