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DISCUSSION PAPER

Reducing Emissions from the Electricity Sector

The Costs and Benefits Nationwide and for the Empire State

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EXECUTIVE SUMMARY

Recent federal policy proposals to reduce emissions of SO_2, NO_x, and mercury from the electricity sector promise important improvements in air quality and reductions in acid deposition in New York State and across the nation. The cost of achieving these reductions depends on the form and stringency of the regulation. In particular, the fact that technologies designed to reduce SO_2 and NO_x can reduce mercury emissions as well has important implications for how producers respond to different types of mercury regulation and for the cost of multipollutant policies aimed at all three pollutants.

Using four models, this study looks at EPA's Clean Air Interstate Rule (CAIR) as originally proposed, which differs in only small ways from the final rule issued in March 2005, coupled with several approaches to reducing emissions of mercury including one that differs in only small ways from the final rule also issued in March 2005. This study analyzes what costs and benefits each would incur to New York State and to the nation at large.

EPA has taken steps toward requiring greater reductions in emissions of SO_2 and NO_x than mandated under current law from electricity generators. To facilitate compliance with the 8-hour ozone standard and with new air quality standards for fine particulates with a size of 2.5 micrometers in diameter and smaller ($PM_{2.5}$) and to meet statutory requirements for reducing emissions of hazardous air pollutants such as mercury, the EPA adopted two new rules early in 2005 that together address SO_2, NO_x, and mercury emissions from the electricity sector. In its Clean Air Interstate Rule, or CAIR, EPA caps emissions of SO_2 and/or NO_x in a large region covering more than 20 states, mostly east of the Mississippi, and the District of Columbia.

Summary of Main Findings

Benefits to the nation and to New York State significantly outweigh the costs associated with reductions in SO_2, NO_x and mercury, and all policies show dramatic net benefits.

The manner in which mercury emissions are regulated will have important implications not only for the cost of the regulation, but also for emission levels for SO_2 and NO_x and where those emissions are located.

Contrary to EPA's findings, CAIR as originally proposed by itself would not keep summer emissions of NO_x from electricity generators in the SIP region below the current SIP seasonal NO_x cap. In the final CAIR, EPA added a seasonal NO_x cap to address seasonal ozone problems. The CAIR with the seasonal NO_x cap produces higher net benefits.

The effect of the different policies on the mix of fuels used to supply electricity is fairly modest under scenarios similar to the EPA's final rules.

A maximum achievable control technology (MACT) approach, compared to a trading approach as the way to achieve tighter mercury targets (beyond EPA's proposal), would preserve the role of coal in electricity generation.

Our evaluation of scenarios with tighter mercury emission controls shows that the net benefits of a maximum achievable control technology (MACT) approach exceed the net benefits of a cap and trade approach.

This regulation allows for emissions trading, and restrictions are imposed in two phases with the first beginning in 2010 and the second beginning in 2015. In the first phase, the program allocates 3.7 million tons of SO_2 allowances and 1.6 million tons of NO_x allowances to electricity generators within 25 states and the District of Columbia. In 2015, the total allocations for annual emissions drop to 2.6 million tons for SO_2 and 1.3 million tons for NO_x. Actual emissions are expected to exceed these targets for some years beyond 2015 due to the opportunity to bank emission allowances distributed in earlier years for use in later years. The percent reductions in emissions within the CAIR region are comparable to those that would be required nationwide under the Clear Skies Initiative, except they happen on a somewhat accelerated schedule. The regulation also institutes a cap on seasonal summertime emissions of NO_x in a region with a slightly different boundary.

In the second new rule, EPA adopts a national plan to reduce emissions of mercury from electricity generators using a cap-and-trade approach applied to all coal-fired generating units in the nation. The rule distributes allowances for 38 tons of emissions from all coal and oil-fired electricity generators beginning in 2010 and 15 tons beginning in 2018. The rule allows for emission banking. According to the EPA actual emissions are expected to exceed 15 tons for many years beyond 2015 due to the role of banking. In the final rule, the cap-and-trade approach to reducing mercury was selected over a maximum achievable control technology (MACT) approach, which was also included as an option for consideration in the proposed rule.

We analyze four different multipollutant policy scenarios that coincide with recent proposals. All of these scenarios include EPA's Clean Air Interstate Rule for SO_2 and NO_x in its original proposed form in combination with different approaches to reducing mercury emissions from electricity generators nationwide.

1. **CAIR plus EPA Mercury Cap**: The Clean Air Interstate Rule (CAIR) as originally proposed coupled with a companion national mercury cap, based on EPA's mercury cap in the proposed and final mercury rule, with unrestricted trading of mercury emission allowances. Under this scenario, the seasonal cap-and-trade program for NO_x for electricity generating units in the State Implementation Plan (SIP) seasonal NO_x trading program is no longer in effect. In all of the CAIR and national allowance trading programs, allowances are distributed initially based on historic emissions.

2. **CAIR plus EPA Mercury and Seasonal SIP NO_x Policy**: This scenario combines scenario 1 with the continuation of the seasonal cap-and-trade program for NO_x emissions from electricity generating units in the NO_x SIP Call region. Although the originally proposed CAIR rule would have suspended the current seasonal NO_x policy, in the final rule a seasonal program is reconstituted.

3. **CAIR plus Tighter Mercury with MACT**: This scenario includes the CAIR as represented in scenario 1 coupled with a national requirement that all coal-fired generators achieve either

a 90% reduction in mercury emissions or a target emission rate of 0.6 lbs of mercury per trillion Btu of heat input, whichever is less expensive at the particular facility.

4. **CAIR plus Tighter Mercury with Trading**: This scenario models the CAIR coupled with a national cap-and-trade program for mercury where the national annual emission cap for mercury in each year is set at the mercury emission level realized under the version of the Tighter Mercury with MACT rule modeled in scenario 3.

Our analysis shows that benefits to the nation and to New York State significantly outweigh the costs associated with reductions in SO_2, NO_x, and mercury, even under cautious assumptions about the valuation of the expected health effects. Depending on the policy, between 10 and 13% of the total national health benefits associated with reduced emissions of SO_2 and NO_x occurs in New York State, a function of the state's population and its location downwind of major emission sources. This estimate is based on a calculation of expected improvements in human health resulting from changes in particulate matter and ozone concentrations, which are thought to capture the most important benefits. We find the health benefits of reducing particulate matter are nearly two orders of magnitude greater than the health benefits of reducing ozone. Several benefit categories including visibility effects, reduced acidification and other ecological improvements and the effects of mercury on human health and the environment would increase the calculated net benefits even further. The magnitude of benefits for ecological improvement in the Adirondack Park and for reduction of mercury emissions, based on recent unpublished estimates, is discussed in the analysis.

We find that, with one exception, the set of policies will have fairly small impacts on the average price of electricity nationwide and in New York. However, the manner in which mercury emissions are regulated will have important implications not only for the cost of the regulation, but also for emission levels for SO_2 and NO_x and where those emissions are located.

Our research also shows that contrary to EPA's findings, the CAIR rule, as originally proposed, by itself would not keep summer emissions of NO_x from electricity generators in the SIP region below the current SIP seasonal NO_x cap. As a result, average summertime 8-hour and 24-hour ozone concentrations in New York and elsewhere are higher under the originally proposed version of the CAIR policy than under the baseline. The remedy to this could include either tighter annual caps or continuation of seasonal controls. We find combining a continuation of the SIP seasonal NO_x cap with the CAIR plus EPA Mercury scenario corrects this situation and does so at relatively low cost to firms and virtually no cost to electricity consumers nationwide. In the final version of the CAIR rule, EPA reconstitutes a seasonal cap-and-trade program for NO_x in a subset of the region to address this concern.

As an alternative to the EPA schedule of caps, we model a more stringent set of mercury policies that lead to about 67% further reductions in mercury emissions. An important environmental effect of the tighter mercury cap is that it brings about substantial ancillary reductions in emissions of SO_2. Under Tighter Mercury with Trading, the SO_2 cap is no longer binding by 2010 as generators rely more on installation of flue gas desulfurization (FGD) units (known as SO_2 scrubbers) to reduce mercury and less on activated carbon injection (ACI).

Despite showing positive and significant net benefits, we hasten to add two important qualifications that preclude an endorsement of the CAIR policy coupled with EPA Mercury Cap and the continuation of the NO_x SIP Call - the policy that comes closest to the one embodied in the EPA's final CAIR and mercury rules. First, this calculation does not include benefits from mercury reductions, which would increase the benefit estimates of the tighter mercury standard. In a discussion of potential benefits we draw on recent research by Rice and Hammitt (2005) on the benefits of mercury emissions reductions associated with the Clear Skies Initiative to infer estimates of potential benefits of different levels of mercury control. This information suggests that inclusion of benefits from the tighter mercury standard would reduce the gap in net benefits between the Tighter Mercury policies and the policies with the EPA Mercury Cap. Second, our study indicates the benefits of additional tons of SO_2 reduction beyond the CAIR rule far exceed the costs. We do not investigate alternative levels of SO_2 control.

We provide an uncertainty analysis that varies the most important parameters in our estimations—the atmospheric model and value of a statistical life—and that includes somewhat more speculative estimates of the human health benefits of reduced mercury emissions and a partial analysis of ecological benefits. For the Low values in the uncertainty analysis, the CAIR policy coupled with EPA Mercury Cap and the continuation of the NO_x SIP Call remains the policy with the greatest net benefits. However, under the High value cases, although all policies show dramatic net benefits, the policies with the Tighter Mercury standard have the greatest net benefits.

The effect of the different policies on the mix of fuels used to supply electricity is also fairly modest. The scenarios that combine CAIR with the EPA Mercury Cap see a significant switch among types of coal, accounting for about 45% of the reduction in SO_2 emissions, but there is only a slight switch away from coal to natural gas, which accounts for just 4% of the reduction in SO_2 emissions. The switch from coal to natural gas tends to be much larger under the Tighter Mercury with Trading Policy, and this switch accounts for roughly 19% of the reduction in mercury relative to the baseline. The policy also produces large ancillary reductions in emissions of CO_2, which fall by 11% of baseline levels nationally and 26% in New York State in 2020. Since it is often stated by the current federal administration that it is not the purpose of environmental regulation to force fuel switching away from coal, then a maximum achievable control technology (MACT) approach may be preferred to a trading approach as the way to achieve tight mercury targets (beyond the cap in EPA's mercury rule) because it preserves the role of coal in electricity generation.

A key factor in the design of environmental policy is the incidence of burden, which varies for consumers and for producers depending on whether a trading approach is used. Consumers bear all of the cost of EPA's proposed policies in 2010. In New York, producers benefit from the policies. By 2020, nationwide we find the burden is shared fairly equally between consumers and producers. In 2020 the cost in New

York State is very small, due in part to the implementation of New York's multipollutant rule that is included in the baseline.

Replacing the EPA mercury rule with the tighter mercury standards yields additional costs for both consumers and producers in 2010, when consumers bear an additional cost of about $1.3 billion nationwide and producers bear an additional cost of $2.2 billion. In 2020 the additional cost of the Tighter Mercury with MACT policy falls entirely on consumers, who bear an additional cost of $2.8 billion, while producers bear no additional cost. Overall, consumers bear over 75% of the cost of the Tighter Mercury with MACT policy in 2010 and over 70% in 2020. There is no additional cost of the tighter mercury standard using a MACT approach in New York State in 2010 or 2020.

Implementing tighter mercury standards using a trading approach imposes significantly more cost on the electricity sector than using a MACT standard to achieve the same emission target due to the internalization of the opportunity cost of mercury emissions allowance prices and the corresponding change in resources use including fuel switching to natural gas. Consumers bear the entire burden from tight mercury controls with trading. In the aggregate producers actually benefit substantially due to higher electricity prices, but the effect on individual firms is likely to vary greatly, depending on the portfolio of generation assets they operate.

In conclusion, we find that all four policies we investigated which would regulate multiple pollutants from the electricity sector, including policies with the tighter mercury controls, would deliver substantial benefits to residents of New York State and the nation. Contrary to EPA's findings, CAIR as originally proposed by itself would not keep summer emissions of NO_x from electricity generators in the SIP region below the current SIP seasonal NO_x cap. In the final CAIR, EPA added a seasonal NO_x cap to address seasonal ozone problems. The final CAIR with the seasonal NO_x cap produces higher net benefits relative to the originally proposed CAIR. Our modeling indicates that additional SO_2 emissions reductions beyond those called for by the EPA rules would yield benefits that substantially exceed the additional cost. Our evaluation of scenarios with tighter mercury emission controls shows that the net benefits of a maximum achievable control technology (MACT) approach exceed the net benefits of a cap and trade approach. It is important to note that we do not include estimates of the benefits of mercury reductions, which if included, would improve the net benefits of more stringent mercury controls.

REDUCING EMISSIONS FROM THE ELECTRICITY SECTOR: THE COSTS AND BENEFITS NATIONWIDE AND IN THE EMPIRE STATE

Karen Palmer, Dallas Burtraw, and Jhih-Shyang Shih*

Section 1

INTRODUCTION

The electricity sector is a major source of emissions of several air pollutants of concern, including sulfur dioxide (SO_2) which contributes to acid rain and fine particle concentrations in the atmosphere, nitrogen oxides (NO_x) which contribute to both of these pollution problems and to ground-level ozone, mercury, which is a toxic substance linked to neurological and other health problems, and carbon dioxide (CO_2), which contributes to global warming. The electricity sector contributes roughly 68 percent of national emissions of SO_2 emissions, 22 percent of NO_x, 40 percent of mercury, and 40 percent of CO_2.[1] The effects of the emissions of SO_2 and NO_x are particularly strong in the northeast, which is downwind of the large number of coal-fired generators located in the Mid-Atlantic states and the Ohio Valley.

A number of federal legislative proposals have emerged over the past few years that seek a long-term, coordinated approach to pollution control at power plants in the United States. All of these federal bills propose to make important cuts in emissions SO_2 and NO_x, and all rely on tradable permits as the central strategy for achieving the emission reductions in a way that minimizes the cost to society. The proposals differ in the timetable over which these cuts take effect, in the approach advocated for reducing mercury emissions, and in mercury emission reduction targets and whether or not they include CO_2. None of the

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[1] According to the EPA's 1999 National Emissions Inventory.

federal bills has advanced to the floor of either house of Congress, largely because of the lack of consensus among various groups about the appropriate treatment of CO_2. However, several states, including New York and North Carolina, have already adopted policies to reduce emissions of SO_2 and NO_x below levels required by federal law at electricity plants within their borders. New York State has been the leader in a regional initiative to reduce emissions of greenhouse gases (GHG).[2]

Although federal multipollutant legislation has not yet been passed, the current administration has used a regulatory approach to be implemented by the EPA to advance a number of the key elements of its legislative proposal, known as the Clear Skies Initiative. One new regulation, the Clean Air Interstate Rule (CAIR), was promulgated in March 2005 and uses a cap-and-trade approach to reduce annual emissions of SO_2 and/or NO_x in the electricity sector in a region that covers more than 20 states, mostly east of the Mississippi, and the District of Columbia. These states are spelled out in a footnote below.[3] In a second rule also issued in March 2005, the U.S. Environmental Protection Agency's (EPA) established a national plan to reduce emissions of mercury from electricity generators using a cap-and-trade approach.

This research project analyzes how the proposed regulations that led to these new federal rules to reduce emissions of SO_2, NO_x, and mercury from the electricity sector will likely affect air quality and acid deposition and the cost of supplying electricity to New York residents and to electricity consumers across the nation. The research analyzes CAIR coupled with a number of different proposed approaches to reducing mercury emissions from the electricity sector. How mercury emissions are regulated will have important implications not only for the cost of the regulation, but also for emission levels for SO_2, NO_x, and CO_2 and where those emissions take place.

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[2] A number of states have adopted policies to reduce greenhouse gas emissions (GHG) emissions from electricity generators and other sources within their boundaries. The Regional Greenhouse Gas Initiative (RGGI) is an effort by nine northeastern and Mid-Atlantic States to develop a regional, mandatory market-based, cap-and-trade program to reduce greenhouse gas emissions. The effort was initiated formally in April 2003 when New York Governor George Pataki sent letters to fellow governors in the Northeast and Mid-Atlantic states, and each of the nine participating states has assigned staff to a working group that is charged with developing a proposal in the form of a model rule.

[3] The final version of the CAIR rule targets different states for the annual caps on NO_x and SO_2 and for the seasonal caps on NO_x emissions. Twenty-two states—Alabama, Delaware, Florida, Illinois, Indiana, Iowa, Kentucky, Louisiana, Maryland, Michigan, Mississippi, Missouri, New Jersey, New York, North Carolina, Ohio, Pennsylvania, South Carolina, Tennessee, Virginia, West Virginia, and Wisconsin—and the District of Columbia are included in both the annual and seasonal programs. Georgia, Minnesota, and Texas are included in the annual programs only and Arkansas, Connecticut, and Massachusetts are included in the Seasonal NO_x program only. States covered by the annual program have been targeted because they are in danger of failing to comply with new stricter National Ambient Air Quality Standards for fine particulates. States in the seasonal program are at risk of noncompliance with the ozone standard.

This project brings together a suite of models, including RFF's Haiku model of the U.S. electricity sector, an integrated assessment model of air transport and environmental effects, and a state-of-the-art air chemistry model for the eastern United States. These tools are integrated in a sophisticated analysis combining science, economics, and public policy that allows us to assess in a unified framework both the environmental benefits and the economic costs of a host of different regulatory proposals.

The report is organized as follows. Section 2 summarizes the multipollutant policy debate. Section 3 provides an overview of the modeling platform, followed in Section 4 by a description of the scenarios we investigate. The results of the policy alternatives on electricity generation, fuel choice, emissions, electricity price and other measures of social cost are presented in Section 5. The environmental public health benefits associated with reductions in ozone and fine particulate pollution are presented in Section 6, followed by a conclusion in Section 7.

Section 2

THE MULTIPOLLUTANT POLICY DEBATE

By some measures, the electricity sector is a story of successful air pollution policy and successful implementation of incentive-based approaches to pollution control. The Clean Air Act Amendments of 1990 ushered in large reductions in pollution. Title IV of these amendments created the first national cap-and-trade program for a major pollutant, capping total SO_2 pollution from power plants. Roughly a decade later, regulations triggered by the ozone standards in this bill led to seasonal caps on total NO_x emissions from electricity generators in the eastern half of the country. By 2010, total SO_2 from power plants will be about 9.2 million tons, while national annual NO_x emissions are forecasted to be about 4.6 million tons.[4] Both are roughly half the levels predicted in 1990 to occur in 2010 in the absence of the amendments.[5]

Despite these important reductions in emissions, several regions of the country are still not in attainment of air quality standards for atmospheric concentrations of ozone to which emissions of NO_x contribute importantly and many regions are not expected to comply with forthcoming standards for concentrations of fine particulates to which emissions of both NO_x and SO_2 contribute. The electricity sector also is a major emitter of mercury into the atmosphere and these emissions are subject to regulation under Section 112 of the Clean Air Act, the title that regulates emissions of hazardous air pollutants.[6] To combat these and other pollution concerns the electricity sector faces a host of potential new federal environmental regulations to be promulgated by EPA over the next several years under current statutes. The timing and form of these anticipated regulations will have important implications for their cost and the timing of the associated benefits.

To promote greater synergies across pollutants and a more predictable schedule of future regulation of the electricity sector a number of legislative proposals were introduced in the 108th Congress.[7] Senator Jeffords

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[4] Annual emissions of SO_2 are expected to exceed allowance allocations in 2010 of 8.95 million tons because of draws on the allowance bank, which was built up in Phase I (1995-2000) of the trading program. The projection of 9.2 million tons is proximate to various projections from EPA and Energy Information Administration (EIA). See for example: http://www.epa.gov/air/clearskies/technical.html (accessed 4.5.05).

[5] U.S. NAPAP, 1991: 221-222.

[6] On March 15, EPA revised and reversed an earlier finding from 2000 that it was “appropriate and necessary” to regulate coal- and oil-fired coal-fired power plants under section 112 of the Clean Air Act. Instead the agency has chosen to regulate mercury under sections 110(a)(2)(D) and 111 of the law.

[7] The major legislative proposals are summarized in detail in Appendix 2.

(I-VT) reintroduced the most aggressive plan, Senate Bill 366, known as The Clean Power Act, which would cap annual national emissions of SO_2 and NO_x from the electricity sector at 25% of their 1997 levels and annual emissions of mercury at 10% of 1999 levels by 2009. This is equivalent to annual caps of about 2.25 million tons for SO_2, 1.5 million tons for NO_x, and 5 tons for mercury. The bill also caps annual electricity sector emissions of CO_2 at 1990 levels beginning in 2008. The bill allows for emissions trading for all gases except mercury.

The Bush administration's proposal, known as Clear Skies, though less aggressive, nonetheless offers important reductions. Senators Inhofe (R-OK) and Voinovich (R-OH) reintroduced it in the 108th Congress as Senate Bill 485. The proposal caps annual emissions of SO_2 at 4.5 million tons in 2010 and at 3.0 million tons in 2018, annual emissions of NO_x at 2.1 million tons in 2009 and 1.7 million tons in 2018, and annual emissions of mercury at 26 tons in 2010 and 15 tons in 2018.[8] This proposal permits the trading of emission allowances for all three pollutants.

In between these two proposals is Senate Bill 843, the Clean Air Planning Act, sponsored by Senator Carper (D- DE). This act imposes emission caps for SO_2, NO_x, and mercury and timetables for achieving those caps, both of which generally fall in between the other two proposals. This bill also includes a phased-in cap on CO_2 emissions from electricity generators, but allows for the use of emission offsets from outside the electricity sector to lower the cost of achieving those caps. Mercury emission trading is allowed, although generators must meet facility-specific emission reduction targets.

Multipollutant legislation has not yet advanced in Congress. However several states have passed laws or regulations to reduce emissions of some or all of the same pollutants from electricity generators. Most of these laws or proposals, such as new regulations in Connecticut and Massachusetts that limit non-ozone season emissions of NO_x, are formulated as limits on emission rates. The largest state action is in North Carolina, which has recently placed emission caps on its largest coal-fired plants. A similar plan has been adopted in New Hampshire for all existing fossil fuel generators. New York also has caps on emissions of SO_2 and NO_x from large generators within the state.

EPA has also taken steps toward requiring greater reductions in emissions of SO_2 and NO_x from electricity generators than mandated under current law. To facilitate compliance with the 8-hour ozone standard and with new air quality standards for fine particulates with sizes 2.5 microns in diameter or less ($PM_{2.5}$) and to meet statutory requirements for reducing emissions of hazardous air pollutants such as mercury, the EPA

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[8] The Clear Skies initiative does not include a cap on CO_2 emissions, but instead proposes to cut greenhouse gas intensity on an economy-wide basis by 18% over the next 10 years using mostly voluntary initiatives and providing a formal mechanism for recognizing cuts that are made voluntarily.

issued two rules that together address SO_2, NO_x, and mercury emissions from the electricity sector. In a rule known as the Clean Air Interstate Rule, or CAIR, EPA imposes annual caps on emissions of SO_2 and/or NO_x in a region covering more than 20 states, mostly east of the Mississippi, and the District of Columbia.[9] This regulation allows for emission trading, and restrictions are imposed in two phases with the initial phase beginning in 2010 and the second phase beginning in 2015. Beginning in 2010 the program allocates roughly 3.7 million tons of SO_2 allowances and 1.5 million tons of NO_x allowances to electricity generators within the region. In 2015, total regional emission allocations drop to 2.6 million tons for SO_2 and 1.3 million tons for NO_x. The percent reductions in emissions within the CAIR region are comparable to those that would be required nationwide under the Clear Skies Initiative, except they happen on a somewhat accelerated schedule.

In a separate rule EPA caps emissions of mercury from all coal and oil-fired electricity generators at 38 tons nationally beginning in 2010 and 15 tons beginning in 2018. This cap-and-trade program is national in scope.

The final rules issued in March 2005 differ in some important ways from the proposed form of the rules analyzed here. First, the final CAIR rule includes a separate seasonal summertime cap-and-trade program for NO_x emissions not included in the originally proposed rule. Second, the set of states included in the CAIR rule has changed slightly, with Kentucky being dropped from the list. A total of 22 states are included in both the annual NO_x and SO_2 annual programs and the NO_x seasonal program established in the CAIR rule. Three states, Arkansas, Connecticut, and Massachusetts, are included in the seasonal NO_x program only and three other states, Georgia, Minnesota, and Texas, are included in the annual SO_2 and NO_x programs only. Third, the change in the set of states covered by the annual program in the CAIR rule means there has been a slight downward adjustment in the annual emissions caps. The final mercury rule includes a more relaxed mercury emissions cap for phase I than the proposed rule with the expectation that generators will build up a bank of excess emission reductions during phase I that they can draw upon during phase II. Also, the final mercury rule does not include a safety valve price on mercury emission allowances, but instead the rule anticipates that the enlarged allowance bank will keep down the costs of compliance in the beginning of the second phase.

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[9] The EPA CAIR is summarized in Appendix 3.

Section 3

OVERVIEW OF MODELS

In this project, we use four models to analyze the costs and benefits of several different multipollutant policies within the electricity sector. The interrelationships among these four models, including the data flows among models, are illustrated in Figure 1.

The Haiku model looks at the effects of the policies on the behavior of electricity producers and consumers and the resulting implications for costs, prices to consumers and the level and location of emissions. The TAF model is used to translate changes in emissions of SO_2 and NO_x from power plants into changes in air quality, human health and monetary benefits of those changes in health status. An important component of the TAF model is the source receptor coefficients that translate changes in emissions in source areas resulting from the policy to changes in concentrations of associated air pollutants in receptor areas, as well as changes in deposition of sulfur and nitrogen.

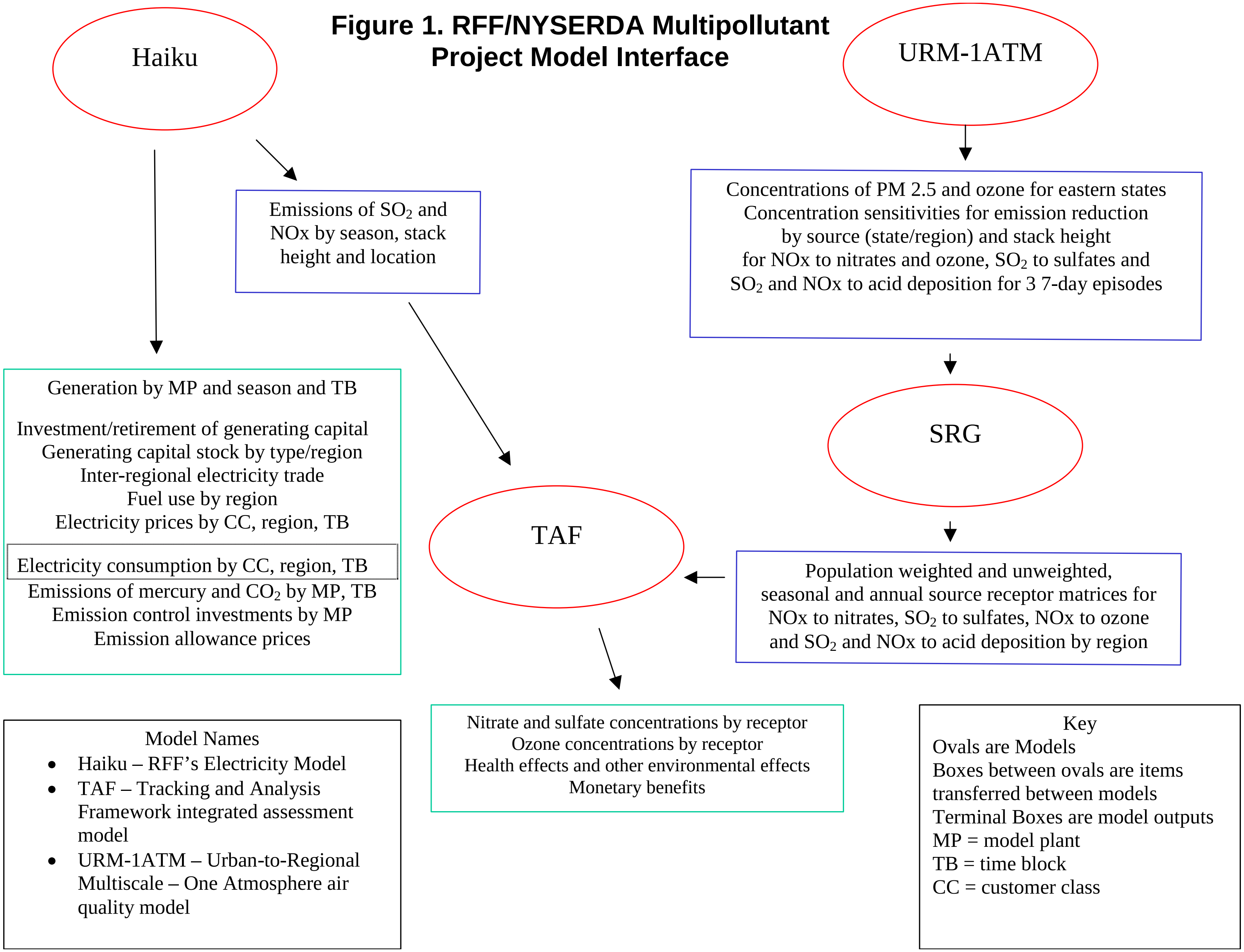
As a part of this project we used information from the URM-1 ATM air quality model and an associated post-processing model called the SRG, which stands for Source-Receptor Generator, to update the source receptor coefficients in TAF for SO_2 and NO_x contributions to particulate concentrations and for NO_x contributions to ozone. Previously, TAF contained source receptor coefficients from the Advanced Source Trajectory Regional Air Pollution (ASTRAP) model for particulates, but had no source receptor coefficients for ozone. Updating these coefficients represented an important and significant component of the research. We use the ASTRAP model as a point of comparison for the new coefficients. For deposition of sulfur and nitrogen we continue to rely on ASTRAP because of advantages discussed below, and use URM as a point of comparison.

In the following sections each of the models is described in greater detail.

3.1 HAIKU MODEL

The Haiku model simulates equilibrium in regional electricity markets and interregional electricity trade with an integrated algorithm for SO_2, NO_x, and mercury emission control technology choice. The model calculates electricity demand, electricity prices, the composition of technologies and fuels used to supply

Figure 1. RFF/NYSERDA Multipollutant Project Model Interface



Emissions of SO_2 and NOx by season, stack height and location

Concentrations of PM 2.5 and ozone for eastern states
Concentration sensitivities for emission reduction by source (state/region) and stack height for NOx to nitrates and ozone, SO_2 to sulfates and SO_2 and NOx to acid deposition for 3 7-day episodes

Generation by MP and season and TB

Investment/retirement of generating capital
Generating capital stock by type/region
Inter-regional electricity trade
Fuel use by region
Electricity prices by CC, region, TB

Electricity consumption by CC, region, TB
Emissions of mercury and CO_2 by MP, TB
Emission control investments by MP
Emission allowance prices

Population weighted and unweighted, seasonal and annual source receptor matrices for NOx to nitrates, SO_2 to sulfates, NOx to ozone and SO_2 and NOx to acid deposition by region

Nitrate and sulfate concentrations by receptor
Ozone concentrations by receptor
Health effects and other environmental effects
Monetary benefits

Model Names

- Haiku – RFF's Electricity Model
- TAF – Tracking and Analysis Framework integrated assessment model
- URM-1ATM – Urban-to-Regional Multiscale – One Atmosphere air quality model

Key
Ovals are Models
Boxes between ovals are items transferred between models
Terminal Boxes are model outputs
MP = model plant
TB = time block
CC = customer class

electricity, interregional electricity trading activity, and emissions of key pollutants. The main data inputs to the Haiku model, along with the sources for the associated data, are listed in Table 1.[10]

The model solves for the quantity and price of electricity delivered in 13 regions, for four time periods (super-peak, peak, shoulder, and base load hours) in each of three seasons (summer, winter, and spring/fall). For each of these 156 market segments, demand is aggregated from three customer classes: residential, industrial, and commercial, each with its own constant elasticity demand function. Estimates of demand elasticities for different customer classes and regions of the country are taken from the economics literature.

The supply-side of the model is built using capacity, generation, and heat-rate data for the complete set of commercial electricity plants in the United States from various Energy Information Administration (EIA) datasets. For modeling purposes, these plant-level data are aggregated into 39 representative plants in each region. The capacity for a model plant is determined by aggregating the capacity of the individual constituent plants in a given region that are of the same type as the model plant. However, no region contains every one of these model plants. For example, the New England region does not contain a geothermal plant.

A model plant is defined by the combination of its technology and fuel source, which include coal, natural gas, oil, hydropower, and nuclear. There are steam plants that run on oil as well as gas turbine plants that run on oil. The same is true for natural gas. Coal is a little different from the other fuels in that it is divided into 14 subcategories based on the region the coal is from and its level of sulfur content. Table 2 provides a listing these subcategories. The users of coal are broken down into demand regions that have different costs associated with each type of coal, which reflect the varying interregional transport costs. Model plants might switch the type of coal they use in order to reduce their SO_2 or mercury emissions, which may be more cost effective than installing new pollution controls. Table 3 gives a list of the various types of model plants.

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[10] The items listed in Table 1 are largely parameters in the model that rely on real world data or variables derivative of real world data. The Haiku model user also must make assumptions about a number of inputs including the discount rate, year in which to base net present value calculations, and expected rate of transmission capacity growth. Users must also input policy scenario assumptions.

Table 1. Inputs to the Haiku Model

Category	*Variables*	*Source**
Existing Generation		
	Capacity	EIA
	Heat Rate	EIA
	Fixed and Variable O&M Cost	FERC\EIA\EPA
	Existing pollution controls	EPA/RFF
	Planned pollution controls	RFF
	Baseline Emission Rates	EPA (CEMS/NEEDS)
	Scheduled and Unscheduled Outage Rates	NERC GADS data
New Generation Facilities		
	Capacity	EIA
	Heat Rate	EIA\EPA
	Fixed and Variable Operating Cost	EIA
	Capital Cost	EIA
	Outage Rates	NERC GADS data
Fuel Supply		
	Wellhead supply curve for natural gas	Interpolated based on EIA forecasts
	Delivery cost for natural gas	
	Minemouth supply curve for coal by region and type of coal	EIA
	Delivery cost for coal	EIA
	Delivered oil price	EIA
Pollution Controls		
	SO_2 – cost and performance	EPA
	NO_x – cost and performance	EPA
	Hg – cost and performance	EPA
Transmission		
	Inter-regional transmission capacity	NERC
	Transmission charges	EMF
	Inter and intra regional transmission losses	EMF
Demand		
	Data year demand levels by season and customer class	EIA
	Load Duration Curve	RFF
	Trends in Demand Growth by customer class and region	EIA AEO 2004
	Elasticities by customer class	Economics literature

***** Additional information on data is provided in Paul and Burtraw (2002).

Table 2. Mapping of Coal Supply Categories

		2000 Million Short. Tons*	Haiku Coal Supply Mapping
Northern Appalachia	**PA, MD, OH, Northern WV**	**149.14**	
	Medium Sulfur (Premium)	4.66	--
	Low Sulfur (Bituminous)	0.36	--
	Medium Sulfur (Bituminous)	72.61	NAMB
	High Sulfur (Bituminous)	61.41	NAHB
	High Sulfur (Gob)	10.10	--
Central Appalachia	**Southern WV, VA, Eastern KY.**	**258.40**	
	Medium Sulfur (Premium)	47.16	--
	Low Sulfur (Bituminous)	65.91	CSALB
	Medium Sulfur (Bituminous)	145.33	CSAMB
Southern Appalachia	**AL, TN.**	**22.00**	
	Low Sulfur (Premium)	6.82	--
	Low Sulfur (Bituminous)	6.03	CSALB
	Medium Sulfur (Bituminous)	9.15	CSAMB
Eastern Interior	**IL, IN, MS, Western KY.**	**88.09**	
	Medium Sulfur (Bituminous)	30.86	EIMB
	High Sulfur (Bituminous)	56.33	EIHB
	Medium Sulfur (Lignite)	0.90	--
Western Interior	**IA, MO, KS, OK, AR, TX.**	**2.42**	
	High Sulfur (Bituminous)	2.42	--
Gulf	**TX, LA, AR.**	**53.02**	
	Medium Sulfur (Lignite)	36.44	GLML
	High Sulfur (Lignite)	16.58	GLHL
Dakota	**ND, Eastern MT.**	**31.41**	
	Medium Sulfur (Lignite)	31.41	DLML
Powder/Green River	**WY, MT.**	**376.88**	
	Low Sulfur (Bituminous)	1.21	--
	Low Sulfur (Sub-Bituminous)	345.74	PGLS
	Medium Sulfur (Sub-Bituminous)	29.93	PGMS
Rocky Mountain	**CO, UT.**	**55.80**	
	Low Sulfur (Bituminous)	46.64	SWLB
	Low Sulfur (Sub-Bituminous)	9.16	SWLS
Arizona/New Mexico	**AZ, NM.**	**40.43**	
	Low Sulfur (Bituminous)	19.62	SWLB
	Medium Sulfur (Bituminous)	0.00	--
	Medium Sulfur (Sub-Bituminous)	20.81	SWMS
Washington/Alaska	**WA, AK.**	**5.91**	
	Medium Sulfur (Sub-Bituminous)	5.91	--

* Source: *http://www.eia.doe.gov/oiaf/aeo/supplement/sup_ogc.pdf*

Table 3. Model Plant Types in Haiku

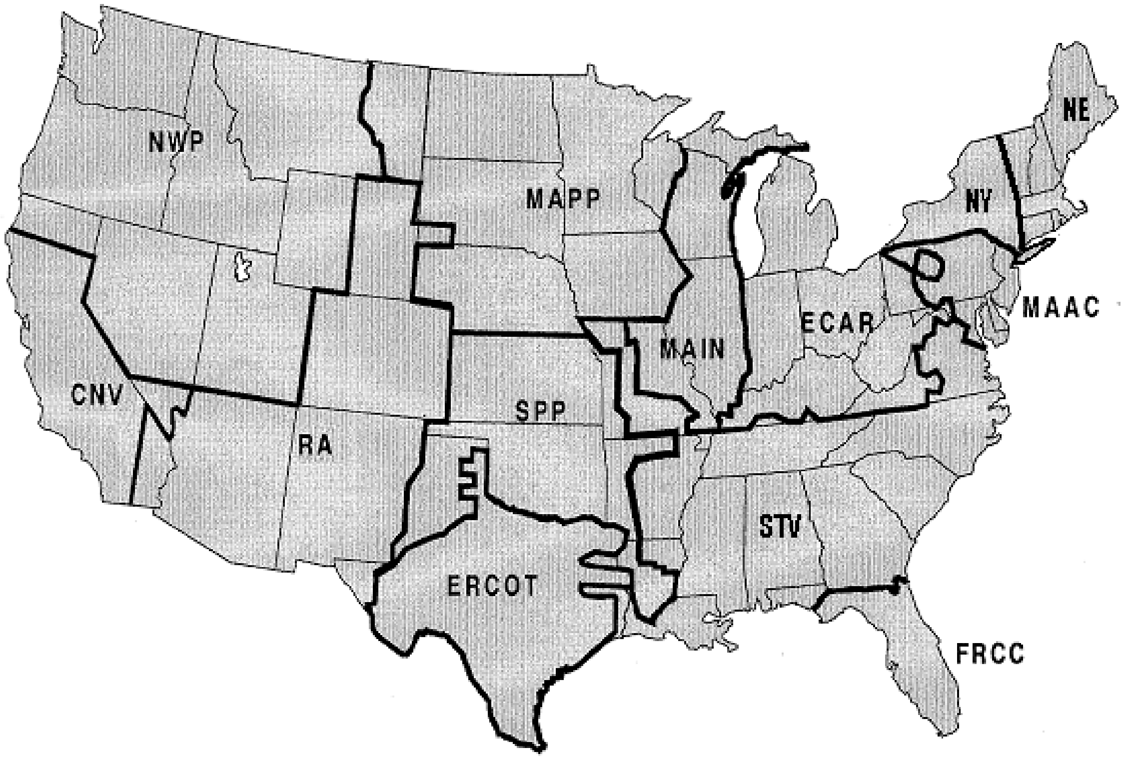
Existing Plants	New or Planned Plants
Natural Gas Fired Combined Cycle	Coal Steam
Oil Combined Cycle	Conventional Natural Gas-Fired Combined Cycle
Efficient Natural Gas Fired Gas Turbine	Natural Gas-Fired Combined Cycle, Combustion Turbine Duct
Inefficient Natural Gas Fired Gas Turbine	Conventional Natural Gas Fired Gas Turbine
Oil Gas Turbine	Landfill Gas Internal Combustion
Conventional Hydro	Biomass IGCC
Hydro Pumped Storage	Wind
Solar	Advanced Natural Gas-Fired Combined Cycle
Wind	Advanced Natural Gas-Fired Gas Turbine
Biomass Steam	Geothermal
Geothermal	Coal IGCC
Efficient Natural Gas Steam	
Inefficient Natural Gas Steam	
Efficient Nuclear	
Inefficient Nuclear	
Oil Steam	
MSW / Landfill Gas	
Coal Steam*	

* The model includes several different categories of existing coal steam model plants, which are distinguished by EIA coal demand region in which the model plant is located. This distinction brings the total number of model plants from the 29 listed here to 39.

Investment in new generation capacity and retirement of existing facilities are determined endogenously in a dynamic framework, based on capacity-related costs of providing service in the future ("going forward costs"). The model determines investment and retirement of generation capacity and new generation capacity is assigned to a model plant representing new capacity of that type. The Haiku model determines the level of new investment in generation capacity and in post-combustion controls, as well as retirement of existing capacity. The model incorporates available information about planned units currently under construction. Generator dispatch in the model is based on the minimization of short run variable costs of generation. All costs and prices are expressed in 1999 real dollars.

Interregional power trading is identified as the level of trading necessary to equilibrate regional electricity prices (accounting for transmission costs and power losses). These interregional transactions are constrained by the assumed level of available interregional transmission capability as reported by the North American Electric Reliability Council (NERC). The 13 NERC regions are displayed in Figure 2.

Figure 2. Haiku Model Regions



Factor prices, such as the cost of capital and labor, are held constant. Fuel price forecasts are calibrated to match EIA price forecasts (U.S. EIA 2004). Fuel market modules for coal and natural gas calculate prices that are responsive to factor demand. Coal is differentiated along several dimensions, including fuel quality and location of supply, and both coal and natural gas prices are differentiated by point of delivery. All other fuel prices are specified exogenously.

For control of SO_2, coal burning model plants are distinguished by the presence or absence of flue gas desulfurization (scrubbers). Unscrubbed coal plants have the option to add a retrofit SO_2 scrubber, and all plants select from a series of coal types that vary by sulfur content and price as a strategy to reduce SO_2 emissions. For control of NO_x, coal-, oil-, and gas-fired steam plants solve for the least costly post-combustion investment from the options of selective catalytic reduction (SCR) and selective noncatalytic reduction (SNCR), and also reburn for coal-fired plants.

The model accounts for ancillary reductions in mercury associated with other post-combustion controls including decisions to install retrofit SO_2 scrubbers and NO_x controls (SCR), and the model includes activated carbon injection

(ACI) as another means of reducing mercury emissions. Using activated carbon injection (ACI) only typically has a mercury removal efficiency of 90-95%, and adding on SO_2 wet scrubbers increases this rate to 97%. For bituminous coal the combination of SCR and SO_2 wet scrubbers yields a removal efficiency of 90%, though this combination is not nearly as effective for subbituminous and lignite coal. In this analysis we base our emission modification factors for mercury on those used by EPA in its analysis of CAIR and the proposed mercury rule and these factors are presented in Table 4. The EPA emission modification factors depend on coal type and the configuration of post-combustion controls including particulate controls. In Haiku these factors are aggregated over particulate controls existing at each model plant to arrive at a weighted average emission modification factor for each combination of SO_2 and NO_x control at that plant. Table 5 reports the emission modification factors for one model plant in the Midwest (ECAR NERC subregion) that apply to that portion of the model plant that has SCR control for NO_x in place. A different set of factors applies in the absence of SCR. Also reported are the emission modification factors for ACI. The variable costs of emission controls plus the opportunity cost of emission allowances under cap-and-trade programs are added to the variable cost of generation when establishing the operation of different types of generation capacity. Utilization of each plant is flexible and demand also may respond to changes in the price of electricity in order to help achieve emission reductions.

Table 4. U.S. EPA Emissions Modification Factors for Mercury

Configuration			*EPA Percent Mercury Removal*		
SO_2 Control	*Particulate Control*	*NO_x Control*	*Bit Coal*	*Sub Bit Coal*	*Lignite Coal*
None	BH	---	89	73	0
Wet	BH	None	97	73	0
Wet	BH	SCR	90	85	44
Dry	BH	---	95	25	0
None	CSE	---	36	3	0
Wet	CSE	None	66	16	44
Wet	CSE	SCR	90	66	44
Dry	CSE	---	36	35	0
None	HSE/Oth	---	10	6	0
Wet	HSE/Oth	None	42	20	0
Wet	HSE/Oth	SCR	90	25	0
Dry	HSE/Oth	---	40	15	0

Notes: SO_2 Controls: Wet = Wet Scrubber, Dry = Dry Scrubber; Particulate Controls: BH = baghouse/fabric filter, CSE – cold side electrostatic precipitator, HSE – hot side elctro static precipitator; NO_x Controls: SCR – selective catalytic reduction, --- = not applicable; Bit = bituminous coal, Sub = subbituminous coal.

Source: U.S. EPA at http://www.epa.gov/clearskies/techinical.html.

Table 5. Representative Emissions Modification Factors for Mercury Used in Haiku at an Existing Coal-Fired Plant in the ECAR NERC Sub-Region with SCR Control

	SO_2 and Mercury Control Choice Combinations					
Coal Supply Category*	**Wet**	**Wet & ACI**	**Dry**	**Dry & ACI**	**ACI**	**None**
NAMB	0.900	0.965	0.364	0.936	0.936	0.359
NAHB	0.900	0.965	0.364	0.936	0.936	0.359
CSALB	0.900	0.965	0.364	0.936	0.936	0.359
CSAMB	0.900	0.965	0.364	0.936	0.936	0.359
EIMB	0.900	0.965	0.364	0.936	0.936	0.359
EIHB	0.900	0.965	0.364	0.936	0.936	0.359
GLML	0.434	0.943	0.004	0.900	0.901	0.007
GLHL	0.434	0.943	0.004	0.900	0.901	0.007
DLML	0.434	0.943	0.004	0.900	0.901	0.007
PGLS	+0.658	0.917	0.350	0.935	0.904	0.037
PGMS	0.658	0.917	0.350	0.935	0.904	0.037
SWLB	0.900	0.965	0.364	0.936	0.936	0.359
SWLS	0.658	0.917	0.350	0.935	0.904	0.037
SWMS	0.658	0.917	0.350	0.935	0.904	0.037

* Coal supply categories are described in Table 2.

3.2 TAF MODEL

The output of the Haiku model is emissions of each pollutant by a representative plant within each of 13 NERC subregions. The emissions are allocated to actual plant locations (latitude and longitude) based on an algorithm that reflects historic utilization and the expected location of new investment. Changes in emissions of SO_2 and NO_x that result from the policies are aggregated to the state level and fed into TAF, a nonproprietary and peer-reviewed integrated assessment model (Bloyd et al., 1996).[11] TAF integrates pollutant transport and deposition (including formation of secondary particulates but excluding ozone), human health effects, and valuation of these effects at the

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[11] TAF was developed to support the National Acid Precipitation Assessment Program (NAPAP). Each module of TAF was constructed and refined by a group of experts in that field, and draws primarily on peer-reviewed literature to construct the integrated model. TAF was subject to an extensive peer review in December 1995, which concluded "TAF represent[s] a major advancement in our ability to perform integrated assessments." (ORNL, 1995) The entire model is available at www.lumina.com\taflist.

state level. Although our version of the model limits benefits only to particulate-related health impacts, these impacts account for the vast majority of all benefits according to the major integrated assessment studies of the impacts of electricity generation (Krupnick and Burtraw, 1996).

In the original version of TAF, pollution transport is estimated from seasonal source-receptor matrices that are a reduced-form version of the Advanced Source Trajectory Regional Air Pollution (ASTRAP) model, which uses 11 years of wind and precipitation data to estimate the variability of model results on the basis of climatological variability. In aggregating to the state level, the source-receptor matrix is calibrated to represent average effects observed in more disaggregate models. The model captures atmospheric chemistry as NO_x and SO_2 react to form nitrates and sulfates, which are constituents of particulate matter less than 10 microns in diameter (PM_{10}). It estimates concentrations of these separate constituents of PM_{10} plus gaseous NO_2 and SO_2.

As a part of this project, we develop another set of source-receptor coefficients that includes both the effects of changes in emission of NO_x and SO_2 on fine particulate concentrations and the effects of changes in NO_x emissions on atmospheric ozone concentrations. The development of these source receptor coefficients is described in the next section of this report. The new coefficients developed with the Urban-to-Regional Multiscale (URM) One Atmosphere Model that is described below encompass only the eastern half of the United States, although this is the most relevant to this project. For the rest of the nation we continue to use coefficients from ASTRAP in our central case. We do a comparison analysis using only the ASTRAP coefficients.

The TAF model does not include any information on transport and fate of mercury emissions and, thus, we are unable to assess the changes in concentrations of mercury in fish or to evaluate changes in consumption of contaminated fish, which is a major pathway for human exposure and adverse health effects. As a result we are unable to value the direct benefits from reductions in mercury emissions associated with the different policies. Given the wide differences in mercury emissions across the various policies that we evaluate, this omission suggests an important caveat to our results about the net benefits of the different policies. Policies that offer greater reductions in mercury could have greater health benefits than those that promise lesser reductions, and those benefits are not captured here.

Health effects are characterized as changes in health status predicted to result from changes in air pollution concentrations. Effects are expressed as the number of days of acute morbidity effects of various types, the number of chronic disease cases, and the number of statistical lives lost. The health module is based on concentration-response functions found in the peer-reviewed literature, including epidemiological articles reviewed in EPA’s Criteria Documents that, in turn, appear in key EPA cost-benefit analyses (U.S. EPA, 1997; U.S. EPA, 1999). The health effects modeled are listed in Table 6.

Table 6. List of Epidemiological Studies Used to Calculate Health Effects of Pollution Changes in TAF Model Runs

Ozone Health Endpoint	*Concentration Response Study [Weight]*
Respiratory Hospital Admissions – All Cause – 65 Up	Schwartz (1995) New Haven – Other: PM10 [0.5] Schwartz (1995) Takoma – Other: PM10 [0.5]
Respiratory Hospital Admissions - All Cause – Under 2	Burnett et al (2001) Other: PM2.5 [1.0]
Asthma Emergency Room Visits – All Ages	Weisel et al (1995) Other: None [0.5] Cody et al (1992) Other: SO_2 [0.5]
School Absence Days – 5 to 17	Gilliand et al (2001) Other: None [0.08] Chen et al (2000) Other: CO, PM10 [0.92]
Minor Restricted Activity Days – 18 to 64	Ostro and Rothschild (1989) Other: None [1.0]
Short Term Mortality – All Ages	Ito and Thurston (1996) Other: PM10 [0.0825] Moolgavkar et al (1995) Other: SO_2, TSP [0.45] Samet et al (1997) Other: CO, NO_2, SO_2, TSP [0.2175] Bell et al (2004) Other: PM10 [0.25]
PM 2.5 Health Endpoint	*Concentration Response Study [Weight]*
Mortality – Under 1	Woodruff et al (1997) Other: None [1.0]
Mortality – 30 Up	Pope et al (2002) 1979 to 83 Air Data – Other: None [1.0]
Chronic Bronchitis – 18 Up	Abbey et al (1995) Other: None [1.0]
Non-fatal Heart Attacks – 18 Up	Peters et al (2000) Other: None [1.0]
Respiratory Hospital Admissions – All Cause – All Ages	Burnett et al (1997) Other: O3 [1.0]
Cardiovascular Hospital Admissions – 18 to 64	Moolgavkar (2000) All Cardio – Other: None [1.0]
Cardiovascular Hospital Admissions – 65 Up	Moolgavkar (2003) All Cardio – Other: None [0.979] Ito (2003) Ischemic Heart Disease – Other: None [0.007] Ito (2003) Dysrhythmia – Other: None [0.007] Ito (2003) Heart Failure – Other: None [0.007]
Asthma Emergency Room Visits – Under 18	Norris et al (1999) Other: None [1.0]
Acute Bronchitis in Children – 8 to 12	Dockery et al (1996) Other: None [1.0]
Upper Respiratory Symptoms in Children – 7 to 14	Pope et al (1991) Other: None [1.0
Asthma Exacerbations – 6 to 18	Ostro et al (2001) Cough – Other: None [0.3718] Ostro et al (2001) Wheeze – Other: None [0.2436] Ostro et al (2001) Short Breath – Other: None [0.3846]
Work Loss Days – 18 to 64	Ostro (1987) Other: None [1.0]
Minor Restricted Activity Days – 18 to 64	Ostro and Rothschild (1989) Other: None [1.0]

Of these effects, mortality effects are the most important. To characterize these effects we use a cross sectional study by Pope et al. (1995). While this study and others have documented the separate effects of PM_{10}, $PM_{2.5}$ and sulfates (a constituent of $PM_{2.5}$) on mortality, none have documented the specific effect of nitrates. Accordingly, we use the separate Pope et al. estimates for the potency of sulfates, but assume that nitrates have the potency of the average PM_{10} particle.

TAF assigns monetary values (taken from the environmental economics literature) to the health-effects estimates produced by the health-effects module. The benefits are totaled to obtain annual health benefits for each year modeled. For the most important aspect, the value of a statistical life (VSL), we have used an estimate of $2.25 million (1999 dollars) from a recent meta-analysis by Mrozek and Taylor (2002) of 203 hedonic labor-market estimates. This estimate is lower than that used in most previous work and less than half of the $6.1 million estimate used by EPA (1997, 1999). The most important reason for this discrepancy is the attribution of wage rate differentials to mortality rate differences in previous studies cited by EPA, while Mrozek and Taylor attribute a larger portion of the wage rate differentials to inter-industry differences that occur for other reasons.[12]

As with past research, values for chronic morbidity effects (e.g., emphysema) are transferred from individual studies, often using a conservative cost-of-illness approach. Values for acute effects are predicted from the meta-analysis of Johnson et al. (1997), which synthesized contingent valuation studies of morbidity effects based on their severity according to a health-status index and other variables.

We also use TAF to calculate expected changes in deposition of sulfur and nitrogen. For this purpose we rely primarily on the ASTRAP coefficients because they have the advantage of preserving mass balance between emissions and deposition and because the ASTRAP model has been compared favorably to the EPA's Regional Acid Deposition Model (RADM).[13]

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[12] There may be other reasons to suspect that the traditional values are too high. Labor market studies rely on the preferences of prime-age, healthy working males facing immediate and accidental risks of workplace mortality. In contrast, particulate pollution primarily affects seniors and people with impaired health status and may occur years after initial exposure. This recognition has led to attempts to estimate values for life extensions (Johnson et al., 1998) and future risks (Alberini et al., 2004). New surveys that use contingent valuation to describe mortality risk reductions in a more realistic health context and that are applied to people of different ages and health status, find that the implied VSLs are far smaller than EPA's estimates, particularly for future risk reductions (Alberini et al., 2004). However, the effects do not appear to be strongly related to age and, although many conjecture that poor health status would reduce willingness to pay, the study finds people in ill health tend to be willing to pay more for mortality risk reductions than people in good health. On the other hand, effects of dread and lack of controllability have not yet been factored into these new analyses.

[13] Shannon, et al. (1997) found the two models' predictions reasonably in agreement for predicting atmospheric sulfate concentrations in the eastern U.S., though RADM actually predicts greater sulfate reductions in the more populated regions including the Mid-Atlantic.

3.3 URM 1-ATM AND SRG[14]

This study takes output from the Urban-to-Regional Multiscale (URM) One Atmosphere Model (URM-1ATM) for several air pollution episodes at a detailed geographic scale and uses that information to construct aggregate source-receptor coefficients for state-level receptors using the Source-Receptor Generator (SRG) model.[15] The episode-specific, source-receptor coefficients are aggregated to annual source-receptor coefficients using weights developed based on a Classification and Regression Tree (CART) analysis of the episode data.[16] The models that are used to perform these tasks and how they work together are described below.

The URM-1ATM and the Regional Atmospheric Modeling System (RAMS) are used to account for the processes significantly affecting ozone and fine particulate concentrations in the atmosphere, including atmospheric physics, chemical reactions in the atmosphere, cloud and precipitation processes, and wet and dry deposition. RAMS is used to recreate the physics of an historical period of time, providing details and spatial coverage unavailable from observations. URM-1ATM solves the atmospheric diffusion equation (ADE) presented in equation (1) for the change in concentration, *c*, of pollutant of species *i* with time,

$$\frac{\partial c_i}{\partial t} + \nabla \bullet \left(\mathbf{u} c_i\right) = \nabla \bullet \left(\mathbf{K} \nabla c_i\right) + f_i + S_i \tag{1}$$

where **u** is a velocity field, **K** is the diffusivity tensor, f*i* represents the production by chemical reaction of species *i*, and S*i* represents sources and sinks of species *i*. As used here, a direct sensitivity capability using the Direct Decoupled Method in Three Dimensions (DDM-3D) is employed to calculate the local sensitivities of specified model outputs simultaneously with concentrations (Odman et al. 2002, Russell, McCue, and Cass 1998). As shown in Equation 2, the sensitivity, S_{ij}, of a model output, C_i (such as pollutant concentration of species *i*) to specified model inputs or parameters, P_j (e.g., emissions of NO_x from elevated sources) is calculated as the ratio of the change in output C_i to an incremental change of input or parameter P_j.

$$S_{ij} = \frac{\partial C_i}{\partial P_j} \tag{2}$$

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[14] Much of this discussion is taken from Shih et al. 2004.

[15] For more information on the URM-1ATM model see Boylan et al. (2002) and Kumar, Odman, and Russell (1994).

[16] For more information about CART analysis see Breiman et al. (1984).

Equations 1 and 2 are solved concurrently and efficiently. The sensitivity in equation 2 is a local derivative, so a linear assumption is in effect when we extrapolate the result to a non-zero perturbation in emissions. This assumption has been well tested for the pollution concentrations of interest for this study, which include ozone and fine particulates. Although we continue to use the ASTRAP coefficients to account for changes in deposition of sulfur and nitrogen for reasons stated above, the URM-1ATM model also provides coefficients for wet deposition for much of the nation. We compare these results with those coming from the ASTRAP model. A more detailed description of the model is available from Boylan et al. (2002) and Bergin et al. (2004).

URM-1ATM model uses a multiscale grid structure encompassing the eastern United States as shown in Figure 3. The finest grids are placed over major source regions such as the Ohio River Valley, where many power plants and large industries are located, and over highly populated regions such as the East Coast corridor. This approach allows evaluation of potential population exposure to pollutants and captures high-population-related sources such as automobile exhaust, fast food restaurants, and so forth. The vertical grid has seven layers, which allow different treatment of sources with low- and high-level stacks.

URM-1ATM is applied to three air quality episodes: February 9 to 13, 1994, May 24–29, 1995, and July 11–19, 1995. These three episodes are used to represent winter, spring and summer weather, respectively. These episodes were selected because high-quality and complete data were available and were previously modeled and because the data covered large meteorological variation with moderate-to-high pollution formation. Meteorological information is developed using the Regional Atmospheric Modeling System (RAMS), found in Pielke et al. 1992.

The sensitivities from the URM-1ATM model are aggregated spatially on the receptor side using the SRG model. The hourly pollutant concentration sensitivity with respect to a uniform 30% reduction in emissions (by states and sources, both elevated and area) and population, for every grid in the entire study domain, are inputs to the SRG Model. The SRG program calculates spatially aggregated (receptor grids) source-receptor coefficients (S-Rs), both population weighted and nonpopulation weighted, for various averaging times (1-hour, 8-hour, and daily) for 22 receptor regions covering a 27 state area.[17] Population-weighted S-Rs are needed for estimating potential health benefits from application of source controls, and also give a better proxy for health effects than do area-weighted measures. The area-weighted S-Rs are useful to see the pure spatial and temporal effects of emissions on concentrations.

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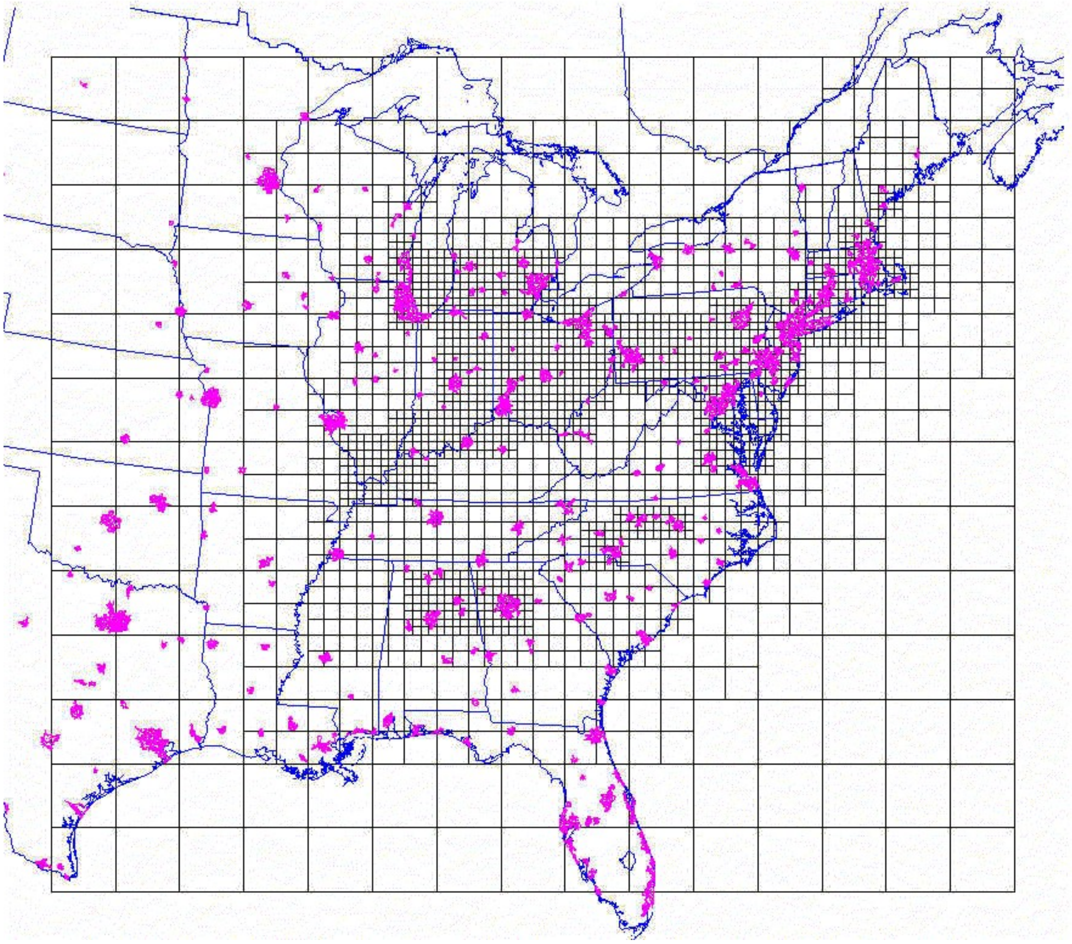
[17] Three sets of states and the District of Columbia fully in the model domain are aggregated into multistate receptor regions. Maine, New Hampshire, and Vermont are aggregated into a single region as are Connecticut, Massachusetts and Rhode Island and Delaware, Maryland, and the District of Columbia. In addition, 11 states on the western border of the eastern domain are aggregated into a single region.

Figure 3. Multi-scale Grid Used to Model Changes in Ozone and Particulate Species from Changes in NO_x and SO_2.



Note: The finest resolution has horizontal grids of 24km per side, and the other cells are 48km, 96km, and 192km per side. The shaded areas represent high population densities (urban areas.) Fine scale cells are placed over areas of high industrial or population densities.

To use the output from the URM model, which is based on distinct episodes of six to nine days, in seasonal or annual policy contexts, the episodes must be re-weighted to reflect the entire season or year. To re-weight the episodes, we follow Deuel and Douglas (1998) in using a Classification and Regression Tree (CART) approach. CART is a non-parametric regression technique that predicts discrete (e.g. high-medium-low) levels of a variable of interest (e.g. PM_{10} or ozone levels) by grouping observations based on the similarity of predictive observables, e.g. independent variables. The model segments the N-dimensional space of independent variables into cells. Our independent variables include average humidity, precipitation, air pressure, average wind speed, resultant wind speed, temperature, and horizontal sigma (standard deviation of horizontal wind directions). Air quality and meteorological data for this analysis are taken from the Whiteface Mountain Base monitoring station. Other upper air meteorological data was obtained from Radiosonde Data of North America from NOAA. From this data set we used upper air observations from the airport at Albany, New York as a proxy.

Seasonal and annual weights are then based on the proportion of days in each cell for an entire five-year (1992–1996) period experienced by New York relative to those in our episodes. Consider particulates as an example. First, we group the PM_{10} days into four classes based on observed daily average PM_{10} concentrations (<6 micrograms per cubic meter ($\mu g/m^3$), 6-20 $\mu g/m^3$, 20-24 $\mu g/m^3$, and >24 $\mu g/m^3$). We then re-weight the days in each class by the proportion of days in the season/year, relative to the episodes. For example, if the episodes have fewer PM_{10} days below 6 $\mu g/m^3$ relative to the yearly average number of days, and more days above 24 $\mu g/m^3$, we would underweight the former and overweight the latter. Then, within each class, we re-weight each day by the proportion of days in the same cell of independent variables predicted to cause that class. For example, within the set of cells predicted to cause high PM_{10} days (>24 $\mu g/m^3$), if we find more hot days where the previous day was cool, relative to the actual number of such days, and fewer back-to-back hot days, we would under-weight the former and over-weight the latter. In this way the episodes are re-weighted to represent the outcomes of interest, and the various types of conditions associated with similar outcomes. We use information on PM_{10} to develop weights for source-receptor coefficients for fine particulates because only data on PM_{10} were available to us.

Section 4

DESCRIPTION OF SCENARIOS

4.1 OVERVIEW

This analysis simulates the effects of different federal multipollutant policies on electricity costs, prices, emissions, air quality, and environmental health benefits both in New York and across the nation by comparing several different multipollutant policy scenarios to a baseline scenario using the models described in the previous section. To be relevant to the current policy debate we evaluate three different multipollutant policy cases that coincide with recent proposals. All of these policies include EPA's Clean Air Interstate Rule for SO_2 and NO_x in combination with different approaches to reducing mercury emissions from electricity generators nationwide:

1. **CAIR plus EPA Mercury Cap**: The Clean Air Interstate Rule (CAIR) as originally proposed coupled with a companion national mercury cap, based on EPA's proposed cap, with unrestricted trading of mercury emission allowances. Under this scenario, the seasonal cap-and-trade program for NO_x for electricity generating units in the State Implementation Plan (SIP) seasonal NO_x trading program is no longer in effect. In all of the CAIR and national allowance trading programs, allowances are distributed initially based on historic emissions.

2. **CAIR plus EPA Mercury and Seasonal SIP NO_x Policy**: This scenario combines scenario 1 with the continuation of the seasonal cap-and-trade program for NO_x emissions from electricity generating units in the NO_x SIP Call region. Although the originally proposed CAIR rule would have suspended the current seasonal NO_x policy, in the final rule a seasonal program is reconstituted.

3. **CAIR plus Tighter Mercury with MACT**: This scenario includes the CAIR as represented in scenario 1 coupled with a national requirement that all coal-fired generators achieve either a 90% reduction in mercury emissions or a target emission rate of 0.6 lbs of mercury per trillion Btu of heat input, whichever is less expensive at the particular facility.

4. **CAIR plus Tighter Mercury with Trading**: This scenario models the CAIR coupled with a national cap-and-trade program for mercury where the national annual emission cap for mercury in each year is set at the national annual mercury emission level realized under the version of the Tighter Mercury with MACT rule modeled in scenario 3.

The variations in how mercury emissions are regulated under these four different scenarios will have important implications for emissions of other pollutants. At many model plants the lowest cost way to reduce mercury emissions is to consider co-control of mercury, SO_2 and NO_x, which could lead to the installation of some combination of SO_2 and NO_x controls. Thus differences in mercury regulations across the different scenarios can affect the level of emissions of SO_2 and NO_x from individual plants and in the aggregate. Tighter restrictions on mercury emissions may necessitate greater use of scrubbers and of SCR, both of which can provide important reductions in mercury emissions, particularly when used in combination at plants that burn bituminous coal. The form of the mercury regulations for a fixed aggregate emission level could also affect the types of controls installed, the location of those controls and thus location of emissions of SO_2 and NO_x and the associated air quality and environmental and health benefits of a policy.

4.2 ASSUMPTIONS THAT ARE MAINTAINED IN ALL POLICY SCENARIOS

The simulations look at a roughly 16-year forecast horizon. The model is solved for the years 2005, 2010, 2015, and 2020 and results are reported for 2010 and 2020. The underlying demand model assumes that national average electricity demand grows at a rate of about 1.8% per year over the forecast period. For New York, the electricity demand functions are scaled to replicate as closely as possible the 2004 NYSERDA electricity demand forecasts for the state in our baseline model run. The NYSERDA forecast assumes an average annual growth rate of about 1% per year between 2005 and 2020. All prices are reported in 1999 dollars.

Throughout this analysis, we make several assumptions about underlying policies, both federal and state environmental policies and market regulatory policies that affect the performance of electricity generators. We assume electricity generators face no requirements to reduce mercury or CO_2 emissions in the baseline scenario. We include all new source review (NSR) settlements announced as of April 2004 in our technical assumptions about emission control at existing generators.[18] We also include a representation of two federal policies to promote renewables. We assume that the renewable energy production credit (for dedicated biomass and wind generation) is extended through 2005 and is then phased out between 2005 and 2010.[19] We also include a perpetual 10% investment tax credit for new geothermal resources.

We do not model the New York renewable portfolio standard (RPS) explicitly because it was not policy at the time that modeling was conducted; however, we do examine it in a special sensitivity analysis. We include several state-

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[18] NSR settlements are those that electricity generating companies have reached with the federal government to bring their plants into compliance with New Source Review requirements for emission reductions that the government claims were violated by past investments at specific facilities. We assume the Cinergy proposed settlement is adopted. We do not include the NRG and AES settlements, although controls at the affected plants result from the policies that we model.

[19] In practice, facilities that qualify receive the credit for 10 years. In our model, they receive the credit indefinitely, but only as long as the credit is active.

level renewables policies in other states. To capture the anticipated effects of compliance with state-level renewable portfolio standards and other renewables policies and programs including green pricing on investment in new renewables, we incorporate EIA's estimates of new renewable resource investments to be put into place to comply with these policies.[20]

We incorporate the policies to limit SO_2 and NO_x in New York State under the Governor's Acid Rain Initiative; however, we do not model potential restrictions on emissions of CO_2 through the Regional Greenhouse Gas Initiative. In practice, the SO_2 and NO_x policies in New York State take the form of caps on emissions from electricity generators. The NO_x policy applies to all fossil fuel–fired electricity generating units larger than 25 MW. This policy applies a cap on NO_x emissions during the months not covered by the NO_x SIP Call. We implement this policy in the model by requiring the NO_x controls that were installed to comply with the SIP Call to run all year long, which results in total NO_x emissions substantially below the effective annual cap of roughly 73,000 tons. The New York State SO_2 policy applies to all Title IV–affected units and is imposed in two phases: 199,600 tons per year beginning in 2005 and 133,000 tons per year beginning in 2008.[21] Unlike the other state-level environmental policies for which exogenous compliance strategies are imposed, we model compliance with this cap endogenously. We also include the anticipated effects of state-level multipollutant policies in the following states: Connecticut, Massachusetts, Missouri, New Hampshire, North Carolina, Texas, and Wisconsin.[22]

With respect to electricity price regulation, we assume that electricity prices are set competitively in six NERC regions—New York, New England, Mid-Atlantic (MAAC), Illinois area (MAIN), the Ohio Valley (ECAR), and Texas (ERCOT)—and that there is time-of-day pricing of electricity for industrial customers in these regions. In all other regions of the country, we assume that prices are set according to cost-of-service regulation at average cost.

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[20] This means we are including the effects of state level RPS policies in Arizona, California, Connecticut, Massachusetts, New Jersey, Nevada, Texas, and Wisconsin. It includes the effects of green pricing programs in several states and renewables mandates in Minnesota. For more information see EIA (2004). This analysis does not include the effects of the New York renewables requirement that was finalized in 2004 or of other state-level RPS policies that were adopted after the end of 2003.

[21] We exclude the following three plants, which each have only one boiler that burns coal (at least in part), from New York's SO_2 trading program: Fort Drum H T W Cogenerator, CH Resources Niagara, and Fibertex Energy LLC (these were the names used to refer to these plants in 1999). These units are all historically non-utility generators and have PURPA exemptions.

[22] Several states have passed laws limiting emissions of some combination of NO_x, SO_2, mercury, and CO_2 from electricity generators. Most of these laws or regulations, such as new regulations in Connecticut and Massachusetts that limit nonozone season emissions of NO_x, are formulated as limits on emission rates. The largest state actions are in North Carolina and New York, which have recently placed emissions caps on their largest coal-fired plants. A similar plan has been adopted in New Hampshire for all existing fossil fuel generators. With the exception of New York, we model compliance with these policies exogenously. The state policies and how they are implemented in our model are described in Appendix 5.

We simulate the model through 2020 and extrapolate our results out to 2030 for purposes of calculating returns to investment choices. We report results for the years 2010 and 2020.

4.3 BASELINE

The baseline scenario includes environmental policies that were already in effect at the time the modeling was done. For SO_2, we assume that the Title IV SO_2 cap-and-trade program is in effect. National SO_2 emissions are phased down over time to reflect the drawdown of existing bank of SO_2 allowances. For NO_x, we assume that the NO_x SIP Call policy is in effect in all regions that contain SIP Call states. The cap that we model is increased from the actual SIP cap levels to incorporate emissions for extra plants within the regions that are not affected by SIP Call.[23] The policy is modeled as a regional cap-and-trade program in summer months. Electricity generators face no restrictions on emissions of mercury or CO_2 in the baseline scenario.

For generators in New York, we assume that the restrictions on SO_2 and NO_x emissions under the regulations implementing the governor's acid rain program come into place in 2005 with the SO_2 cap being substantially scaled down in 2008. We model the New York NO_x policy by assuming that controls put in place to comply with the NO_x SIP Call will be operated year round. The SO_2 policy is modeled as a cap-and-trade program that applies to coal-fired generators affected by Title IV. Under this program, SO_2 allowances are allocated to SO_2 emitting facilities according to updating formula based on heat input.[24]

4.4 CAIR PLUS EPA MERCURY

The first policy scenario that we analyze is the EPA's Clean Air Interstate Rule (CAIR) in combination with the version of EPA's proposed mercury rule that includes mercury trading.[25]

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[23] For modeling convenience our version of the NO_x SIP Call region includes all the generators located in New England, New York, MAAC, ECAR, and SERC. Thus, we inflate the summertime NO_x emissions cap to be large enough to cover emissions from those generators in this region not covered by the regulation.

[24] Under the form of updating modeled in the New York SO_2 policy, emission allowances are distributed to emitting plants based on their share of total electricity generation from all plants covered by the regulation in the year three years prior to the current year. As a facility increases its share of generation, it gradually increases its share of total emission allowances.

[25] The two competing proposals for regulating mercury from EPA and the resulting final rules are described in Appendix 4.

Under the originally proposed version of CAIR, emissions of SO_2 and NO_x are regulated within a 28 state region, mostly east of the Mississippi, plus the District of Columbia.[26] The region is a supplement to the Title IV SO_2 trading program and a replacement for the seasonal NO_x SIP Call program for electricity generating units.

Under the proposed rule, regional annual SO_2 allowance distributions are capped at 3.9 million tons beginning in 2010 and 2.7 million tons beginning in 2015. Actual emissions will be higher over the modeling time horizon due to the allowance bank. We follow EPA modeling of the SO_2 CAIR and Title IV within one national trading regime. A single national region is characterized using model results that account for the opportunity to use Title IV allowances within the CAIR region at an offset ratio that changes over time. The actual emission caps that we model are reported in Table 7.

Under CAIR as proposed, regional annual NO_x emission distributions are capped at 1.6 million tons beginning in 2010 and 1.3 million tons beginning in 2015. The NO_x caps that we model, as reported in Table 7, include an adjustment of about 331,000 tons for units outside the CAIR NO_x region but within the MAPP and New England electricity regions in the model.

Table 7. Annual Emissions under CAIR policy with Proposed EPA Mercury Rule as Modeled in Haiku

(tons)	**2010**	**2015**	**2020**
NO_x (million)	1.931*	1.631*	1.631*
SO_2 (million)	6.078	5.001	4.264
Mercury	30.445	27.565	24.985

*NO_x caps include an adjustment of about 331,000 tons for units outside the CAIR NO_x region but within the MAPP and New England electricity regions in the model.

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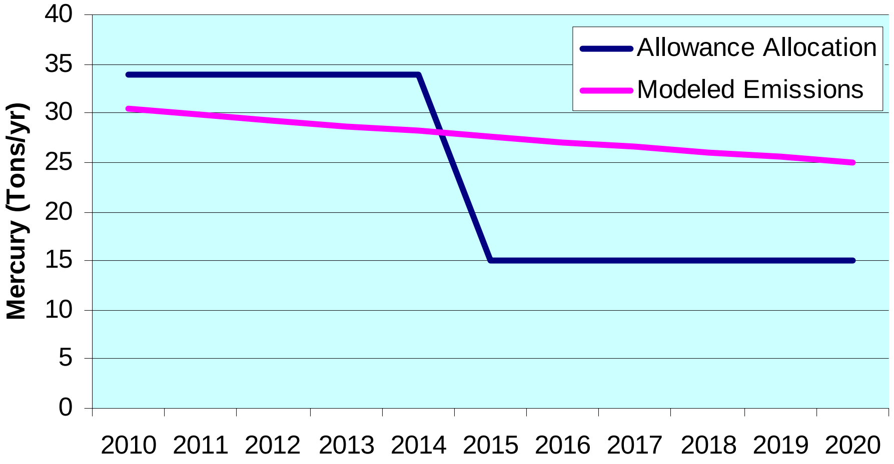
[26] The 28 states included in the region covered by the proposed version of the CAIR rule are: Alabama, Arkansas, Delaware, Florida, Georgia, Illinois, Indiana, Iowa, Kentucky, Kansas, Louisiana, Maryland, Massachusetts, Michigan, Minnesota, Mississippi, Missouri, New Jersey, New York, North Carolina, Ohio, Pennsylvania, South Carolina, Tennessee, Texas, Virginia, West Virginia, and Wisconsin.

Under the mercury cap-and-trade program found in the proposed version of the mercury rule, the national annual allocation of emission allowances is capped at 34 tons beginning in 2010 and 15 tons beginning in 2018. Actual emissions will vary over the modeling time horizon due to the allowance bank and also due to the safety valve that places a ceiling on mercury allowance prices. We model cap and trade for mercury and we adopt as our mercury emission cap EPA's prediction of annual emissions in the presence of a $35,000 per pound safety valve ceiling on the price of mercury permits and the ability to bank allowances. Hence, as shown in Table 7, the mercury emission targets that we actually model are 30.4 tons in 2010, which is lower than the allocation because firms are expected to bank emission allowances. We model emissions of 25.0 tons in 2020, in excess of the allocation for that year, as firms draw down the allowance bank and also because the safety valve price is reached in the EPA modeling. The safety valve ceiling on allowance price in the EPA's proposed rule is implemented by issuing additional allowances. Allowances purchased at the safety valve price reduce the size of the allocation in the following year. However, if the safety valve price were achieved again in the following year then emissions over time would approximate the level that achieves a steady allowance price equal to the safety valve. The effect is to cause total emissions to exceed the intended emission cap, which is illustrated in Figure 4. In the EPA's final rule, the safety valve is removed and replaced by an increase in the number of emission allowances that are distributed in phase I that be banked for use in subsequent periods.

Figure 4. Mercury Allowance Allocation and Modeled Mercury Emissions



Continuation of the SIP Seasonal NO_x Policy

The second policy that we model adds the SIP Seasonal NO_x cap to the combination of the proposed version of the CAIR rule and the EPA Mercury Cap. We investigate this additional scenario because, as indicated in results below, we find emissions during the summer ozone season within the eastern region increase under the CAIR rule as proposed and the EPA Mercury Cap when the seasonal NO_x program is terminated as specified in the draft CAIR rule. Two possible remedies to this increase are tighter annual caps or maintenance of a seasonal cap. The policy scenario we model here is the latter. The policy ensures that emissions of NO_x during the five-month ozone season do not exceed levels established under current policy to help reduce summer ozone problems. Having two NO_x policies of this sort means that generators that are located within both the CAIR region and the SIP region must have two permits for every ton of NO_x emitted in the summer season. The dual programs mean that the costs of NO_x controls will be split between two regulatory targets and the prices of CAIR NO_x allowances are expected to be lower when they are combined with the SIP Call than when they are not.

4.5 PROPOSALS FOR TIGHTER RESTRICTIONS ON MERCURY

The two other national policy scenarios that we analyze involve greater restrictions on emissions of mercury achieved through two different policy measures: a common MACT requirement on all coal-fired generators and a mercury emissions trading approach targeted to achieve the same level of aggregate mercury emissions.

As mentioned above, the Tighter Mercury with MACT scenario includes a requirement that all coal-fired electricity model plants reduce emissions by 90 percent or achieve an emission rate of 0.6 pounds per trillion Btu of heat input, whichever is less expensive. This proposed flexible MACT standard has been advanced by several of the state government representatives to the Working Group for the Utility MACT of the Clean Air Act Advisory Committee, or CAAAC (Working Group for the Utility MACT of the Clean Air Act Advisory Committee 2002).[27] The proposal results in an increase in mercury emissions over time as electricity demand increases and use of coal-fired generators also increases to help meet that demand. Under these scenarios we assume that the preexisting bank of SO_2 emission allowances is drawn down at the same rate as under the CAIR plus EPA Mercury Cap scenario. As discussed below, this assumption may not be consistent with economic behavior if the industry anticipates the changes in SO_2 allowance prices that result from the tighter mercury standard.

Under Tighter Mercury with Trading, the same level of aggregate mercury emissions is achieved as under the MACT standard. Under the trading approach, mercury emission allowances are distributed to coal- and oil-fired generators on the basis of historic emissions of mercury.

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[27] The CAAAC is a committee established to advise the EPA on how issues related to implementation of the 1990 Clean Air Act Ammendments. The state recommendations are found in Appendix C of the Working Group report.

Section 5

ELECTRICITY SECTOR RESULTS

In this section, the results of the electricity model runs for the different scenarios are compared to the baseline runs. A subsequent section focuses on the results of the air quality modeling.

5.1 BASELINE DEMAND

As mentioned above, we modified the parameters of the electricity demand functions in our model to yield the NYSERDA electricity demand forecast for New York in the baseline scenario. Our baseline demand forecasts for New York State are compared to NYSERDA's forecasts in Table 8. This comparison shows that our model came very close to replicating the NYSERDA forecast. These modified electricity demand functions, one for each customer class in each time block and season, are used throughout the scenario analysis.

Table 8. Comparison of NYSERDA Electricity Demand Forecast and Haiku Electricity Demand Forecast for New York State

	2005	2010	2015	2020
NYSERDA Forecast	145.2	157.6	165.0	169.3
Haiku – New York	148.4	160.9	164.2	166.7
% Difference	+2.2%	+2.1%	-0.5%	-1.5%

5.2 ELECTRICITY PRICE, CAPACITY, AND GENERATION

<u>**National Results**</u>

With the exception of the CAIR policy coupled with the Tighter Mercury with Trading, the policies analyzed have relatively small impacts on the national average price of electricity or on the mix of fuels used to generate electricity across the nation. The Tighter Mercury with Trading policy scenario leads to the greatest shifts away from coal and toward natural gas, while the Tighter Mercury with MACT policy results in the smallest amount of shifting away from coal to other fuels. These effects are summarized in Table 9 for 2010 and Table 10 for 2020, which show new additions in capacity after 1999.

Table 9. Overview of Electricity Price, Generation, and New Capacity National Results for 2010

		CAIR plus			
	Baseline	*EPA Mercury CAP*	*EPA Mercury Cap and Seasonal SIP NO_x Policy*	*Tighter Mercury with MACT*	*Tighter Mercury with Trading*
Average Electricity Price (1999$/MWh)	61.9	62.8	62.7	63.2	67.3
National Generation (billion kWh)					
Coal	2,326	2,271	2,257	2,283	1,960
Gas	658.9	684.9	693.4	671.8	903.5
Oil	31.5	23.7	24.8	26.1	37.0
Nuclear	763.6	781.2	786.7	776.3	808.1
Hydro	310.6	310.6	310.8	310.7	310.6
Other Renewable	111	111.2	111.4	110.1	126.2
Total	4,202	4,183	4,184	4,178	4,145
New Capacity (MW)					
Coal	2,226	2,286	1,751	2,047	3,273
Gas	239,500	240,700	240,100	239,400	242,000
Renewables	11,320	11,320	11,320	11,200	12,100
Total	253,100	254,400	253,200	252,700	257,500

The price effects for the CAIR plus EPA Mercury (CAIR/m) both with and without the NO_x SIP Call and CAIR plus Tighter Mercury with MACT scenarios are larger in 2010 than they are in 2020. National electricity price is roughly 1.5% higher with CAIR/m than in the baseline in 2010 and 1.0% higher in 2020. The price impact is greater with the Tighter Mercury with MACT scenario in 2010, when prices rise by 2.1% in 2010 and by 1.9% in 2020. Reductions in demand from these policies are commensurately small.

Under the CAIR plus Tighter Mercury with Trading scenario, the electricity price difference from the baseline is much more substantial. Average national electricity price is 8.7% higher than in the baseline in 2010 and 7.4% higher in 2020. This higher price impact follows from the use of an allowance trading system for mercury emissions and very high prices for mercury allowances under this scenario, which are discussed in Section 5.3 below.

Table 10. Overview of Electricity Price, Generation, and New Capacity National Results for 2020

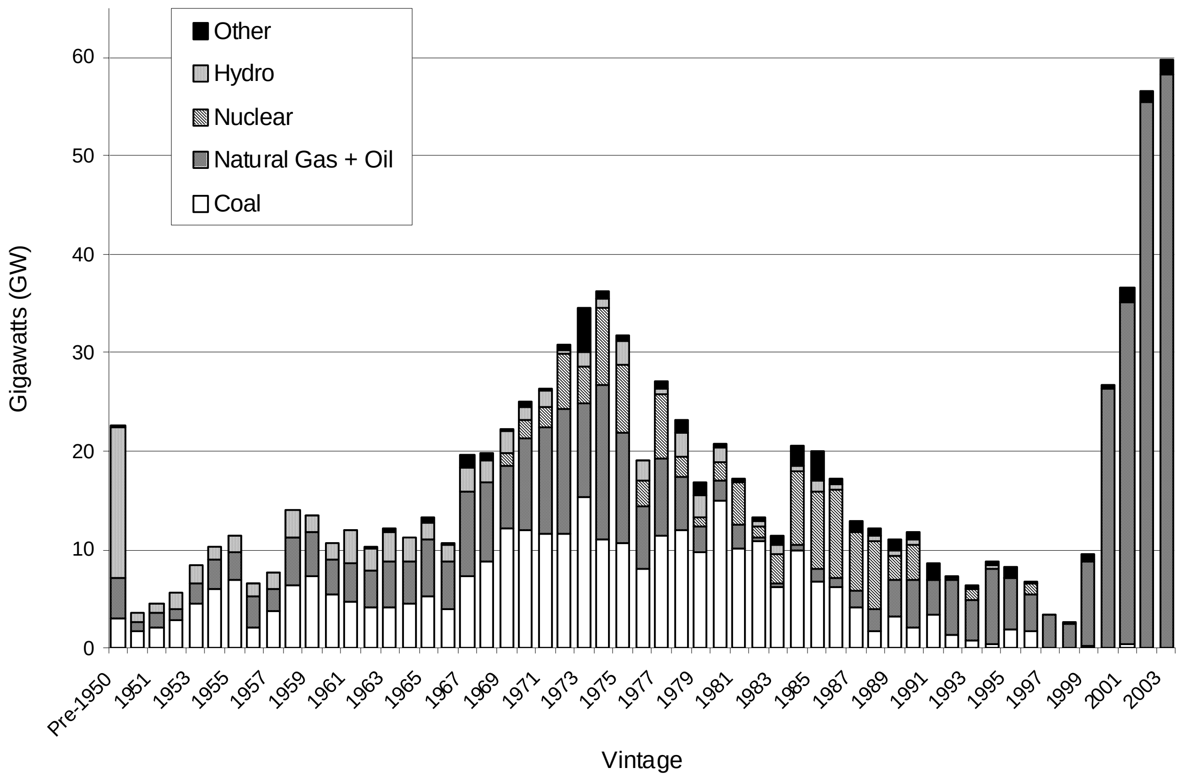
		CAIR plus			
	Baseline	*EPA Mercury CAP*	*EPA Mercury Cap and Seasonal SIP NO_x Policy*	*Tighter Mercury with MACT*	*Tighter Mercury with Trading*
Average Electricity Price (1999$/MWh)	68.6	69.3	69.3	69.9	73.7
National Generation (billion kWh)					
Coal	2,618	2,556	2,536	2,538	2,206
Gas	940.6	988.9	993.5	1,000	1,233
Oil	37	28.0	27.6	22.6	31.4
Nuclear	780.6	798.0	803.8	792.7	825.9
Hydro	310.8	310.8	310.8	310.8	310.8
Other Renewable	170	171.79	171.1	170.8	186.6
Total	4,857	4,853	4,843	4,835	4,794
New Capacity (MW)					
Coal	30,650	28,590	26,860	27,620	33,440
Gas	305,800	312,600	310,700	316,100	327,300
Renewables	18,850	18,960	18,930	18,960	19,870
Total	355,300	360,200	356,500	362,700	380,700

The different policy scenarios have little effect on the mix of new capacity additions by 2010. Additions to coal-fired capacity are actually virtually unchanged from the baseline to the EPA Mercury Cap policy without the NO_x SIP Call, but they fall with the SIP Call and with the Tighter Mercury with MACT scenario. Additions to coal-fired capacity increase with the Tighter Mercury with Trading scenario. Under all scenarios the significant majority of the new capacity is gas-fired and the quantity of new gas-fired capacity brought on-line by 2010 varies little across scenarios. As indicated by Figure 5, most of this increment in new gas-fired capacity is actually on line before 2005. By 2020, the differences in the mix of new capacity additions across the different scenarios are more pronounced. In the Tighter Mercury with Trading scenario, new coal-fired capacity is 9% greater than in the baseline. In the other three scenarios we see a decline in capacity of comparable magnitude. In all cases there is a greater amount of investment in new gas than under the baseline. The greatest change is in the Tighter Mercury with Trading scenario, when the change in new gas-fired capacity is over 7% greater than the significant investment already occurring in the baseline.

The CAIR plus EPA mercury policy has a small but discernable effect on the mix of generation. Coal generation is roughly 2.4% below baseline levels in both 2010 and 2020. Under both the EPA mercury policy with the NO_x SIP Call and the Tighter Mercury with MACT policies, coal generation is 3% below baseline levels in 2020. Under the Tighter Mercury with Trading scenario coal-fired generation falls 16% below baseline levels in 2010 and 2020. Coupled with an increase in new coal-fired capacity in the Tighter Mercury with Trading scenario, we see an important shift in generation away from older, dirtier capacity to generation at newer cleaner capacity in the face of a trading program. This shift is pronounced under the trading program because the high cost of emission allowances imposes a significant opportunity cost on mercury emissions that is not evident under MACT regulation, a point we return to at length below.

Figure 5. Historic Capacity Additions by Year and Fuel

(Source: Energy Information Administration Form 860 datasheet for 2002)



The overall drop in coal generation is largely offset by increases in generation with natural gas and at nuclear plants and small increases in non-hydropower renewables. Natural gas generation in 2010 increases by 1.8% to 5.3% in all scenarios, except the Tighter Mercury with Trading scenario when gas generation increases by 37%. In 2020 the increase in natural gas generation is 5–6% in all scenarios except the Tighter Mercury with Trading scenario, when gas generation increases by 31%.

In actual magnitudes under the Tighter Mercury with Trading scenario, the nearly 366 billion kWh drop in coal generation in 2010 is partially offset by a 245 billion kWh increase in gas generation and a 45 billion kWh increase in nuclear generation. The high price of mercury emission allowances under this scenario provides a strong disincentive to burn coal that doesn’t exist under the other policy scenarios. Total generation is lower in 2010 and 2020 in all the scenarios than in the baseline, but the only substantial decline of 1.1% occurs under the Tighter Mercury with Trading scenario.

New York State Results

The price results for New York State are presented in Tables 11 and 12. With the exception of the Tighter Mercury with MACT scenario, electricity price in New York under all the policies is higher in 2010, with the greatest increase of 9.8% occurring under the Tighter Mercury with Trading scenario. The magnitude of changes in New York in 2010 is slightly greater in absolute terms than for the nation as a whole. In New York, as for the nation, the additional costs of MACT compliance appears to be less than the cost of having to purchase mercury allowances as required under all other mercury policies. The CAIR plus EPA Mercury Cap scenarios (both with and without the NO_x SIP Call) have a larger relative effect on price in New York in 2010 than at the national level.

Table 11. Overview of Electricity Price and Generation
New York State Results for 2010

		CAIR plus			
	Baseline	*EPA Mercury CAP*	*EPA Mercury Cap and Seasonal SIP NO_x Policy*	*Tighter Mercury with MACT*	*Tighter Mercury with Trading*
Average Electricity Price (1999$/MWh)	90.9	93.2	94.4	89.5	99.8
Statewide Generation (billion kWh)					
Coal	30.8	30.7	29.2	30.8	0.9
Gas	35.8	35.3	35.5	36.5	57.5
Oil	13.6	11.2	11.8	11.9	14.2
Nuclear	38.8	38.8	38.8	38.8	38.8
Hydro	25.7	25.7	25.7	25.7	25.7
Other Renewable	2.4	2.4	2.4	2.4	2.9
Total	147.1	144.0	143.4	146.0	140.0
New Capacity (MW)					
Gas	3,128	3,128	3,128	3,128	3,886
Renewables	63	63	63	63	102
Total	3,208	3,208	3,208	3,208	4,006

In 2020 results for New York differ systematically from results for the nation. None of scenarios lead to an increase in electricity price in New York above the baseline, and in some cases there is a price drop, although there is little change in general.

There are two reasons why one would expect the Tighter Mercury with MACT standard to have a smaller effect on electricity price in New York than in other regions or in the nation as a whole. One reason is that in New York coal is responsible for only a little over 20% of all generation whereas nationwide coal accounts for closer to 50% of total generation.

The second reason is that market-based pricing of electricity in New York means that electricity price is based on the cost of the marginal generator. The additional cost of mercury compliance is not automatically reflected in

Table 12. Overview of Electricity Price and Generation
New York Results for 2020

		CAIR plus			
	Baseline	*EPA Mercury CAP*	*EPA Mercury Cap and Seasonal SIP NO_x Policy*	*Tighter Mercury with MACT*	*Tighter Mercury with Trading*
Average Electricity Price (1999$/MWh)	104.5	104.5	104.3	104.1	104.2
Statewide Generation (billion kWh)					
Coal	31.5	31.5	31.5	31.5	0.4
Gas	33.5	39.5	36.2	37.7	75.6
Oil	16.1	13.8	13.4	12.1	12.1
Nuclear	39.8	39.8	39.8	39.8	39.8
Hydro	25.9	25.9	25.9	25.9	25.9
Other Renewable	2.8	3.0	3.0	2.8	3.2
Total	149.7	153.5	149.8	149.8	157.0
New Capacity (MW)					
Gas	3,242	4,201	4,192	3,277	6,397
Renewables	105	106	114	105	131
Total	3,365	4,324	4,323	3,399	6,545

electricity price if coal-fired plants are not the marginal generator. Since coal represents a small portion of electricity generation in New York it is rarely if ever at the margin. In contrast, in other regions with market-based electricity prices, with more coal in the mix, a coal generator is more likely to be the marginal generator during a larger fraction of the year than occurs in New York, and thereby the cost of compliance with mercury standards is more likely to be reflected in price. On the other hand, in regulated regions like the Southeast, where electricity price is based on average cost, the cost of compliance automatically will be reflected in the price. The national average price is a combination of the prices set in competitive regions and in regions that regulate electricity price to be equal to average cost. Hence, we expect the change in the national electricity price to be greater than the change in New York because of greater reliance on coal and because of the way in which electricity prices are set across the nation.

The different multipollutant policies have no effect on cumulative investment in new generation capability in 2010 in New York State with the exception of Tighter Mercury with Trading, when new gas-fired capacity increases by nearly 25%. By 2020 the EPA Mercury Cap (with and without the NO_x SIP Call) and the Tighter Mercury with MACT policies both lead to substantially higher cumulative investment in new gas-fired generating facilities of roughly 30% in New York than under the baseline. Cumulative investment in new gas generation is virtually unchanged under the Tighter Mercury with MACT policy. But new gas is almost double that of the baseline under the Tighter Mercury with Trading policy

The differences in generation in New York from the baseline across the scenarios are less than 2.5% in every case except with the Tighter Mercury with Trading policy. For all scenarios, total generation is less than baseline in 2010 and greater than the baseline in 2020. One reason is that currently planned additions to capacity are relatively less important in 2020 than in 2010. By 2020 the electricity market provides a greater opportunity for new investment. A large share of that is natural gas, which can be located closer to demand centers in New York and can replace some of the generation at coal plants in neighboring regions that supply imported power and which see costs go up under the various policies. In New York, the policies are leading to a decline in oil generation, which is covered by all emission caps, in both 2010 and 2020. By 2020 new gas investment more than offsets the loss in oil generation.

The mix of fuels used to generate electricity in New York changes very little under the EPA mercury and Tighter Mercury MACT policies in 2010. In 2020, there is an increase in gas-fired generation of 8%–18% across these policies. However, the Tighter Mercury with Trading policy leads to a virtually complete shift out of coal and into natural gas exhibited in both the 2010 and 2020 results. A small amount of generation of less than 3% of baseline levels reported in the tables reflects the survival of coal capacity as capacity reserve and its very occasional dispatch. This quantity of generation from the large existing capacity is not distinguishable from zero in the model results. The decline in coal generation is made up largely by greater generation from natural gas with a 61% increase in gas generation in 2010 and a 126% increase in 2020.

The forecast of a complete shift out of coal in New York State under the Tighter Mercury with Trading policy invites analysis of the level of stringency that precipitates this shift. As an extension to this project, Evans et al. (2005) used the model and assumptions to evaluate a schedule of mercury targets, each to be achieved with trading. At a mercury cap level of 11.4 tons, less than one-half the EPA Mercury Cap level of 25 tons, 95% of the coal-fired generation in New York still survives in 2020. However, at levels of stringency beyond this level coal-fired generation falls rapidly. At a mercury cap of 10 tons, generation is just 75% of the level under the EPA Mercury Cap and at 8.73 tons, generation falls to 46% of the mercury cap level. Finally, as noted in Table 12, at the tighter mercury cap of 8.23 tons the level of coal-fired generation in New York is approximately zero. Hence, there appears to be a sharp turning point in fuel choice for generation in New York State that corresponds with a national mercury cap of about 12 tons. At caps above this level, the amount of coal-fired generation in New York State is fairly constant, and below this level coal-fired generation falls rapidly.

5.3 EMISSIONS AND ALLOWANCES

The emissions and allowance price findings are reported in Tables 13 and 14 for 2010 and 2020, respectively. The top section of each table includes national annual emissions from the sector. Only mercury emissions from units affected by the policy including coal- and oil-fired generators are reported. The bottom section includes emissions from generators in New York. The middle section reports allowance prices for all pollutants regulated under a cap-and-trade program including the New York State SO_2 program. In New York State, SO_2 emitting generators covered by Title IV must surrender both a national SO_2 emission allowance and a New York State emission allowance for every ton of SO_2 emitted.

Table 13. Emissions and Allowance Prices in 2010

		CAIR plus			
	Baseline	***EPA Mercury CAP***	***EPA Mercury Cap and Seasonal SIP NO_x Policy***	***Tighter Mercury with MACT***	***Tighter Mercury with Trading***
National Emissions (million tons)					
SO_2	9.64	6.10	6.05	6.05	3.62
NO_x	3.85	2.77	2.82	2.33	2.66
Mercury (tons)	53	30.57	30.57	9.50	9.63
CO_2	2,866	2,808	2,798	2,814	2,555
Allowance Prices ($ per ton)					
National SO2	110	359	346	311	-
NO_x	5,082	1,020	533	932	534
Mercury ($ per lb)	-	80,930	77,980	-	721,800
NY State SO_2	481	14	-	100	-
New York State Emissions (thousand tons)					
SO_2	193.1	182.4	162.9	173.0	43.2
NO_x	55.7	65.7	51.6	44.6	39.3
Mercury (tons)	0.91	0.50	0.57	0.20	0.05
CO_2	66,240	63,810	62,820	65,150	44,870

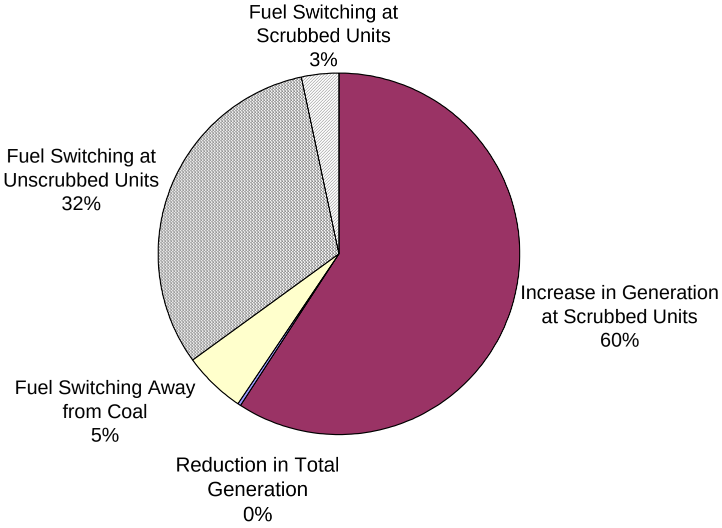
Table 14. Emissions and Allowance Prices in 2020

	Baseline	*CAIR plus*			
		EPA Mercury CAP	*EPA Mercury Cap and Seasonal SIP NO_x Policy*	*Tighter Mercury with MACT*	*Tighter Mercury with Trading*
National Emissions (million tons)					
SO_2	8.94	4.26	4.30	4.31	3.28
NO_x	4.04	2.59	2.56	2.13	2.39
Mercury (tons)	53.5	24.58	24.99	8.17	8.23
CO_2	3,260	3,202	3,186	3,178	2,895
Allowance Prices ($ per ton)					
National SO_2	184	1,347	1,222	1,948	-
NO_x	7,140	1,042	1,048	2,155	581
Mercury ($ per lb)	-	36,040	35,760	-	1,429,000
NY State SO_2	397	-	-	-	-
New York State Emissions (thousand tons)					
SO_2	192.8	127.6	116.7	71.5	36.5
NO_x	55.4	67.6	53.8	39.2	36.8
Mercury (tons)	0.92	0.48	0.52	0.17	0.03
CO_2	67,230	68,220	66,000	66,000	49,880

CAIR plus EPA Mercury Cap

All of the policies analyzed in this report lead to important reductions in national emissions of SO_2, NO_x, and mercury with varying degrees of ancillary reductions in carbon emissions. Under the CAIR policy with EPA Mercury Cap, national annual emissions of SO_2 and NO_x are 37% and 28% lower, respectively, than the baseline in 2010 and 52% and 36% lower, respectively, in 2020. Figure 6 illustrates how emission reductions are achieved.[28] Compared to the baseline, about 60% of emission reductions in 2020 are due to an increase in generation at scrubbed units. This applies to increased generation at units with preexisting scrubbers and generation at units with new retrofitted scrubbers. About 32% of the emission reductions come from switching to lower sulfur coal at unscrubbed units. Switching of fuel from coal to natural gas accounts for just 5% of emission reductions. We find that 3% of the emission reductions are achieved by the use of lower sulfur coals than were used in the baseline at scrubbed units. Reduction in total electricity demand accounts for nearly zero reduction in emissions.

Figure 6. How SO_2 Reductions Are Achieved in the CAIR plus EPA Mercury Policy



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[28] These shares are calculated under the assumption that increases in generation of scrubbed coal facilities come from reductions in generation from unscrubbed coal facilities. To calculate the share of emission reductions for each option in Figure 6 we use one of two approaches. For changes in generation using a specific technology or fuel we calculate the change (increase) in generation for that option relative to the baseline generation (MWh) multiplied by the difference in the emission rate for that compliance option relative to the average baseline emission rate (lb/MWh) for unscrubbed coal. For changes in emission rates due to post-combustion controls or fuel switching, the emission reductions are calculated by multiplying the change in emission rate (lb/MWh) from the baseline by the amount of generation (MWh) for that compliance option in the policy case. We assume also that reductions in consumption lead directly to reduction in generation from unscrubbed coal.

The ratcheting down of the SO_2 and NO_x caps in the CAIR policy leads to large reductions in national emissions of these pollutants after 2010, and annual mercury emissions also fall over the 2010 to 2020 decade. The CAIR plus EPA Mercury Cap policy results in a slight (roughly 2%) drop in CO_2 emissions from electricity generators nationwide.

An important difference between the baseline and the CAIR plus EPA Mercury Cap policy is that summertime emissions of NO_x increase. The CAIR policy imposes a national emission cap but it supplants the NO_x SIP Call and as a consequence we find emissions increase in summer. Without the NO_x SIP Call we find CAIR leads to emissions of NO_x during the five-month summer season in 2010 that are 21% above those achieved when the NO_x SIP Call is maintained, and about 19% above in 2020.

As a result of the tighter cap on emissions, the price of an SO_2 allowance is three times as large with the CAIR plus EPA Mercury Cap policy as it is in the baseline in 2010. In 2020, the ratio of the two prices is greater than seven. In the baseline, the NO_x price is for a seasonal allowance in the SIP region and thus the capital costs of NO_x control at the marginal unit are spread over a smaller quantity of NO_x reductions. Under CAIR, the NO_x policy becomes annual and the price per ton of NO_x is substantially lower. In addition, NO_x controls play a role in reducing mercury emission through the oxidation of mercury at SCR units, and this lowers the price of NO_x emission allowances because the requirement to reduce mercury emission presents a second reason to install such controls and their cost is reflected in part in the mercury allowance price. Note that when CAIR is combined with the NO_x SIP Call, generators in the SIP region must also surrender a SIP region NO_x allowance for each ton of NO_x emitted during the summer season. The price of the NO_x SIP Call allowances is $3,287 in 2010 and $1,127 in 2020. The decline in the price over time reflects the increasing stringency of constraints on SO_2 and mercury, which serves to reduce the opportunity cost of the NO_x SIP Call constraint. These values are somewhat less than in the baseline, where the prices are $5,082 in 2010 and $7,140 in 2020. With or without the NO_x SIP Call remaining in effect, the EPA Mercury Cap policy imposes a cap on mercury emission from coal-and oil-fired generators across the country. The allowance price is roughly $80,000 per pound of mercury emitted in 2010 and around $36,000 per ton in 2020, with the tighter caps on SO_2 and NO_x helping to lower the opportunity cost of mercury controls.

In New York the CAIR plus EPA Mercury Cap policy results in a reduction in SO_2 emission. Tables 13 and 14 show a price at or close to zero for New York SO_2 emission allowances, indicating the New York SO_2 cap does not bind under this policy in either 2010 or 2020.[29] Emissions of NO_x in New York are roughly 20% higher under the CAIR

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[29] If a constraint is important in determining the result of the model then the constraint is said to "bind." Alternatively, if the constraint does not influence the outcome then the constraint is said to be "slack."

plus EPA mercury policy without the NO_x SIP Call than in the baseline in both 2010 and 2020, but they are still below the New York annual NO_x cap of 72,972 tons. The addition of the NO_x SIP Call remedies this increase and NO_x emissions in New York are slightly lower than under the baseline.

The effect of the CAIR policy with the EPA Mercury Cap on installation of different combinations of pollution controls is presented in Table 15. The policy without the NO_x SIP Call results in roughly 30,000 MW of additional SO_2 scrubbing above the baseline level of approximately 126,000 MW in 2010 and 70,000 additional MW of scrubbing relative to a baseline level of roughly 159,000 MW in 2020. With the NO_x SIP Call in place there is a slightly smaller increase in scrubbing. The lion's share of the additional scrubbers is wet and most of those are used in combination with SCR, which helps maximize the mercury reductions from bituminous coal.

The total amount of SCR installed is about 12,000 MW lower with the CAIR plus EPA Mercury Cap policy than in the baseline in 2010 as firms have more flexibility and a wider market for NO_x allowances under CAIR than they did under the baseline. When CAIR is combined with the SIP seasonal NO_x policy, installations of SCR are unchanged relative to the baseline in 2010. However, the total amount of capacity without any NO_x control falls by 7,000 MW reflecting some retirement.

In 2020 there is an increase of SCR relative to the baseline in policies without and with continuation of the NO_x SIP Call, but in the latter case the increase is more than double and in addition there is about 13,000 MW more capacity with SNCR controls in 2020. The EPA Mercury Cap policy also brings about the installation of approximately 54,000 additional MW of new ACI controls in 2010 and about 76,000–79,000 additional MW in 2020, depending on whether the SIP Seasonal NO_x Policy is in place.

CAIR plus Tighter Mercury with MACT

Combining CAIR with the Tighter Mercury with MACT standard leads to greater reductions in mercury and other pollutants as well. Tables 13 and 14 indicate that nationwide mercury emissions fall to 18% of baseline levels in 2010 and 16% in 2020, levels that are about one-third those obtained by the CAIR plus EPA Mercury Cap policy. National emissions of NO_x fall by almost half from their baseline levels by 2020, and about 18% less than under CAIR with the EPA Mercury Cap. Emissions of SO_2 are 16% lower in 2010 in moving from the EPA Mercury Cap to the Tighter Mercury with MACT policy, but they are unaffected in 2020. In New York, the state SO_2 cap has a minimal effect on compliance decisions, as indicated by the price of $100 in 2010 and the policy does not bind in 2020 when state SO_2 allowances have a price of zero.

Table 15. Incremental Pollution Controls Installed on Coal-Fired Capacity

(Change from Baseline Measured in MW)

	CAIR plus			
	EPA Mercury CAP	***EPA Mercury Cap and Seasonal SIP NO$_x$ Policy***	***Tighter Mercury with MACT***	***Tighter Mercury with Trading***
	2010			
SO$_2$ / Mercury Controls				
Wet Scrubbers with NO SCR	-8,484	-2,605	-40,399	-3,464
Wet Scrubbers with SCR	27,490	24,660	65,880	26,540
Wet Scrubbers with ACI	7,994	4,145	7,319	21,524
Dry Scrubbers without ACI	-555	-566	-11,382	-2,922
Dry Scrubbers with ACI	3,815	2,356	33,102	60,972
ACI Alone	42,681	46,521	134,661	27,881
None	-87,400	-82,800	-249,867	-178,440
Selected NO$_x$ Controls				
Total SCR	-11,800	-200	23,300	-38,300
Total SNCR	-9,790	160	160	-7,950
Total with No NO$_x$ Controls	12,400	-6,900	-35,700	-1,200
	2020			
SO$_2$ / Mercury Control				
Wet Scrubbers with NO SCR	-11,917	-7,127	-40,727	-11,127
Wet Scrubbers with SCR	53,300	50,400	57,000	28,300
Wet Scrubbers with ACI	14,317	9,927	23,387	24,927
Dry Scrubbers without ACI	4,734	-1,366	-12,056	3,744
Dry Scrubbers with ACI	10,036	13,876	44,766	69,586
ACI Alone	56,941	55,891	115,661	34,761
None	-143,100	-139,800	-246,332	-195,520
Selected NO$_x$ Controls				
Total SCR	3,800	8,100	34,700	-29,400
Total SNCR	-8,950	4,300	11,330	-4,760
Total with No NO$_x$ Controls	-9,500	-27,200	-66,380	-14,900

National NO_x emissions under this policy are also lower in both 2010 and 2020 than under the EPA Mercury Cap policy. Aggregate annual emissions of NO_x within the CAIR region remain at the capped level set by the policy; however, emissions of NO_x outside the CAIR region fall substantially.

Lower emissions follow directly from more widespread application of SO_2 and NO_x controls at many plants to comply with the combination of the SO_2 and NO_x caps and the Tighter Mercury with MACT regulation. As shown in Table 15, more units install both wet and dry scrubbers with the Tighter Mercury with MACT policy than under the EPA Mercury Cap. Virtually all of the units that have wet scrubbers install SCR to get the added mercury reduction benefit. Use of ACI also grows substantially with the Tighter Mercury with MACT policy, although wider application of this technology yields no additional reductions in emissions of the other pollutants.

The Tighter Mercury with MACT policy also yields important reductions in emissions from generators within New York State, where mercury emissions fall by close to 82% of the baseline in 2020, and they are roughly one-third the levels achieved under the CAIR plus EPA Mercury Cap policy. Emissions of SO_2 from the electricity sector are roughly 63% below the baseline level in 2020 and emissions of NO_x are roughly 30% lower than baseline, and they are also substantially lower than the levels achieved with the EPA Mercury Cap policy.

CAIR plus Tighter Mercury with Trading

This scenario uses a cap-and-trade approach to achieve the level of total emissions of mercury nationwide in each year that resulted under the Tighter Mercury with MACT policy. Because the MACT policy did not involve an explicit cap, but instead reductions in emission rates, the total level of mercury emissions obtained under a MACT policy changes over time. Annual mercury emissions from affected facilities are roughly 9.6 tons in 2010 and 8.2 tons per year in 2020.

The effect of the Tighter Mercury with Trading policy on emissions of other pollutants follows in part from the large shift from coal to natural gas that happens with this policy and from the mix of control technologies used to reduce mercury. By 2010 with the introduction of mercury trading, national SO_2 emissions fall to 38% of the baseline level and 59% of the level achieved under the EPA Mercury Cap policy in 2010. These ancillary reductions mean that the federal SO_2 cap is not binding in 2010 or 2020 and national SO_2 allowance prices fall to zero. Were the bank allowed to adjust to the introduction of the tighter mercury standards, one would expect greater emissions of SO_2 in the early years since there is no value to preserving emission allowances in the bank. However, by 2010 the role of the SO_2 bank would be offset by the influence of additional controls on mercury, and we believe the results would be largely consistent with our findings.

NO_x emissions under the Tighter Mercury with Trading policy are lower than with the EPA Mercury Cap, but not as low as under the Tighter Mercury with MACT policy. The CAIR NO_x emission cap continues to bind and NO_x prices are lower than under the EPA Mercury Cap.

Fuel switching away from coal also yields a significant reduction in carbon emissions to roughly 11% below baseline levels in 2010 and 2020. These reductions are substantially larger than the carbon emission reductions obtained under the other two policies.

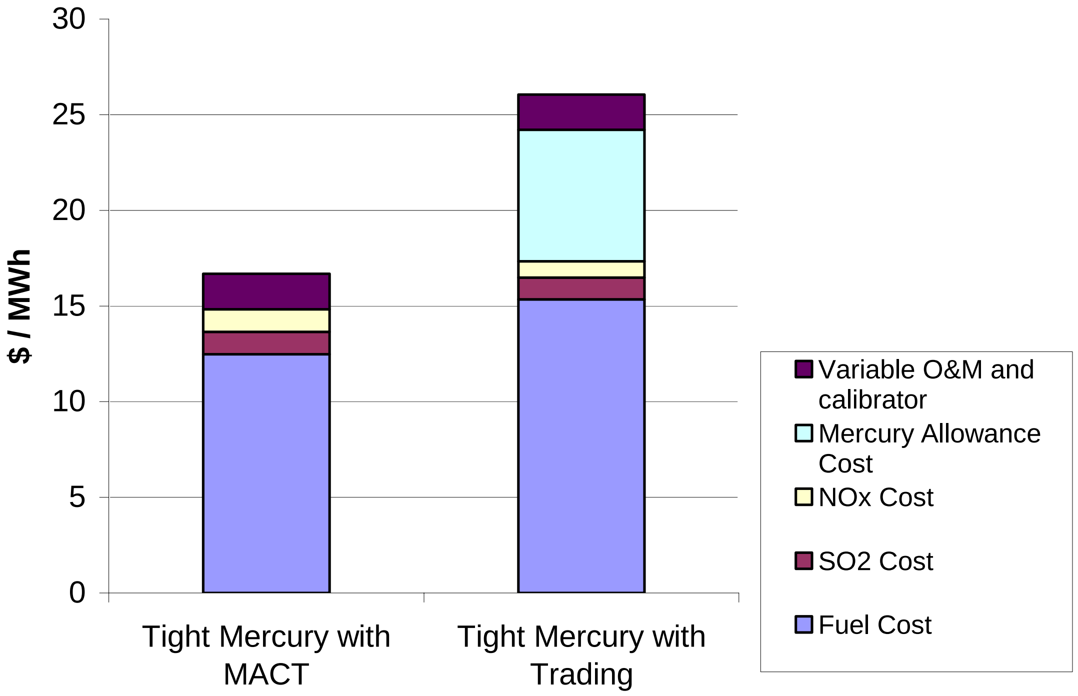
Very high prices for mercury allowances under the Tighter Mercury with Trading scenario help to explain the fuel switching away from coal and toward natural gas. In the Tighter Mercury with Trading scenario, mercury permits are expensive. The cost is roughly \$722,000 per pound in 2010, which is roughly an order of magnitude higher than the price in the EPA Mercury Cap scenario. This tenfold increase in costs corresponds with roughly a 68% further reduction in mercury emissions from coal and oil-fired generators. The mercury emission allowance price is \$1.4 million per pound in 2020.

The reason mercury allowance prices can achieve such high levels is that at the stringent mercury cap the incremental cost of the last unit of reduction in mercury is great. A variety of compliance options are available to each facility, and most will have an *average cost* per ton removed that is significantly less than the marginal cost. The average cost per ton for an option is the cost of that option divided by the change in emissions relative to its control in the baseline. However, emission allowance prices reflect the *opportunity cost* or *marginal cost* of each compliance option, which is the comparison of the cost effectiveness of that option compared to the next least stringent option.

First we provide an abstract example, and subsequently we illustrate the example with specific model results. For an example of the difference between marginal cost and average cost of mercury control, consider the options at a coal-fired plant. Following conventional wisdom, imagine that the cost of ACI for mercury control approaches \$30,000 per pound. This notion is based on the total tons reduced divided by total costs at that plant, therefore it is the average cost of emission reduction (at a plant that is run with a high utilization factor). Allowance prices are based on marginal cost, e.g. the opportunity cost of removing the last pound of mercury. Imagine that a plant already has wet scrubbing for SO_2 with SCR for NO_x and burns bituminous coal, as it might if it were planning to comply with the CAIR plus EPA Mercury Cap policy. These controls for SO_2 and NO_x yield an emission modification factor of 0.9 for mercury (depending on the coal that is used). For this plant to achieve further mercury reductions it would have to put on ACI in place of or possibly in addition to the SO_2 control strategy, thereby achieving an emission modification factor for mercury of .94 to .96. The incremental emission modification is only 0.04 to 0.06. The opportunity cost of this investment balloons to roughly \$570,000 per pound removed, when the ACI control option is compared with the next-best alternative. Moreover, if the mercury cap is sufficiently stringent then controls will be added to plants with lower utilization rates or burning coals with lower mercury content, thereby driving up opportunity cost and emission allowance price farther.

In analysis to determine the sensitivity of the mercury emission allowance price to the level of the cap we ran additional scenarios. We find the mercury price increases very quickly at the tighter mercury cap levels and as we loosen the cap, the allowance prices fall pretty dramatically. At a cap of 8.23 tons (our tighter mercury cap scenario) the allowance price in 2020 is $1,429,000 per pound. When we increase the cap to 8.73 tons we obtain an allowance price of $954,000. At a cap of 8.97 tons we obtain an allowance price of $762,000and, at a cap of 11.21 tons, the allowance price is $261,400. At a cap of 16.08 tons we obtain a price of $40,710.

Figure 7. Variable Generation Cost of a Large Coal-Fired Model Plant in ECAR for Summer 2010.



We illustrate the effect of the high mercury allowance prices under the Tighter Mercury Cap with Trading on the operations of this typical coal facility in the East Central Area Reliability (ECAR) region in Figure 7. This graph shows the fuel, pollution–control, and non-fuel operating cost components of total variable cost and compares total operating cost and its components under the two tighter mercury policies in 2010. The relatively small emission allowance costs for NO_x and SO_2 are subsumed in the pollution costs, and mercury control costs are not separated from SO_2 control cost. The figure shows that variable operating cost is $9.36 per MWh higher under the Tighter Mercury with Trading than it is under the Tighter Mercury with MACT, and that nearly three-quarters of the increment in variable cost is due to the cost of mercury allowances under trading. Fuel costs are also higher with trading due in part to a switch toward greater use of low sulfur coal as individual plants take advantage of the flexibility of the trading program. Some plants choose to use low sulfur coal in place of higher sulfur coal at an additional fuel cost in order to avoid the capital cost associated with post-combustion controls that would be required under a MACT approach. This large operating cost increase leads to a roughly 20% drop in generation from the plant illustrated in Figure 7 during the summer season as coal plants are dispatched less and gas generation starts to fill in.

In New York State, the ancillary SO_2 emission reductions from the tighter mercury policies are achieved on an accelerated basis under the Tighter Mercury with Trading, with emissions that are 22% of baseline levels in 2010, and 25% of the level achieved under the Tighter Mercury with MACT policy. In 2020 the SO_2 emissions are only 19% of baseline levels, and about one-half of the emissions achieved under the Tighter Mercury with MACT policy. Ancillary reductions in carbon emissions are 26% of baseline levels in 2020. This reduction is due to the virtual elimination of coal-fired generation in New York. In contrast, carbon emissions in New York under the other policies including the Tighter Mercury with MACT policy vary only slightly from baseline.

5.4 COSTS OF CAIR COUPLED WITH DIFFERENT MERCURY CONTROL POLICIES

The various multipollutant policies analyzed here impose different types and amounts of costs on regulated firms and on society. The effect of the policies on electricity price is one measure of those costs, but it is an incomplete one. The additional costs borne by the power generation sector include the costs of pollution control and the costs of switching fuels, either among different coal types or from coal and oil to natural gas. Another measure of the costs of the policy often used by economists is the effect of the policy on producer and consumer surplus in the electricity markets. All of these measures are summarized below, first at the national level and then for New York State.

Measures of Costs of Multipollutant Policies at the National Level

The effects of each of the three multipollutant policies on post-combustion control costs and the costs of fuel to industry in 2010 and 2020 for the nation as a whole are summarized in Table 16. This table reports annual incremental costs relative to the baseline scenario.

Table 16. Incremental Costs of Multipollutant Regulatory Policies Nationwide

(Billions of $1999—Difference from Baseline)

		CAIR plus			
	Baseline	***EPA Mercury CAP***	***EPA Mercury Cap and Seasonal SIP NO$_x$ Policy***	***Tighter Mercury with MACT***	***Tighter Mercury with Trading***
			2010		
Incremental Control Costs*	7.62	2.27	2.26	5.36	4.93
Incremental Fuel Costs*	48.67	0.07	0.21	0.73	8.37
			2020		
Incremental Control Costs*	8.12	4.57	4.47	6.19	5.29
Incremental Fuel Costs*	63.33	0.80	0.58	1.69	10.84

*Incremental costs do not include cost of changes in investment and retirement of generation capital. Also, generation is not held constant across the policy scenarios being compared.

Table 16 shows that use of post-combustion pollution controls dominates fuel switching as a strategy for complying with CAIR coupled with the EPA Mercury Cap. Annual investment and operating costs of pollution controls increase by $2.27 billion ($2.26 billion with the NO$_x$ SIP Call plus CAIR) from a baseline level of $7.62 billion in 2010 and by $4.57 billion ($4.47 billion with the NO$_x$ SIP Call) from a baseline level of $8.12 billion in 2020. The costs of fuel switching are just over 0.5% of baseline annual fuel costs to the industry in 2010 and 2020, which total about $48.7 and $63.3 billion respectively.

In the Tighter Mercury with MACT policy fuel switching plays a somewhat more important role than with the EPA Mercury Cap. Fuel switching includes switching among different types of coal as well as increased natural gas–fired generation relative to the baseline. However, the use of post-combustion controls still dominates fuel switching under the Tighter Mercury with MACT policy. The policy results in more than double the amount of incremental annual pollution control costs in 2010 and about 38% more in 2020 relative to the EPA Mercury Cap policy. In 2020 the increment in annual pollution-control costs of $6.19 billion approaches in magnitude the annual level under the baseline scenario of $8.12 billion.

As shown in Tables 9 and 10 switching among coals and from coal to natural gas is an important part of compliance under the Tighter Mercury with Trading policy, and the cost of fuel switching is more significant than incremental control costs. As Table 16 shows, total fuel costs are $8.37 billion higher in 2010 than the $48.7 billion baseline level and this increase exceeds by $3.4 billion the increase in annual capital and operating costs of pollution-control equipment. Incremental fuel costs rise to $10.84 billion in 2020, more than double the annual costs of additional post-combustion controls, which are an additional $5.29 billion.

Figure 8. How Mercury Emission Reductions Are Achieved in the CAIR plus Tighter Mercury with MACT Policy

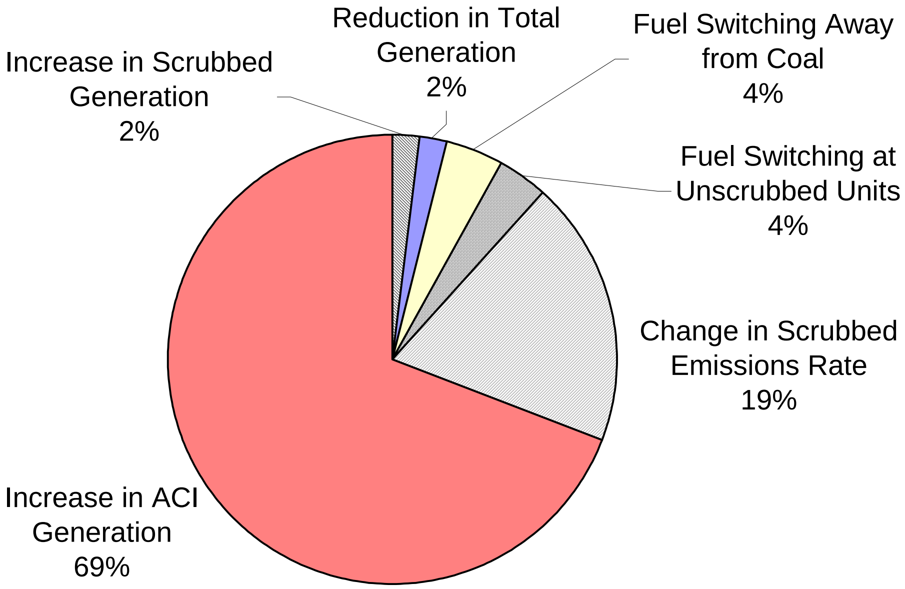
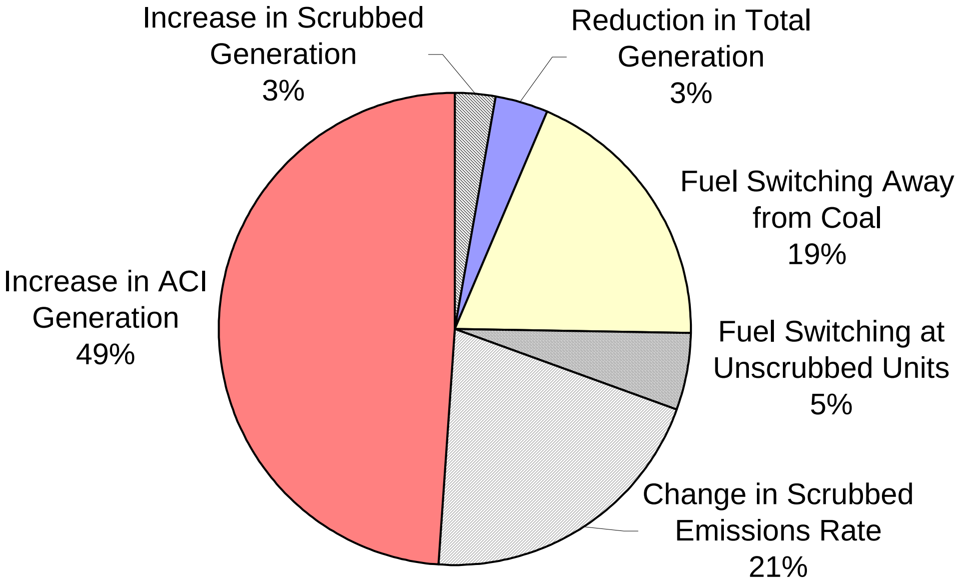


Figure 8 illustrates how the emission reductions under the tighter mercury standards are achieved in the MACT policy. The figure shows that 69% of the decrease in mercury emissions relative to the baseline is achieved through an increase in the use of ACI. The category indicating the increase in generation at units with ACI includes stand-alone ACI units as well as those combining a wet or dry SO_2 scrubber with ACI. The second largest category is the change in the emission rate at scrubbed units. This category captures the addition of SCR at scrubbed units, plus in some instances changes in coal type. Fuel switching represents substitution away from coal to sources including natural gas, renewables and nuclear, which do not emit mercury. This fuel switching accounts for only 4% of the emission reduction. The reduction in total generation accounts for only 2% of the emission reduction, assuming that reduction occurs entirely through reduced utilization of unscrubbed coal plants.[30]

Figure 9 shows how emission reductions are obtained in the Tighter Mercury with Trading policy. The largest share is still the increase in generation at facilities with ACI, however this drops by almost one-third to account for only 49% of the emission reductions. The second largest category remains the change in the emission rate at scrubbed units, including the installation of SCR, but this category grows by 10% compared to the to the MACT approach. The other large change is the role of fuel switching away from coal, which increases to account for 19% of the mercury emission reductions. The difference in compliance strategy, especially the additional fuel switching and the greater use of scrubbers, leads to the larger reductions in ancillary emissions of SO_2 and NO_x than are achieved with the trading policy.

Figure 9. How Mercury Emission Reductions Are Achieved in the CAIR plus Tighter Mercury Cap with Trading Policy



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[30] The category reporting fuel switching at unscrubbed units is specious but it is included for completeness. For almost all model plants there is no coal type that achieves the MACT standard with no post-combustion controls. However, every model plant has about .0003%-.0005% of its capacity identified as having no control in order to maintain minimums in the model that allow for convergence. This category of capacity will often dispatch in the MACT run because there are no mercury prices. The presence of SO_2 prices provides incentives to switch to lower sulfur coal relative to the baseline. Unscrubbed generation is about 1.3% of total generation in this scenario.

Another way to view the costs of the different multipollutant policies is to measure their effects on economic surplus, which is the sum of consumer and producer surplus, in the electricity market. Consumer surplus is an economic measure of the well being of consumers, and one can think of it as consumer profits. More technically, it is a measure of the difference between the willingness to pay by consumers for electricity and the amount they actually have to pay. Willingness to pay typically will differ among consumers, even if the price they actually have to pay does not. Producer surplus can be thought of as producer profits above the cost of capital to the firm. These measures of consumer and producer surplus are the standard way that modern cost–benefit analysis is performed.

Table 17 shows a snapshot of the change in consumer and producer surplus in 2010 and 2020 under each of the four policies relative to the baseline at the national level. All the policies result in aggregate surplus losses in both years, indicating simply that the policies have a cost. In 2010 producers actually gain relative to the baseline under the EPA Mercury Cap with and without the NO_x SIP Call, and producers gain substantially under the Tight Mercury with Trading policy. In 2020 producers also gain under the Tight Mercury with Trading policy. The greatest decline in producer surplus in 2010 occurs under the Tighter Mercury with MACT policy. By 2020 producers are largely indifferent in the aggregate between the CAIR plus Mercury Cap policies and the Tighter Mercury with MACT policy. Note that the producer surplus numbers reported here include only surplus changes within the electricity industry. [31]

The high cost of the Tight Mercury Cap with Trading policy relative to the MACT approach reflects only a partial accounting because it ignores changes in resource allocation between the electricity sector and other sectors of the economy. According to economic theory, the trading approach will always be more efficient within the entire economy because it will properly reflect opportunity costs in the price of goods and services. The Tight Mercury Cap with Trading leads to a higher electricity price than the MACT approach and a substitution by consumers away from electricity consumption. While this may be more efficient for the economy, it is not preferable from the standpoint of consumers and producers within the electricity sector, which is the measure of economic surplus reported in this paper.

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[31] The producer surplus calculations account for all costs including fuel costs. If fuel switching away from coal to natural gas or between different coal types pushes up the market-clearing price of a particular fuel, then the incremental fuel costs to electricity producers could be partially offset by surplus gains to fuel suppliers, which are not accounted for here. Likewise reductions in demand for a fuel could cause its price to fall, resulting in surplus losses for other fuel suppliers that are also not accounted for here.

Table 17. National Economic Surplus as Difference from Baseline

(Billions of 1999$)

	CAIR plus			
	EPA Mercury CAP	***EPA Mercury Cap and Seasonal SIP NO_x Policy***	***Tighter Mercury with MACT***	***Tighter Mercury with Trading***
	2010			
Consumer Surplus	-3.68	-3.14	-5.01	-21.06
Producer Surplus	0.79	0.14	-1.45	4.91
TOTAL Economic Surplus	-2.89	-3.00	-6.46	-16.15
	2020			
Consumer Surplus	-3.08	-2.99	-5.90	-23.14
Producer Surplus	-2.52	-2.21	-2.33	2.23
TOTAL Economic Surplus	-5.60	-5.20	-8.23	-20.91

The consumer surplus results confirm that electricity consumers bear at least half of the economic surplus costs of the pollution policies. The size of the consumer surplus loss increases with the stringency of the mercury policy. Under the Tighter Mercury with Trading policy, consumers are particularly hard hit relative to producers, who actually benefit from the policy. This result is due to the substantial increase in electricity price that harms consumers unambiguously but can benefit producers (See Table 9) Consumer surplus losses in both years under the Tighter Mercury with Trading Policy are several times their levels with either of the other two policies. As with producer surplus, the changes in consumer surplus account only for changes within the electricity sector.

Overall the economic cost of the Tighter Mercury with MACT policy is over twice that of the CAIR plus EPA Mercury Cap in 2010, and about 50% greater in 2020. This comparison provides a somewhat intuitive glimpse of the cost of the tighter mercury policy. A more surprising comparison may result from comparing the use of MACT versus trading to achieve the tighter mercury policy. The cost of the Tighter Mercury with Trading policy is 2.5 times as great as the Tighter Mercury with MACT policy. This measure accounts only for economic cost within the electricity sector. Economic theory suggests that emission trading leads to lower cost than would technology standards such as a MACT approach. However, the benefits of trading do not necessarily accrue within the electricity sector. The benefit of an emission-trading program accrues within the entire economy, and one outcome may be the allocation of resources away from electricity production and consumption in order to achieve a more efficient distribution of resources in the entire economy. That reallocation stems from the increase in electricity price, which leads to higher costs from trading within the electricity sector but is expected to lead to benefits outside the sector.

Table 18. Incremental Costs of Multipollutant Regulatory Policies in New York

(Millions of $1999—Difference from Baseline)

		CAIR plus			
	Baseline	***EPA Mercury CAP***	***EPA Mercury Cap and Seasonal SIP NO$_x$ Policy***	***Tighter Mercury with MACT***	***Tighter Mercury with Trading***
	2010				
Incremental Control Costs*	181.2	-43.3	-29	48.4	-169.5
Incremental Fuel Costs*	2.2	-66.4	-59.5	-64.9	377.8
	2020				
Incremental Control Costs*	192.0	-29.3	1.9	71.4	-182.2
Incremental Fuel Costs*	2.5	194.0	10.7	3.1	1,024.7

*Incremental costs are compared to Baseline. Incremental costs do not include cost of changes in investment and retirement of generation capital. Also, generation is not held constant across the policy scenarios being compared.

Costs of Policy in New York

The effects of the different policies on pollution control and fuel costs to electricity producers within New York State vary substantially across the different policies as shown in Table 18. With the EPA Mercury Cap annual post-combustion control costs are roughly 20% lower in 2010 than the estimated $181 million in the New York State baseline. In 2020 they are just under 15% lower without the NO$_x$ SIP Call, and about comparable with the NO$_x$ SIP Call to the $192 million under the baseline scenario. Under the CAIR policy the seasonal NO$_x$ cap within the SIP Call region is no longer enforced. In the model scenario we assume New York State generators would be free to reduce the use of post-combustion controls for NO$_x$ during the summer season and would generally invest less than they would when subject to a seasonal cap.

Under the Tighter Mercury with MACT policy, the incremental costs of post-combustion controls in New York are positive, and they reflect an increase in costs of about 27% from baseline in 2010 and 37% in 2020. The increase in control costs is offset in 2010 by a larger decrease in fuel costs. This finding is consistent with the technology focus of this particular control technology, which essentially requires installation of some combination of pollution controls at all coal-fired power plants. In 2020 fuel costs are roughly unchanged relative to the baseline.

Expenditures on post-combustion pollution controls in New York are lower under the Tighter Mercury with Trading Policy than under the baseline. This policy allows greater flexibility in how these reductions are achieved. In New York State firms comply by switching away from coal to greater use of natural gas. The substantial increase in fuel cost associated with this shift to natural gas is shown in the $378 million increase in fuel costs within New York under this policy in 2010 and the $1 billion increase in 2020, representing a 17% increase in 2010 and a 40% increase in 2020 over total fuel expenditures in the baseline scenario.

The effects of the different policies on economic surplus within the electricity sector in New York State are summarized in Table 19.[32] The producer surplus results mirror those at the national level in 2010, when producers tend to profit under all of the policies except the Tighter Mercury with MACT policy. That is, in 2010 producer surplus gains are greater under the policies that include trading of mercury allowances than under the MACT policy. However, producers typically lose in the trading regimes in 2020. Again the Tighter Mercury with MACT policy is the exception and in this case producers benefit in 2020.

The effects of these different policies on consumer surplus in New York mirror the price findings in Tables 11 and 12. When a policy leads to an increase in electricity price, there is an associated drop in consumer surplus. In 2010, only the Tight Mercury MACT policy results in a lower electricity price that brings about increases in consumer surplus, but this increase is not sufficient to offset the losses to producers and total economic surplus is negative. In 2020 there is very little change in electricity price among all the policies, but all are at or below baseline levels. Hence, consumers in New York benefit by small amounts in all of the scenarios compared to the baseline.

The net effect in New York of the change in economic surplus—the sum of changes in producer and consumer surplus—is varied. In 2010 economic surplus falls by $30 million under the CAIR plus EPA Mercury Cap policy

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[32] Allocation of NO_x emission allowances to electricity generating units in New York State as originally proposed in CAIR and as modeled in this analysis was 52,448 tons in 2010 and 43,707 tons in 2015. In the final version of CAIR, the New York State allowance was reduced to 45,617 in 2010 and 38,014 in 2015. The reduction raises costs to producers in New York State. Many state allocations were increased or decreased in the final rule.

with the NO_x SIP Call. At the tighter mercury cap economic surplus rises by $60 million under MACT regulation but falls by nearly $250 million under mercury trading. In 2020 there is a small loss in total economic surplus under the CAIR plus EPA Mercury Cap without the NO_x SIP Call. Like 2010, there is a small gain in surplus in New York under the Tighter Mercury with MACT policy, but a significant decline of $174 million under the Tighter Mercury with Trading policy.

Table 19. New York State Economic Surplus as Difference from Baseline

(Millions of $1999)

	CAIR plus			
	EPA Mercury CAP	***EPA Mercury Cap and Seasonal SIP NO_x Policy***	***Tighter Mercury with MACT***	***Tighter Mercury with Trading***
	2010			
Consumer Surplus	-380.0	-570.0	220.0	-1,420.0
Producer Surplus	412.5	553.9	-160.1	1,171.3
TOTAL Economic Surplus	32.5	-16.1	59.9	-248.7
	2020			
Consumer Surplus	0.0	30.0	70.0	50.0
Producer Surplus	-66.0	-54.0	42.0	-224.0
TOTAL Economic Surplus	-66.0	-24.0	112.0	-174.0

New York State Renewable Portfolio Standard

In all the analysis described to this point the renewable portfolio standard adopted by the New York State Public Service Commission in September 2004 is not modeled. We conducted a sensitivity analysis to see how the adoption of the state standard would affect the costs of the national policies.

The New York State policy aims to increase the share of electricity sold in the state that comes from renewable generation from about 19 percent to 25 percent by 2013. The technologies that qualify as renewables that we modeled include biomass cofiring at coal-fired power plants, landfill gas, and wind. Change in hydroelectric generation in New York constitutes a very small portion of expected changes in total renewable generation, and we do not include this change in the analysis. In addition we model an increase in renewable energy as a component of imports from Canada. We model the policy by imposing the expanded capacity and generation that is forecasted by New York State as well as projected increases in electricity bills, which could have a small effect on aggregate electricity demand.

Table 20. Overview of Electricity Price and Generation
New York Results for 2020
***Sensitivity Analysis*: New York State Renewable Portfolio Standard**

	Standard Assumption: No NYS Renewable Policy		*Sensitivity Analysis with NYS Renewable Policy*	
	Baseline	*CAIR plus EPA Mercury Cap and Seasonal SIP NO_x Policy*	*Baseline*	*CAIR plus EPA Mercury Cap and Seasonal SIP NO_x Policy*
Average Electricity Price (1999$/MWh)	104.5	104.3	$103.60	$104.3
Statewide Generation (billion kWh)				
Coal	31.5	31.5	29.6	29.6
Gas	33.5	36.2	28.7	29.8
Oil	16.1	13.4	15.4	12.6
Nuclear	39.8	39.8	39.8	39.8
Hydro	25.9	25.9	25.9	25.9
Other Renewable	2.8	3.0	11.4	11.5
Total	149.7	149.8	150.8	149.2
New Capacity (MW)				
Gas	3,242	4,192	3,219	3,845
Renewables	105	114	2,365	2,365
Total	3,365	4,323	5,601	6,228

Table 20 reports an overview of electricity price and generation for 2020. The first two columns of data repeat results reported earlier to enable a comparison with and without the New York renewable policy. We find a slight drop in average electricity price with the renewable policy in the absence of the CAIR rule. This can occur because renewables have low variable cost, and they displace generation with higher variable cost at the margin, which is typically natural gas. Since electricity price is determined by variable cost, one can see a decline in the market-clearing price. This effect outweighs the increment to electricity price that is added to pay for the renewable program. However, with the CAIR policy and the EPA Mercury Cap-and-Trade policy in place (and the NO_x SIP Call continued) electricity price in New York is unchanged in the presence or absence of the renewable policy.

Generation by all fossil fuels declines due to the renewable policy. The greatest decline comes from natural gas. This is a familiar result because new renewables often compete with new natural gas, which is the technology chosen most often for new generation capacity. Also, gas and oil are typically the marginal supply of generation in the short-run, and this will be displaced by new renewable generation.

Table 21 reports changes in emissions and allowance prices at the national level and in New York. The renewable policy leads to small declines in SO_2, NO_x, and CO_2 at the national level in the baseline. There is a slight increase in mercury emissions at the national level. This occurs because of the slight decline in the SO_2 allowance price and a small change in abatement strategy for $SO_{2,}$ which has an ancillary effect on mercury emissions. In the policy case emissions of SO_2, NO_x, mercury, and CO_2 are very similar with and without the renewable policy. In New York State there also is a relatively small effect on emissions due to the renewable policy, with the exception of $CO_{2,}$ which declines by almost 8% in 2020 due to the renewable policy.

Table 21. Emissions and Allowance Prices in 2020

***Sensitivity Analysis*: New York State Renewable Portfolio Standard**

	Standard Assumption: No NYS Renewable Policy		*Sensitivity Analysis with NYS Renewable Policy*	
	Baseline	***CAIR plus EPA Mercury Cap and Seasonal SIP NO_x Policy***	***Baseline***	***CAIR plus EPA Mercury Cap and Seasonal SIP NO_x Policy***
National Emissions (million tons)				
SO_2	8.94	4.30	8.93	4.25
NO_x	4.04	2.56	4.03	2.54
Mercury (tons)	53.5	24.99	53.81	24.91
CO_2	3,260	3,186	3,248	3,185
Allowance Prices ($ per ton)				
National SO_2	184	1,222	167	1,235
NO_x	7,140	1,048	-	1,013
Mercury ($ per lb)	-	35,760	-	38,180
NY State SO_2	397	-	427	-
New York State Emissions (thousand tons)				
SO_2	192.8	116.7	194.5	114.2
NO_x	55.4	53.8	55.0	51.9
Mercury (tons)	0.92	0.52	0.91	0.52
CO_2	67,230	66,000	62,760	60,880

Analysis of Mercury Trading

The results of the analysis above suggest several interesting findings about the effects of using a cap-and-trade approach with a tighter cap on mercury on the costs of mercury control. Three main lessons emerge. First, resource costs, which are the sum of incremental pollution-control costs and incremental fuel costs under Tighter Mercury with Trading, are not necessarily less than the costs under Tighter Mercury with MACT. Pollution-control costs can be lower or higher, but fuel costs are typically always higher. The trading policy internalizes in variable costs the opportunity cost of emissions through the introduction of an emission allowance price. With the tighter mercury policies, the allowance price is sufficiently high that it initiates substantial substitution away from coal, and greater resource costs are incurred in order to avoid the regulatory cost associated with allowances.

Second, producers strongly prefer the trading approach to MACT. Under the tighter mercury control scenario, producer surplus is higher with trading than with a MACT approach. [33] Greater producer profits under trading follows from the fact that electricity prices tend to be higher with trading and thus producers on the whole tend to profit. Although the variable costs of some facilities are dramatically affected due to the mercury allowance cost, as illustrated in Figure 7, the well being of producers in the aggregate can improve because the allowances are distributed at zero cost.

Third, consumers strongly prefer the MACT approach to trading. Consumer surplus losses are typically substantially greater under the Tighter Mercury with Trading policy than under the MACT approach. This result also follows from the substantially higher electricity prices under this scenario, which in turn follow from the high price of mercury allowances.

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[33] Note that the producer surplus change calculation accounts for the difference in SO_2 allowance expenditures under the two policies.

Section 6

ENVIRONMENTAL BENEFITS

6.1 OVERVIEW

The multipollutant policies analyzed here yield important changes in concentrations of fine particulate matter and of ozone in the atmosphere. They have an effect on visibility in national parks and residential areas.[34] They reduce the amount of wet and dry deposition of nitrates and sulfates into forests, lakes, and streams. They also reduce the amount of mercury deposited from the atmosphere into water bodies and onto the soil.

Reductions in these various pollutants yield a variety of ecological and environmental and health benefits. In this analysis we focus on the benefits that past studies have shown to be of the greatest magnitude, at least according to quantifiable information, and those for which we have good information.[35] The effects of fine particles and ozone on human health are relatively well understood and a large literature has developed on the values of those health effects. The ecological effects of changes in ozone and reduced acidification can also be assessed, but the economic values of those changes tend to be small compared to the economic values of health effects of changes in particulates, and we do not calculate these values.

As described previously, the predictions of two atmospheric transport models are used. Our central case estimates of changes in particulate concentrations rely on URM 1-ATM for the eastern states that it covers, and the transport coefficients for western states are filled in with the ASTRAP model. The eastern states are the most important region with respect to SO_2 emissions in the aggregate and with respect to environmental effects in New York. However, important emission changes occur in the west that have a bearing on particulate concentrations there and in the eastern states. The western share of total emissions increases between 2005 and 2020 by roughly ten percent of total national emissions in the policy cases with the CAIR plus EPA Mercury Cap. The western percentage of total emissions is roughly unchanged in the Tighter Mercury with MACT policy, and it falls slightly in the Tighter Mercury with Trading policy. Hence we use the ASTRAP model coefficients to capture the different influences of emissions in the western states.

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[34] Visibility concerns are particularly key in states to the west of the CAIR region and given that wind patterns flow predominantly from the west to the east, reductions in emissions in eastern states are likely to yield few visibility benefits in the west. However, the ancillary reductions in SO_2 and NO_x with the tighter mercury policies, which are nationwide policies, could have visibility benefits in the western states.

[35] For example, Burtraw et al. 1998.

Less well understood are the effects of mercury on human health. There is a great deal of uncertainty about the nature of the different health effects, the relative importance of different pathways and the severity of the effects. Uncertainty also abounds in how to model the diffusion of mercury emissions from a source to receptor regions, which severely limits analysts' ability to identify exactly where mercury pollution will decrease with a change in policy.

Despite this uncertainty, Rice and Hammitt (2005) of the Harvard School of Public Health have analyzed the mercury emission changes and the results of mercury transport and fate modeling by EPA for the Clear Skies legislation in conjunction with other estimates of resulting changes in fish contamination, human fish consumption and associated health effects related to myocardial and neurological events. Their study finds that the annual health benefits associated with mercury reductions brought about by the Clear Skies legislation range from $2.8 billion for the 26 ton cap in the first phase of the program (representing an approximately 22 ton reduction) to $4 billion for the 15 ton per year cap in the second phase of the program (representing a 33 ton reduction). The Rice and Hammitt analysis used a value of statistical life of $5.8 million (1999$) whereas the benefits analysis in this report assumes a more conservative $2.2 million. To put their estimates of the mercury benefits from Clear Skies, which are roughly comparable to the mercury benefits from the EPA Mercury Cap in the proposed rule, the mortality portion of the benefits would have to be adjusted by the ratio of these values or 0.36, which yields $1.1 billion in benefits for phase I and $1.6 billion in phase II.

Analysis of the fate and transport of mercury emissions changes was outside the scope of this research and, thus, we do not attempt to quantify the ecological or human health benefits of reductions in mercury pollution from the different policies that we consider. This omission is an important one because there is a large distinction in the level of mercury emissions between the policies that include an EPA Mercury Cap and those that include the tighter mercury constraints. The missing mercury benefits must be kept in mind when comparing our incomplete measures of benefits across the different policies, especially in light of the high benefit estimates from Rice and Hammitt (2005). Based on the existing environmental economics and epidemiological literature, we believe that even with mercury benefits excluded we have captured the majority of the human health benefits by including those associated with mortality and morbidity effects of changes in concentrations of fine particles and ozone. Since in every case we find benefits that exceed costs, we focus on describing in detail the benefit categories that are well understood and that are sufficient to achieving this threshold. However, we can also offer some observations on what adding in the mercury benefits might mean for the relative ranking of different policies in net benefits terms.

6.2 HEALTH EFFECTS OF PARTICULATES AND OZONE

We use two approaches to analyze the health benefits of the policy scenarios based on two different sets of source-receptor coefficients. In our **central case analysis** we use the source-receptor coefficients derived from URM-

1ATM model in conjunction with the SGM model for an area covering the majority of the population of the United States. To measure the effects of particulate matter in other parts of the nation we rely on the source-receptor coefficients from the ASTRAP model. Estimates of the benefits from reduced ozone coefficients are limited to the area covered by the URM model, which includes the majority of area and population with problem achieving compliance with the ozone health standard. These coefficients were added to the TAF model for this project.

In our **alternative case analysis** we use the ASTRAP source-receptor coefficients for particulate matter for the entire nation. To calculate ozone benefits we use the URM model, and these benefits are calculated only for the eastern United States. As the results below show our central case is a more conservative (lower) assessment of the benefits of the policy.

6.3 HEALTH BENEFITS IN THE CENTRAL CASE

A summary of our central case estimates of the incremental national health benefits of the different policies is presented in Table 22. This table provides separate estimates of the benefits of reduced mortality and morbidity for particulates and ozone in both 2010 and 2020. Our results are consistent with results from other studies (EPA 2004a), which show that across the different policies the health benefits attributable to a reduction in particulate concentrations are nearly two orders of magnitude higher than the benefits from ozone reductions.

National benefits of the CAIR policy coupled with the EPA Mercury Cap rise from more than $13 billion in 2010 to nearly $19.5 billion in 2020. Adding a SIP seasonal policy to CAIR raises has almost no effect on ozone-related benefits in 2010 but it yields a 7% increase in 2020. Particulate related health benefits rise by 2% in 2010 but fall by 1% in 2020.

When the CAIR policy is combined with the Tighter Mercury with MACT approach, the incremental health benefits from reduction in particulates and ozone relative to the baseline in 2010 are comparable to those when CAIR is combined with the EPA Mercury Cap. In 2010 the benefits are $340 million greater under the tighter mercury standard, and in 2020 they are $50 million less. The lower benefits in 2020 follow directly from the slightly higher level of estimated emissions of SO_2 in that year, which differ by a small degree from the emission cap. The difference in emissions reflects the degree of convergence in the model.

Allowing mercury trading under the tighter mercury cap hastens the realization of ancillary SO_2 reductions and the associated health benefits from reductions in fine particles. Benefits from reduced particulate concentrations are roughly 50% higher than with the Tighter Mercury with MACT in 2010,and in 2020 they are about 13% greater.. This stems from the fact that there is significantly less investment in SCR for NO_x control under the Tighter Mercury with Trading policy, and despite the fact there is less coal-fired generation there are greater NO_x emissions on net.

Table 22. National Health Benefits – Central Case (URM Model*)

(Millions of $1999)

	CAIR plus			
	EPA Mercury CAP	***EPA Mercury Cap and Seasonal SIP NO_x Policy***	***Tighter Mercury with MACT***	***Tighter Mercury with Trading***
	2010			
Ozone Mortality	61	61	60	28
Ozone Morbidity	100	100	107	55
Ozone Total	161	161	167	83
PM 2.5 Mortality	10,590	10,830	10,930	16,380
PM 2.5 Morbidity	2,555	2,617	2,647	3,938
PM 2.5 Total	13,140	13,450	13,580	20,320
GRAND TOTAL	13,310	13,610	13,750	20,400
	2020			
Ozone Mortality	90	97	95	68
Ozone Morbidity	163	173	179	133
Ozone Total	253	270	274	201
PM 2.5 Mortality	15,520	15,370	15,460	17,550
PM 2.5 Morbidity	3,692	3,658	3,683	4,159
PM 2.5 Total	19,210	19,030	19,140	21,710
GRAND TOTAL	19,470	19,300	19,420	21,910

* The “URM model” has ozone and particulate benefit estimates for 22 eastern states. Particulate benefits for the remainder of the nation are calculated using ASTRAP, and there are no ozone benefits calculated for the remainder of the nation.

Table 22 also indicates that ozone-related benefits fall, even as particulate benefits rise, when comparing the Tighter Mercury with Trading policy with the other policies. Emissions of NO$_x$ are comparable among the policies, however, the source of emissions changes. In the Tighter Mercury with Trading policy we find a significant decrease in coal-fired generation, which is characterized by tall stacks and is considered an elevated source of emissions in our model. These emissions are made up by an increase from natural gas–fired plants, which have lower stacks and are considered a surface source. We find emissions from the lower stacks are more potent with respect to ozone formation, and so the ozone-related benefits of emission reductions are eroded.

Table 23. New York Health Benefits – Central Case (URM Model*)

(Millions of $1999)

	CAIR plus			
	EPA Mercury CAP	***EPA Mercury Cap and Seasonal SIP NO_x Policy***	***Tighter Mercury with MACT***	***Tighter Mercury with Trading***
	2010			
Ozone Mortality	8	8	7	6
Ozone Morbidity	12	13	11	11
Ozone Total	20	21	18	17
PM 2.5 Mortality	1,311	1,408	1,442	1,981
PM 2.5 Morbidity	349	375	384	526
PM 2.5 Total	1,660	1,783	1,826	2,506
GRAND TOTAL	1,680	1,804	1,844	2,524
	2020			
Ozone Mortality	11	12	10	9
Ozone Morbidity	18	19	17	17
Ozone Total	29	31	27	26
PM 2.5 Mortality	2,059	2,081	2,057	2,183
PM 2.5 Morbidity	538	544	538	571
PM 2.5 Total	2,597	2,625	2,595	2,753
GRAND TOTAL	2,626	2,656	2,622	2,779

* The "URM model" has ozone and particulate benefit estimates for 22 eastern states. Particulate benefits for the remainder of the nation are calculated using ASTRAP, and there are no ozone benefits calculated for the remainder of the nation.

The ozone- and particulate-related health benefits of the different policies in New York for the central case are summarized in Table 23. Consistent with the high population of the state and its location downwind of important emission sources, between 10 and 15% of the national health benefits of these policies are realized in New York. As is the case nationwide, typically 99% of the benefits are due to reduced concentrations in particulates. In 2010, the Tighter Mercury with Trading policy brings about the greatest benefits. This policy also yields the greatest benefits in 2020 but the differences among policies are much smaller in that year. Continuing to require compliance with a seasonal NO_x cap under the CAIR policy with the EPA Mercury Cap increases total health benefits of that policy by 7% in 2010 and by 1% in 2020.

6.4 HEALTH BENEFITS IN THE ALTERNATIVE CASE

In the alternative case we use the source-receptor coefficients from the ASTRAP model for the entire nation to analyze the health benefits of the SO_2 and NO_x emissions changes in the electricity sector resulting from the various policies. The national health benefits estimates from this exercise are presented in Table 24. The ozone-related health benefits presented here are the same as those in the earlier tables because the ASTRAP model does not include source-receptor coefficients for ozone and thus we continue to use the URM coefficients for ozone.

The national health benefits in the alternative case are roughly 20% higher than those with the central case source-receptor coefficients for the two scenarios that combine CAIR with the EPA Mercury Cap. The difference is somewhat larger for the Tighter Mercury with Trading policy that results in larger changes in national emissions of SO_2.

Table 24. National Health Benefits – Alternate Case (ASTRAP Model*)

(Millions of $1999)

	CAIR plus			
	EPA Mercury CAP	***EPA Mercury Cap and Seasonal SIP NO_x Policy***	***Tighter Mercury with MACT***	***Tighter Mercury with Trading***
	2010			
Ozone Mortality	61	61	60	28
Ozone Morbidity	100	100	107	56
Ozone Total	161	161	167	84
PM 2.5 Mortality	13,030	13,210	13,230	20,320
PM 2.5 Morbidity	3,139	3,185	3,192	4,882
PM 2.5 Total	16,170	16,390	16,420	25,210
GRAND TOTAL	16,330	16,550	16,590	25,290
	2020			
Ozone Mortality	90	97	95	68
Ozone Morbidity	163	173	179	133
Ozone Total	253	270	274	201
PM 2.5 Mortality	18,670	18,580	18,520	21,490
PM 2.5 Morbidity	4,431	4,413	4,402	5,088
PM 2.5 Total	23,100	22,990	22,920	26,580
GRAND TOTAL	23,350	23,260	23,190	26,780

* The “ASTRAP model” calculates particulate benefits for the entire nation. Ozone benefits are calculated for 22 eastern states using URM.

Table 25. New York Health Benefits – Alternate Case (ASTRAP Model*)

(Millions of $1999)

	CAIR plus			
	EPA Mercury CAP	*EPA Mercury Cap and Seasonal SIP NO_x Policy*	*Tighter Mercury with MACT*	*Tighter Mercury with Trading*
	2010			
Ozone Mortality	8	8	7	6
Ozone Morbidity	12	13	11	11
Ozone Total	20	21	18	17
PM 2.5 Mortality	1,418	1,520	1,415	2,197
PM 2.5 Morbidity	378	405	378	585
PM 2.5 Total	1,797	1,925	1,793	2,782
GRAND TOTAL	1,817	1,946	1,811	2,799
	2020			
Ozone Mortality	11	12	10	9
Ozone Morbidity	18	19	17	17
Ozone Total	29	31	27	26
PM 2.5 Mortality	2,116	2,151	2,074	2,323
PM 2.5 Morbidity	555	564	544	609
PM 2.5 Total	2,671	2,715	2,618	2,932
GRAND TOTAL	2,700	2,746	2,645	2,958

* The “ASTRAP model” calculates particulate benefits for the entire nation. Ozone benefits are calculated for 22 eastern states using URM.

Table 25 presents the alternative estimates of health benefits in New York State. Here the differences between the central case (URM) and alternative case (ASTRAP) estimates are smaller, but the alternate case estimates are generally larger than those in the central case, and particularly so under the Tighter Mercury with Trading policy.

The differences in the estimates from the two models can be explained in part by the integrated nature of URM-1ATM. One of the strengths of the model is that it accounts for ammonia and its interaction with sulfate and nitrate formation at baseline levels of concentrations. Ammonia as a limiting agent accounts for a slight bounce back in nitrate concentrations when SO_2 emissions are reduced in the eastern United States because the associated reduction in sulfates frees up ammonia to contribute to the formation of nitrates. This tends to lessen the predicted benefits of

SO_2 emission reductions. Another difference between models is the approach used to derive source-receptor coefficients. The URM-1ATM model uses the Direct Decoupled Method in Three Dimensions (DDM-3D) to calculate the local sensitivities of specified model outputs simultaneously with the levels of concentrations. This sensitivity is a local derivative, so a linear assumption is made and the effects of emissions changes on concentrations under the different scenarios are based on a linear extrapolation of the sensitivities at that point. However, if the relationship between emissions of SO_2 and fine particulates is nonlinear and concave, say due in part to the role of ammonia in sulfate and nitrate formation, and the emissions perturbation is big, then the model may undervalue the effects of large changes in SO_2 emissions on concentrations of fine particulates.

In contrast, the ASTRAP model uses 11 years of data and takes advantage of the large variation in emissions over that time period to estimate a sensitivity of pollution concentrations to changes in emissions. The variations in emissions over the 11-year time period are probably similar in size to those occurring under the policies considered here, but they are from a time when baseline emissions levels were much higher. Both models are exercised in this analysis to project changes beyond the range of observable data on which the models are calibrated.

Table 26. Acid Deposition in New York State from Electricity Sector (ASTRAP Model)

(Kilograms per Hectare)

		Reductions from Baseline for CAIR Plus			
Compound	***Baseline***	***EPA Mercury CAP***	***EPA Mercury Cap and Seasonal SIP NO_x Policy***	***Tighter Mercury with MACT***	***Tighter Mercury with Trading***
2010					
Wet Sulfur	4.4680	2.0220	2.1510	1.8710	3.1840
Dry Sulfur	3.0070	1.2820	1.4300	1.3310	2.2460
Wet NO_x – Nitrates	0.7535	0.3006	0.3125	0.3291	0.3055
Dry NO_x – Nitrates	0.5683	0.2099	0.2455	0.2560	0.2743
2020					
Wet Sulfur	4.2380	2.8400	2.8490	2.6280	3.0880
Dry Sulfur	2.9030	2.0090	2.0560	2.0300	2.2630
Wet NO_x – Nitrates	0.7788	0.3690	0.3987	0.4226	0.3995
Dry NO_x – Nitrates	0.5856	0.2523	0.2946	0.3199	0.3276

6.5 ACID DEPOSITION

The effects of the different policies on the components of acid deposition in New York State are presented in Table 26. The baseline column in this table includes total deposition of acid precursors from electricity sources only and the subsequent columns report reductions in the different categories of acid precursors resulting from each policy.

All of the policies yield substantial reductions in acid deposition in New York State. Under the two CAIR policies that include the EPA Mercury Cap, wet sulfur deposition falls by about 50–55% in 2010 and 33% in 2020. The percentage declines in dry sulfur deposition are slightly greater in 2010 and slightly less in 2020. Wet nitrogen deposition and dry nitrogen deposition falls by 50%-60% for these policies. Changes in deposition are always the same or slightly higher for sulfur or nitrogen under the CAIR policy coupled with the Seasonal SIP NO_x Policy.

The CAIR policy with the tighter mercury standards yields larger changes in deposition of acid precursors in New York that are roughly proportional to the larger changes in emissions of SO_2 and NO_x. In the tighter mercury policy with trading, deposition of wet sulfur falls by more than 70% in 2010 and 2020 from the levels in the baseline. In 2020, deposition of dry sulfur falls by nearly 80% under the tighter mercury policy with trading. Deposition of wet and dry nitrogen falls by more under the Tighter Mercury with MACT policy than under the Tighter Mercury with Trading policy in both 2010 and 2020.

One recent study provides an estimate of willingness to pay for ecological improvements in the Adirondack Park by New York State residents (Banzhaf et al. 2004). The modeled level of improvement corresponds roughly to improvements expected to result from emission reductions that would be associated with CAIR. The benefit estimates for New York State residents range from $305 million to $1.0 billion per year (1999$). The range depends on the magnitude of benefits that would result, and on technical assumptions in the modeling. Because these estimates are not yet peer-reviewed we do not include them in our central analysis. The footnote to Tables 29 and 30 points to an illustration of the magnitude of these potential benefits included in Figure 10.

6.6 MERCURY BENEFITS

Our analysis of the effects of mercury policies focuses on reductions in emissions and does not consider the transport or fate of mercury emissions or the health benefits of reduced human exposures to mercury in the environment. However, we can speculate about what the likely health benefits of mercury reductions might be by drawing on recent estimates. Rice and Hammitt (2005) analyze the mercury benefits associated with compliance with the Clear Skies Initiative legislative proposal, which imposes a mercury emission cap of 26 tons by 2010 and 15 tons by 2020. Drawing on EPA’s analysis of the effects of the Clear Skies Initiative on mercury concentrations in the environment, Rice and Hammitt use information from various epidemiological studies to estimate the health effects of those changes and information from the environmental economics literature to assign associated dollar benefit values. The authors focus on two health benefits: reductions in intelligence scores (IQ deficits) associated with fetal exposure and the somewhat more controversial cardiovascular effects and premature mortality. They develop a range of potential benefits depending on assumptions about the size of the relevant exposed populations.

In the case of both the IQ deficits and the cardiovascular and mortality effects, the benefits of emission reductions appear to be roughly linear over the range of reductions analyzed. We exploit this linearity to calculate an average benefit per ton of emission reduction from the Rice and Hammitt work and then apply those benefits per ton to the total national mercury emission reductions in 2010 and 2020. These benefit estimates are presented in Tables 27 and 28. Table 27 uses the $2.2 million (1999$) value of statistical life (VSL) employed throughout this study, while the second table uses the $5.8 million (1999$) VSL employed in the Rice and Hammitt study.

Table 27 shows that using the lower VSL estimate, the annual benefits of mercury reductions under the EPA cap in 2020 range from $121 million to $1.7 billion per year. Under the tighter mercury cap, the annual mercury benefits are roughly twice as high, ranging from $230 million to $3.3 billion. Thus the incremental benefits of moving from the EPA Mercury Cap to the tighter mercury cap could be as high as $1.6 billion in 2020. Table 28 indicates that if the higher VSL is assumed, the mercury benefits under the tighter mercury cap range from $320 million to $8.5 billion.[36]

Table 27. Mercury Benefits

(Millions and Billions of $1999 using $2.2 VSL)

	IQ Deficits from Fetal Exposure to MeHg	*Cardiovascular effects and premature mortality*	*Total*
Benefits per Ton of Mercury Reduced	$4.0M – $10.1M	$1.0M – $ 63.2M	$5.0M – $73.3M
	Total Annual Benefits - 2010		
EPA Mercury Cap	$96M - $239M	$24M - $1.5B	$120M - $1.7B
Tighter Mercury Cap	$176M - $439M	$44M - $2.7B	$220M - $3.1B
	Total Annual Benefits – 2020		
EPA Mercury Cap	$97M - $242M	$24 M - $1.5B	$121M – $1.7B
Tighter Mercury Cap	$184M - $459M	$46M - $2.9B	$230M - $3.3B

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[36] One other recent study presents an estimate of the benefits and costs of mercury control from power plants. Gayer and Hahn (2005) consider only the IQ benefits in children. On the basis of this measure alone, the authors find the benefits are much less than the costs of the EPA proposal.

Table 28. Mercury Benefits

(Millions and Billions of $1999 using $5.8 VSL)

	IQ Deficits from Fetal Exposure to MeHg	*Cardiovascular effects and premature mortality*	*Total*
Benefits per Ton of Mercury Reduced	$4.0M - $10.1M	$2.8M – $172.3M	$6.8M - $182.5M
	Total Annual Benefits – 2010		
EPA Mercury Cap	$99M - $247M	$68M - $4.2B	$167M - $4.4B
Tighter Mercury Cap	$176M - $454M	$124M - $7.7B	$300M - $8.2B
	Total Annual Benefits – 2020		
EPA Mercury Cap	$100M - $250M	$68M - $4.3B	$168M - $4.5B
Tighter Mercury Cap	$190M - $474M	$130M - $8.1B	$320M - $8.5B

6.7 NET BENEFIT ANALYSIS

To facilitate a comparison of human health benefits and economic costs within the electricity sector, we display the national cost and benefit estimates of the different policies together in Table 29. To illustrate that our analysis does not include ecological benefits of these policies or any benefits associated with reduced mercury pollution, we include placeholder rows for these missing benefits. We also include a placeholder for the effects of the policies on economic surplus outside the electricity sector, which we are unable to measure with our model. Thus, the net benefits that we report for each policy are incomplete. However, the included categories of benefits and costs are thought to constitute the significant majority of quantifiable measures, and these are the measures that are the most significant in recent Regulatory Impact Assessments by the EPA. Typically the EPA does not include a measure of consumer and producer surplus due to the limitation of the model they use, but instead they report total resource costs for the regulatory policy, which will be somewhat less than the surplus measures we report.

To control for the large differences in mercury emissions under the policies illustrated in the first two and last two columns of the table, we use a double line to separate the table into two halves. In the first two columns are the measurable net benefits under two versions of the CAIR policy with the EPA Mercury Cap. The last two columns include the CAIR with the two policies that impose tighter restrictions on mercury emissions. The relevant comparisons are those within each section of the table as total national mercury emissions are not constant across the two grouped scenarios.

Table 29. Summary of Modeled National Benefits and Costs for Central Case

(URM Model; Billions of $1999)

	CAIR plus		*CAIR plus*	
	EPA Mercury CAP	***EPA Mercury Cap and Seasonal SIP NO_x Policy***	***Tighter Mercury with MACT***	***Tighter Mercury with Trading***
2010				
Benefits				
Ozone Health Benefits	0.16	0.16	0.17	0.08
Particulate Health Benefits	13.31	13.61	13.75	20.40
Ecological and Visibility Benefits	N/A[a]	N/A[a]	N/A[a]	N/A[a]
Mercury Benefits	N/A[a]	N/A[a]	N/A[a]	N/A[a]
Costs				
Economic Surplus Changes in Electricity Sector	-2.89	-3.00	-6.46	-16.15
Economic Surplus Changes in Rest of Economy	-N/A	-N/A	-N/A	-N/A
Measurable Net Benefits	10.58	10.77	7.46	4.33
2020				
Benefits				
Ozone Health Benefits	0.25	0.27	0.27	0.20
Particulate Health Benefits	19.21	19.03	19.14	21.71
Ecological and Visibility Benefits	N/A[a]	N/A[a]	N/A[a]	N/A[a]
Mercury Benefits	N/A[a]	N/A[a]	N/A[a]	N/A[a]
Costs				
Economic Surplus Changes in Electricity Sector	-5.60	-5.20	-8.23	-20.91
Economic Surplus Changes in Rest of Economy	-N/A	-N/A	-N/A	-N/A
Measurable Net Benefits	13.86	14.10	11.18	1.00

a) Ecological benefits to NY State residents for reduced acidification in the Adirondack Park and the health benefits or reduced mercury emissions are included in the uncertainty analysis in Figure 10.

All of the policies have positive annual net benefits that generally increase over time. The net benefits of the policies that include the EPA Mercury Cap are greater than \$10 billion per year in 2010 and roughly \$14 billion per year in 2020, suggesting that the policies are very worthwhile. Furthermore, maintaining the SIP seasonal NO_x program with the CAIR, when coupled with the EPA Mercury Cap, will produce positive incremental net benefits from a national perspective in both 2010 and 2020, compared to the CAIR plus EPA Mercury Cap but without the SIP seasonal NO_x program.

It is also noteworthy that our results are consistent with previous studies that find that the efficient level of control of SO_2 is significantly tighter than in CAIR. Banzhaf et al. (2004) find the average and marginal benefits of particulate-health related SO_2 reductions are approximately equal over an extended range of emission reductions and fairly constant over this range. This implies that the average benefit per ton of the emission reductions we model would continue for further emission reductions. Our benefit estimates for SO_2 reductions are commingled with the benefit of NO_x reductions. However, the average benefit per ton of NO_x emission reductions are less than for SO_2 reductions in our model, so if we calculate an average benefit per ton of emission reduction based on the sum of benefits for the cumulative tons of SO_2 and NO_x emission reductions we will identify a lower bound of the average benefit for further SO_2 reductions. This lower-bound average calculates to about \$2,900 per ton in 2010 and \$3,100 per ton in 2020. In contrast, we identify the marginal cost of further SO_2 reductions as the allowance price for SO_2, which is about \$350 per ton in 2010 and \$1,300 per ton in 2020. Hence, although not our central focus we offer compelling evidence that further reductions in SO_2 emissions would be justified on economic grounds.

The latter two columns show the effects of the high costs of controlling mercury emissions on net benefits. In 2010 the annual net benefits of these policies range from \$4.3 billion to \$7.5 billion. Between 2010 and 2020 net benefits under the Tighter Mercury with MACT policy rise from \$7.5 billion to \$11.2 billion. Under the Tighter Mercury with Trading policy net benefits of \$4.3 billion in 2010 fall to \$1.0 billion in 2020. Despite the fact that trading allows generators to lower the costs of reducing mercury, relative to a technology standard, allowing for mercury trading introduces an opportunity cost associated with mercury emission allowances (over \$1,000,000 per pound) that stimulates switching from coal- to gas-fired generation. The switch results in higher prices to electricity consumers and associated consumer surplus losses. Thus, even though the trading scenario produces greater ancillary reductions in SO_2 in 2010, the large increase in electricity price more than offsets that difference compared to the Tighter Mercury with MACT policy. In 2020, the measured net benefits of CAIR coupled with Tighter Mercury with Trading are one-tenth those of CAIR coupled with Tighter Mercury with MACT.

Table 30. Summary of Modeled New York Benefits and Costs for Central Case

(URM Model; Billions of $1999)

	CAIR plus		*CAIR plus*	
	EPA Mercury CAP	***EPA Mercury Cap and Seasonal SIP NO_x Policy***	***Tighter Mercury with MACT***	***Tighter Mercury with Trading***
2010				
Benefits				
Ozone Health Benefits	.02	.02	.02	.02
Particulate Health Benefits	1.66	1.78	1.83	2.51
Ecological and Visibility Benefits	N/A[a]	N/A[a]	N/A[a]	N/A[a]
Mercury Benefits	N/A[a]	N/A[a]	N/A[a]	N/A[a]
Costs				
Economic Surplus Changes in Electricity Sector	.03	-.02	.06	-.25
Economic Surplus Changes in Rest of Economy	-N/A	-N/A	-N/A	-N/A
Measurable Net Benefits	1.71	1.79	1.90	2.27
2020				
Benefits				
Ozone Health Benefits	.03	.03	.03	.03
Particulate Health Benefits	2.60	2.63	2.60	2.75
Ecological and Visibility Benefits	N/A[a]	N/A[a]	N/A[a]	N/A[a]
Mercury Benefits	N/A[a]	N/A[a]	N/A[a]	N/A[a]
Costs				
Economic Surplus Changes in Electricity Sector	-.07	-.02	.11	-.17
Economic Surplus Changes in Rest of Economy	-N/A	-N/A	-N/A	-N/A
Measurable Net Benefits	2.56	2.63	2.73	2.61

a) Ecological benefits to NY State residents for reduced acidification in the Adirondack Park and the health benefits or reduced mercury emissions are included in the uncertainty analysis in Figure 10.

The costs and benefits of the different policies in New York State are reported in Table 30. As in Table 29, a double line is used to divide the table into those scenarios that incorporate EPA's Mercury Cap and those that include the more stringent mercury policies. Also, this table only includes the benefits and costs analyzed in this study. Therefore, it excludes the costs outside the electricity sector and the benefits of mercury reductions. When looking at this table it is important to keep in mind that the costs and the benefits included here are not necessarily directly linked. Actions to reduce emissions from electricity generators in New York State will yield environmental benefits in New York, but they will also yield environmental benefits outside of New York. Likewise, the benefits obtained in New York under the various policies will be the result of a mixture of actions taken at generating units in New York and those undertaken in upwind states. Thus the costs and the benefits are not necessarily directly comparable. Nevertheless, the net benefits estimates are very relevant for New York residents and businesses and therefore we include them in this report.

The results show that in 2010 all of the policies generate net benefits in New York. The net benefits in New York State are highest under the Tighter Mercury with Trading scenario and lowest under the EPA Mercury Cap scenario. This happens because the particulate health benefits for that scenario in that year are nearly 40% higher than under any other scenario, substantially outweighing the $300 million in additional cost within the state. In 2020, the net benefits in New York are virtually identical under all four scenarios.

6.8 MAGNITUDE OF IMPORTANT UNCERTAINTIES

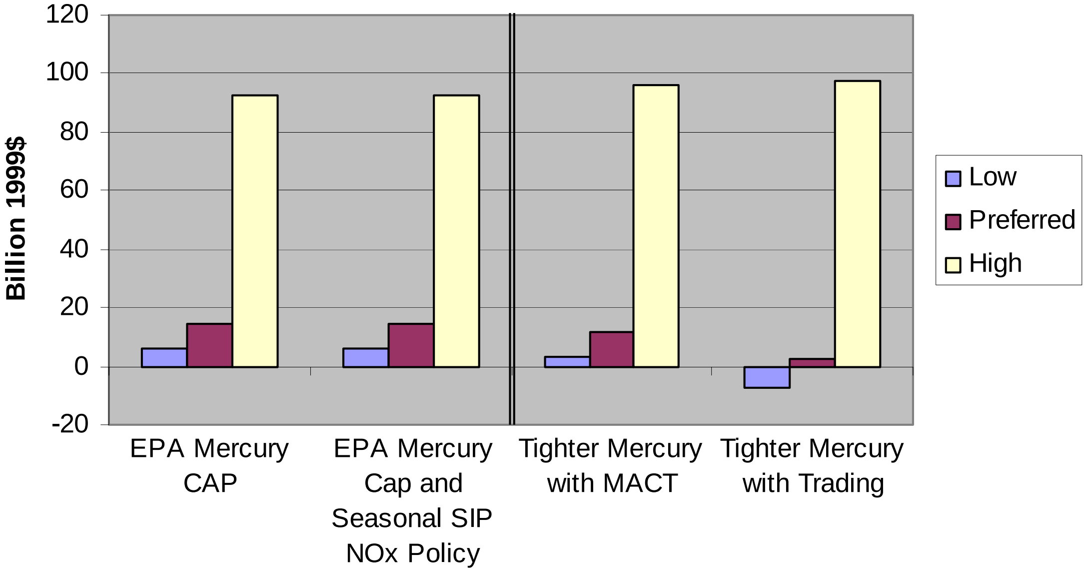
Four prominent uncertainties are woven through our analysis of benefits. Systematically we have chosen to make cautious choices about these uncertainties that lead our estimates of benefits to be toward the low side of the range of defensible estimates. For instance, two uncertainties underlie the estimates we provide of health benefits associated with reduced emissions of SO_2 and NO_x, including the atmospheric modeling of pollution formation and transport and the value of a statistical life. The net benefits reported in Table 29 rely on the URM source-receptor coefficients for particulates. If the alternative case benefits calculated for 2020 using ASTRAP coefficients are used, the net benefits estimates will increase by about $4 billion for the two scenarios that include the EPA Mercury Cap, as well as for the Tighter Mercury with MACT policy, and about $4.9 billion for the Tighter Mercury with Trading policy. Use of a value of statistical life equal to $6.1 million, the value preferred by the U.S. EPA, would increase the mortality related portion of measured benefits, which is the lion's share of what we estimate, by over two-and-one-half times.

We also choose not to include in our main analysis the estimates of two potentially important benefit categories. These two omissions are the health benefits associated with reduced mercury emissions (described in Tables 27 and 28) and the ecological benefits of reduced acidification. Their inclusion would increase our estimate of benefits and net benefits.

Nonetheless, two important questions drive further consideration of uncertainties. Would alternative assumptions or inclusion of additional benefit categories (1) cause net benefits for any policy option to be negative, meaning benefits are less than costs; or (2) change the ranking of policies we examine with respect to their net benefits to society?

Figure 10 provides an illustration of the range of potential net benefits when the four sources of uncertainty outlined above are included in the analysis. The policy scenarios are arrayed across the horizontal axis, with three associated values of net benefits. The Low value represents net benefits under the lowest defensible values for each uncertain item. The Preferred value is that which is described throughout this paper, with a small amendment. The High value is that which would obtain under the highest defensible values for each uncertain item.

Figure 10. The Effect of Uncertainties on Annual Net Benefits and the Ranking of Policy Options, 2020



In the Low value case, the atmospheric transport model is the URM model, the same as in our preferred case. However, we use the low end of $1 million for the value of a statistical life from the range of values surveyed by the U.S. EPA as background for determining the value in recent regulatory impact assessments (EPA 2004b). The category of mercury-related benefits is included, but the Low estimate includes only IQ-related benefits for mercury. The ecological benefit in the Adirondack Park, based on Banzhaf et al., is also included, but at the low value in the range of reported values of $305 million to $1 billion per year.

The Low value case preserves the ranking of CAIR plus the EPA Mercury Cap and with the continuation of the Seasonal SIP NO_x policy as the policy yielding the greatest net benefits, and the ranking of the other policies also are unchanged from the Preferred case. However, in the Low value case the CAIR plus Tighter Mercury with Trading policy yields negative net benefits, meaning that benefits are less than costs. This results because the costs of this policy within the electricity sector are greater than for any other policy, and the benefits are significantly reduced due to the Low value case assumptions. The most influential of these assumptions is the $1 million value of a statistical life.

The Preferred value case also includes use of the URM atmospheric transport model. The value of a statistical life is $2.25 million. This is still substantially lower than the value that is used by the U.S. EPA. We continue to use cautious assumptions about the mercury-health and ecological values that we used in the Low value case. These values were not included in Tables 29 and 30, and they have little influence on the calculation of net benefits. In the Preferred value case, the CAIR plus the EPA Mercury Cap and with the continuation of the Seasonal SIP NO_x policy continues to be the policy yielding the greatest net benefits. In the Preferred value case, all policy options yield positive net benefits.

The High value case yields a different ranking of policy options. The High value case includes use of the ASTRAP atmospheric transport model for particulates. Most importantly, however, it includes a value of statistical life of $10 million, which is the high end of the range of values surveyed by the U.S. EPA (EPA 2004b). This value is over four times greater than the value used in the Preferred value case. Also, the value incorporates the high end of mercury-health related benefits, including cardiovascular effects and premature mortality. It also includes the high end of ecological benefits.

Use of High values for benefit estimates dramatically boosts the net benefits of all the policy options, but it also changes the ranking of policies. The CAIR plus Tighter Mercury with Trading emerges as the policy yielding the greatest net benefits. This is driven by two factors. The most influential is the value of statistical life, which raises the estimated value of reduced particulate exposure sufficiently to overcome the higher cost of the policy. Also, the mercury-health benefits are significant and this raises the ranking of both policies with the tighter mercury standard relative to the EPA Mercury Cap.

Throughout the majority of this presentation we continue to use cautious assumptions about benefit estimates. Our primary motivation for doing so is that even with cautious assumptions we find that the annual net benefits of the proposed policies are significant. Given the important uncertainties that surround these estimates, we feel it is useful for the policymaker to know that estimates are not likely to overstate the benefits of the policy, especially given that the estimates support the policy.

Finally, we note there are many other sources of uncertainties and omissions on the benefits as well as the costs that extend beyond the current capability to model in a quantitative manner. For instance, benefits from improved visibility and from improved ecological health for the entire nation are not included in this analysis. On the other hand, costs incurred outside the electricity sector due to the interaction of environmental policy with preexisting regulations and taxes tend to increase the overall cost of environmental policy to the nation (Goulder et al., 1999). We feel the sources of benefits and costs that we include are the most important and most relevant to policymakers and their constituencies, given current knowledge and modeling capability.

6.9 COMPARISON WITH EPA'S ANALYSIS OF CAIR RULE AND EIA'S ANALYSIS OF ALTERNATIVE MERCURY CONTROL STRATEGIES

In January of 2004, EPA issued an analysis of the benefits and costs of the CAIR, called the Interstate Air Quality Rule (IAQR) at that time (EPA 2004a).[37] The EPA analysis estimated the annual costs of the rule to be $2.9 billion and the annual health benefits associated with particulates and ozone to be $56.9 billion. Their analysis also included $0.9 billion in visibility benefits and yielded a net benefit estimate of $55 billion or $54.1 billion excluding visibility.

Our estimate of the annual cost of the CAIR policy combined with the EPA Mercury Cap in 2010 is $2.9 billion, the same as that of the EPA. Our estimates include the economic cost of changes in consumer responses to changes in electricity price, so one would expect our estimate to be greater than the EPA's, which is simply a measure of resource cost. Since electricity price changes are very small the two estimates are proximate.

However, our benefits estimates are substantially lower than those in the EPA study. The difference shrinks when we use the alternate case benefits estimates, which raises total health benefits in 2010 to $16.3 billion. A more important explanation of the difference is the difference in the value of a statistical life that is assumed in the two different analyses. As discussed above, EPA uses an estimate of $6.1 million per life saved, but we rely on an estimate that is more than 60% lower. If one factors up our alternate health benefits estimate to adjust for this difference one gets a value for net benefits of $39.6 billion, thereby accounting for most of the difference between this study and EPA (2004a).

A small portion of the remaining $14.5 billion difference in these two health benefits estimates can be attributed to differences in the NO_x emission findings for the two analyses. First, the EPA analysis of the CAIR model finds that the seasonal caps on NO_x are achieved without explicitly imposing them, just by virtue of compliance with the NO_x piece of the CAIR policy. In our analysis, we find that seasonal emissions of NO_x in the SIP region exceed the SIP seasonal NO_x cap without explicitly imposing that cap.

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[37] This analysis does not include any restrictions on mercury emissions.

When we do the analysis including the SIP NO_x policy (keeping national annual emissions of NO_x unchanged), we obtain an additional $0.2 billion in health morbidity and mortality benefits, which when translated in terms of the EPA VSL assumptions, amounts to $0.3 billion. Another source of difference is the roughly 230,000 additional tons of reduction in national annual emissions of NO_x that EPA finds compared to our estimate of national annual NO_x emissions with the CAIR policy in 2010. Roughly speaking this could contribute another $1 billion to the difference in estimates. This accounting leaves about $13 billion difference in the estimated benefits between our analysis and that of EPA for the CAIR plus EPA Mercury Cap model. This is about 24% of the EPA estimated health benefits.

The results of our study can also be compared to a recent analysis that the Energy Information Administration (EIA) undertook of several different proposals to reduce mercury emissions from electricity generators. In response to a request from Senators James M. Inhofe (R-OK) and George V. Voinovich (R-OH), the EIA used its NEMS model of the U.S. energy sector to analyze the costs and effects on fuel mix and use of emission controls of several different mercury control policies. The policies analyzed include EPA's mercury cap-and-trade proposal, the EPA mercury MACT standard and three versions of a stricter mercury MACT that required 90% reduction in mercury emissions, but included different assumptions about the performance and availability of ACI technology by 2008. The EPA Mercury Cap-and-Trade proposal is modeled using the assumed $35,000 per ton safety valve and that safety valve price is binding in the analysis. In the most pessimistic case, they assume that ACI technology is not available until after 2025. All of these policies were compared to a baseline scenario that included the proposed CAIR rule.

In this analysis EIA found that none of the mercury control cases except the one where ACI is precluded during the forecast horizon has any real effect on electricity price relative to the baseline scenario that includes the CAIR rule. This result is consistent with our finding that a strict mercury MACT policy will result in only a very small increase in electricity price relative to the case with the EPA Mercury Cap included. We did not run a scenario that included CAIR with no cap on mercury and thus we cannot make the same comparison that can be made using the EIA model runs. The EIA study also concludes, comparable to our findings, that there is very little fuel switching away from coal with the stricter mercury MACT policy. Only when EIA restricts the performance of ACI or its availability does fuel switching become a more frequently chosen method for reducing mercury emissions. When ACI is assumed to be unavailable the EIA model also installs almost twice as many new scrubbers as in other cases and substantially more SCR as well.

Under optimistic technology assumptions, the EIA study finds that the discounted value of total resource costs over the forecast horizon of the mercury MACT standard that requires 90% reduction are about four times the size of the sum of total resource costs plus allowance payments of the EPA Mercury Cap-and-Trade policy. Our incremental cost calculation is not directly comparable to EIA's because each of the cost estimates in our report include the cost of complying with the CAIR rule in addition to the cost of complying with the mercury regulations, whereas EIA has included the CAIR rule in their baseline and reports only the incremental cost of mercury controls. Our analysis focuses on costs in particular years and does not calculate present discounted value. For 2010 we find that the resource costs of the MACT standard we model, which is more stringent than the one modeled by EIA, are just 30% greater than the sum of resource costs plus allowance payments for the CAIR plus EPA Mercury Cap policy. Our preferred way to represent costs is in changes in economic surplus. In 2020 the MACT policy is just 26% greater in our model. We find that the annual cost in economic surplus losses of the mercury MACT program is twice the cost of the combination of the CAIR rule plus the EPA Mercury Cap in 2010 and roughly 1.5 times as large in 2020.

Section 7

CONCLUSION

Recent federal policy proposals to reduce emissions of SO_2, NO_x, and mercury from the electricity sector promise important improvements in air quality and reductions in acid deposition in New York State and across the nation. In this study we look at EPA's proposed CAIR to reduce annual emissions of NO_x and SO_2 in 28 states and the District of Columbia coupled with a number of different policies for mercury and, in one case, a continuation of the SIP seasonal NO_x cap.

This project uses four models to analyze the costs and benefits of the different policies within the electricity sector. The Haiku model looks at the effects of the policies on the behavior of electricity producers and consumers and the resulting implications for costs, prices to consumers, and the level and location of emissions. The TAF model is used to translate changes in emissions of SO_2 and NO_x from power plants into changes in air quality, human health, and monetary benefits of those changes in health status. For this project we incorporate a new set of source-receptor coefficients derived from the URM-1ATM air quality model and an associated post-processing model called the SRG into TAF. Previously, TAF contained source-receptor coefficients from the ASTRAP model for particulates, but had no source-receptor coefficients for ozone. In this analysis, we use the ASTRAP model as a point of comparison for the new coefficients. For deposition of sulfur and nitrogen we continue to rely on ASTRAP.

We find benefits to the nation and to New York State significantly outweigh the costs associated with reductions in SO_2, NO_x, and mercury, even under cautious assumptions about the valuation of the expected health effects. Depending on the policy, between 11 and 13% of the total national health benefits occur in New York State, a function of the state's population and its location downwind of major emission sources. We calculate and value expected improvements in human health resulting from changes in particulate matter and ozone concentrations, which are thought to capture the most important benefits. We find the health benefits of reducing particulate matter are nearly two orders of magnitude greater than the health benefits of reducing ozone. Several benefit categories including improved visibility, reduced acidification, and other ecological improvements and the effects of mercury on human health and the environment would unambiguously increase the calculated net benefits even further. While we do not assign monetary values to the effects in our central analysis, we do find that the policies yield important reductions in deposition of acid precursors in New York State, particularly when the tighter mercury targets are in place. We discuss the potential value of reductions in acidification to the Adirondack Park, based on one recent study.

The mercury emission levels that we model are taken from EPA analysis that accounts for the opportunity for emission banking and for a safety valve price on mercury emissions. The effect of the safety valve is to cause total emissions to exceed the intended emission cap. We do not model explicitly the benefits of mercury reductions, however we can extrapolate based on estimates in other recent studies to infer the potential magnitude of mercury reductions.

We find that, with the exception of the Tighter Mercury with Trading, the set of policies will have fairly small impacts on the average price of electricity nationwide and in New York. However, how mercury emissions are regulated will have important implications not only for the cost of the regulation, but also for emission levels for SO_2 and NO_x and where those emissions are located.

Our research shows that contrary to EPA's findings, the originally proposed CAIR rule by itself will not keep summer emissions of NO_x from electricity generators in the SIP region below the current SIP seasonal NO_x cap. As a result, average summertime 8-hour and 24-hour ozone concentrations in New York and elsewhere are higher under the originally proposed version of the CAIR policy that we model than under the baseline. Two possible remedies are tighter annual caps or continuation of the seasonal cap. We model the latter and find that combining a continuation of the SIP seasonal NO_x cap with the CAIR plus EPA Mercury Cap corrects this situation and does so at relatively low cost to firms and no cost to electricity consumers nationwide. In the final version of the CAIR rule, EPA reconstitutes a seasonal cap-and-trade program for NO_x in a subset of the region to address this concern. The CAIR with the seasonal NO_x cap produces higher net benefits relative to the originally proposed CAIR.

We compare the EPA Mercury Cap with more stringent mercury policies that lead to about 67% further reductions in mercury emissions by 2020. An important environmental effect of the tighter mercury cap is that it brings about substantial ancillary reductions in emissions of NO_x and SO_2. Under the MACT version of this policy, additional NO_x reductions equal to 11% of baseline emissions are achieved by 2020. Under Tighter Mercury with Trading smaller additional reductions in NO_x are achieved but the SO_2 cap goes slack by 2010 as generators rely more on installation of flue gas desulfurization (FGD) units (known as SO_2 scrubbers) to reduce mercury and less on activated carbon injection (ACI). In 2020 this results in 1 million tons fewer emissions of SO_2 relative to the other policies.

We find that all four policies to regulate multiple pollutants from the electricity sector that we investigated, including policies with the tighter mercury controls, would deliver substantial benefits to residents of New York State and the nation. Our modeling indicates that additional SO_2 emissions reductions beyond those called for by the EPA rules would yield benefits that substantially exceed the additional cost. Our evaluation of scenarios with tighter mercury emission controls shows that the net benefits of a maximum achievable control technology (MACT) approach exceed the net benefits of a cap and trade approach. It is important to note that we do not include estimates of the benefits of mercury reductions, which if included, could improve the net benefits of more stringent mercury controls. Extrapolating from Rice and Hammitt's (2005) findings suggest that adding in these benefits could increase the benefits of the tighter mercury policies by roughly $1 billion.

Use of the EPA assumption about the value of a statistical life would have the single biggest effect on the calculation of net benefits, but it would do little to distinguish the EPA Mercury Cap policies and the Tighter Mercury with MACT because the particulate-related health benefits of these three would be inflated about equally. However, use of the EPA assumption would boost the relative net benefits of Tighter Mercury with Trading, making it the policy with the greatest net benefits in 2010. However, in 2020 it would still not yield net benefits as great as the other policies.

In New York the health benefits from reduced exposure to ozone and fine particulates are the highest under the Tighter Mercury with Trading Scenario, especially in 2010. However, the benefits in New York in 2020 under the Tighter Mercury with Trading are roughly only 6% greater than with MACT or with the EPA Mercury Cap policies. For the rest of the nation they are roughly 12% greater. The difference stems from the location of emissions and emission reductions.

We give less emphasis to monetary estimates of the benefits of reduced acidification and from improved health due to lessened exposure to mercury because the literature on which this is built is not yet completed peer-reviewed. However, the evidence suggests that reduced acidification would contribute another $305 million to $1 billion in annual benefits, accounting just for the benefits that would accrue to residents of New York State from improvements in the Adirondack Park. The benefits from reduced emissions of mercury at the national level range from $121 million to $1.7 billion under the EPA Mercury Cap, and from $230 million to $3.3 billion under the tighter cap, depending on which health effects are included.

We explore the major uncertainties in our estimates in order to see if it is likely that different values would identify a different policy option as more efficient. The range of parameter uncertainties include low and high values resulting from the choice of atmospheric model for predicting particulate concentrations and low and high values for the value of a statistical life, based on the range of values in the literature. We also add in recent estimates of the value of mercury reductions for human health and ecological improvements in the Adirondack Park. This uncertainty analysis indicates that all policies continue to yield positive net benefits (benefits greater than costs) with one exception. Under the Low value case illustrated in Figure 10, the CAIR plus Tighter Mercury with Trading yields benefits less than costs. The most important factor causing this reversal is the use of a value of statistical life of $1 million, less than one-half of our preferred value, and less than one-sixth of the EPA's preferred value. We also find that for the Low and Preferred value cases in the uncertainty analysis, the CAIR plus EPA Mercury Cap with continuation of the Seasonal SIP NO_x policy yields the greatest net benefits. However, for the High value case, while net benefits for all policies increases dramatically, the CAIR plus Tighter Mercury with Trading emerges as the policy with the greatest net benefits.

The effect of the different policies on the mix of fuels used to supply electricity is also fairly modest in most cases. The scenarios that combine CAIR plus the EPA Mercury Cap, and with the Tighter Mercury with MACT policy, see a small switch away from coal to natural gas. The switch from coal to natural gas is much larger under the Tighter Mercury with Trading Scenario. The current federal administration has often stated that it is not the purpose of environmental regulation to force fuel switching away from coal. From this perspective, a MACT approach may be preferred to a trading approach as a way to achieve tighter mercury targets (beyond EPA's proposal) because it preserves the role of coal in electricity generation.

The Tighter Mercury with Trading produces large ancillary reductions in emissions of CO_2 of 11% of baseline levels nationally in 2010 and 9% in 2020. In New York State carbon emissions fall by almost one-third in 2010 and by over one-quarter in 2020. The other policies never lead to a decrease in carbon emissions of more than 2.5%.

A key factor in the design of environmental policy is the incidence of burden, which varies for consumers and for producers depending on whether a trading approach is used. Consumers bear virtually all of the cost of EPA's proposed policies in 2010. In New York, producers benefit from the policies. By 2020, nationwide we find the burden is shared fairly equally between consumers and producers, although consumers still bear the greater cost. In 2020 the cost in New York State is very small, due in part to the implementation of New York's multipollutant rule that is included in the baseline. Producers bear the entire cost in 2020.

Combining the CAIR rule with tighter mercury standards yields substantial changes in the incidence of burden. Nationwide in 2010, consumers still bear most of the cost under a MACT approach but consumers and producers share in the incremental cost of the tighter mercury standard. In 2020 consumers are entirely bearing the additional cost. There is no additional cost of the tighter mercury standards using a MACT approach in New York State in 2010 or 2020.

However, implementing tighter mercury standards using a trading approach imposes significantly more cost on the electricity sector, due to the internalization of the opportunity cost of mercury emission allowance prices and the corresponding change in resources use including fuel switching to natural gas. Consumers bear the entire burden from tight mercury controls with trading, while producers in the aggregate actually benefit due to higher electricity prices. It is important to note that the effect on individual firms is likely to vary greatly, depending on the portfolio of generation assets they operate.

Our analysis has several limitations and three primary ones should be kept in mind. First, we focus on the electricity sector, and thus are unable to account for the general equilibrium social costs of the different policy scenarios, which could significantly raise the estimate of costs.

Second, we do not assign monetary values to changes that would result from the reduction in acid deposition in New York State resulting from the policies. We also do not value visibility improvements or other ecological effects from reduced particulate matter and ozone. And, most importantly we do not value the benefits of a reduction in mercury. The benefits of mercury reductions are the reason for considering the alternative policies. Quantifying and valuing these pathways could significantly raise the estimate of benefits as the Rice and Hammitt (2005) findings suggest.

Third, some important assumptions play a significant role in the analysis. One of these is the assumed value of reducing premature mortality, known as the value of a statistical life. We use estimates that are roughly one-third of those preferred by the EPA. The choice of different estimates would alter the estimate of mortality-related health improvements in a direct manner, and these health improvements are thought to be the significant majority of benefits accruing from pollution reduction.

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Appendices

Appendix 1. Glossary of Economic Terms and List of Acronyms

Glossary:

Cap-and-Trade Regulation: A regulation that caps total emissions of a particular pollutant from all relevant sources, creates allowances for each unit of emissions and allows individual sources to trade in those emission rights. Emission allowances may be distributed or auctioned to industry sources.

Constant Elasticity Demand Function: A demand function that states that consumer demand for a product or service responds in constant proportion to a change in price at all underlying price levels.

Demand Elasticity: The degree to which consumer demand for a product or service responds to a change in price. When there is no perceptible response, demand is said to be inelastic. Generally elasticity is represented by an estimate of the percentage change in quantity demanded in response to a percentage change in price.

Dynamic Framework: An economic model is said to have a dynamic framework when it includes the possibility for capital investment and retirement.

Endogenous: Within the context of a model such as the RFF Haiku model of the electricity sector, an endogenous variable is one that is generated by the model. Endogenous variables in the Haiku model include investment, generation, electricity transmission, price of coal and natural gas, emissions of different pollutants, emission allowance prices, and retail electricity price.

Exogenous: Within the context of a model such as the RFF Haiku model of the electricity sector, an exogenous variable is one that is not generated by the model but instead is parametric. Examples of exogenous variables in the Haiku model include the price of oil, the quantity of existing generation capacity and the heat rate of existing capacity.

Factor Demand: The demand for inputs used in the production of a product or service. In the case of electricity production, the input factors include fuel, labor and equipment.

Factor Prices: The prices of the inputs used to produce a product or service.

Market Equilibrium: A market equilibrium is when total demand for a particular good in a market at a given price equals total supply of that good at the same price.

Opportunity Cost: The choice that is forgone when another choice is made. For example, when a firm invests in a particular piece of pollution-control equipment it may be unable to make other productive investments and the loss of the returns on the best of those investments is the opportunity cost of the investment in pollution control equipment.

Short-Run Variable Cost: Costs that vary with the level of production holding capital investment fixed.

Value of a Statistical Life: The monetary value associated with avoiding a premature mortality. This value is derived from measurement of individuals’ willingness to pay to avoid small changes in risk of premature mortality, and those changes are then extrapolated to a large population.

Acronyms:

ACI	activated carbon injection
ADE	atmospheric diffusion equation
ASTRAP	Advanced Source Trajectory Regional Air Pollution, model name
Btu	British thermal unit
CAAAC	Clean Air Act Advisory Committee
CAIR	Clean Air Interstate Rule
CAIR/m	Clean Air Interstate Rule with Mercury
CART	Classification and Regression Tree
CO_2	carbon dioxide
ECAR	Ohio Valley region of NERC, see below
EIA	Energy Information Administration
EPA	Environmental Protection Agency
SO_2	sulfur dioxide
ERCOT	Texas region of NERC, see below
FGD	flue gas desulfurization
GHG	greenhouse gas
MAAC	Mid-Atlantic region of NERC, see below
MACT	maximum achievable control technology
MAIN	NERC Region containing Illinois and parts of surrounding states, see below
MAPP	Mid-Continent Area Power Pool
NERC	North American Electric Reliability Council
NO_x	nitrous oxides
NO_x SIP Call	EPA regulatory cap-and-trade program restricting emissions of NO_x in summertime in 19 eastern states and the District of Columbia
NO_x SIP Call Region	Shorthand for group of 19 states plus DC covered by EPA NO_x SIP Call
NYSERDA	New York State Energy Research and Development Authority
PM	particulate matter
RADM	Regional Acid Deposition Model
RAMS	Regional Atmospheric Modeling System, model name
SCR	selective catalytic reduction
SNCR	selective noncatalytic reduction
SIP	State Implementation Plan
SRG	Source-Receptor Generator, model name
TAF	Tracking and Analysis Framework, model name
URM	Urban-to-Regional Multiscale, abbreviated model name
URM-1 ATM	URM One Atmosphere Model, full model name

Appendix 2.

Legislative Comparison of Multipollutant Proposals S. 366, S. 1844, and S. 843.[1]

Features	S. 366 – Jeffords (108th)	S. 1844 – Clear Skies (108th)[2]	S. 843 – Carper (108th)
Affected Facilities	Electricity-generating facilities with a nameplate capacity of 15 MW or more.	Electricity-generating facilities with a nameplate capacity of 25 MW or more.	Electricity-generating facilities with a nameplate capacity greater than 25 MW.
National Annual Allowance Allocation Caps			
Sulfur Dioxide (SO_2)	2.25 million tons in 2009. Split into two regions.[3]	4.5 million tons in 2010. 3.0 million tons in 2018.	4.5 million tons in 2009. 3.5 million tons in 2013. 2.25 million tons in 2016.
Nitrogen Oxides (NO_x)	1.51 million tons in 2009.	2.19 million tons in 2008. 1.79 million tons in 2018. Split into two regions.[4]	1.87 million tons in 2009. 1.7 million tons in 2013.
Mercury	5 tons in 2008. Facility specific emissions limitations without trading.	34 tons in 2010. 15 tons in 2018.	24 tons in 2009. 10 tons in 2013. Facility-specific limitations apply.[5]
Carbon Dioxide (CO_2)	2.05 billion tons in 2009.[6]	No CO_2 policy.	2.57 + billion tons in 2009.[7] 2.47 + billion tons in 2013.[8] + additional tonnage through sequestration incentives.
Allowance Allocation Cap Changes and Additional Annual Allowance Availability			
High Costs	None except to exercise penalty	Units can purchase future	None except to exercise penalty

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[1] Prepared by David Lankton, Billy Pizer, Karen Palmer, and Dallas Burtraw.
[2] The Bush administration has proposed regulatory rules, similar to the policies in S. 1844, to be published in the Federal Register by early February of 2004.
[3] Under S. 366, the western region has a 0.275 million ton cap on SO_2 and the non-western region has a 1.975 million ton cap on SO_2.
[4] Under S. 1844, the western region has a 0.715 million ton cap on NO_x and the eastern region has a 1.475 million ton cap on NO_x. The eastern NO_x cap is reduced to 1.074 million tons in 2018.
[5] For S. 843, from 2009 to 2012, mercury emissions cannot exceed 50% of the total mercury present in delivered coal at each affected facility. After 2012, the percentage drops to 30%. Also, emissions may not exceed an output-based rate determined by the administrator.
[6] The CO_2 cap is specified in S. 366 and it approximates 1990 level CO_2 emissions from the electricity sector.
[7] The S. 843 2009 allowance cap is equal to 2006 electricity sector CO_2 emissions as projected by EIA in the most recent report as of date of enactment. The number we report is EIA's *AEO 2003* projection for 2006.
[8] The S. 843 2013 emissions cap is equal to actual 2001 electricity sector CO_2 emissions. The number we report is EIA's *AEO 2003* projection for 2001.

Features	S. 366 – Jeffords (108th)	S. 1844 – Clear Skies (108th)[2]	S. 843 – Carper (108th)
“Safety Valve”	provisions for excess emissions.	allowances for current use: **SO_2:** \$2,000 (per ton). **NO_x**: \$4,000 (per ton). **Mercury**: \$2,187.50 (per ounce).[9]	provisions for excess emissions.
Carryover from Title IV SO_2 and NO_x SIP Call programs	**SO_2, NO_x:** Banked pre-2008 Title IV NO_x and SO_2 allowances can be traded 4:1 for S. 366 NO_x and SO_2 allowances, respectively. **SO_2, NO_x:** SO_2 and NO_x allowances banked as a result of meeting new source performance standards between 2001 and 2008 are considered full value S. 366 allowances of the appropriate type.	**SO_2:** Banked pre-2010 Title IV SO_2 allowances can be traded 1:1 for S.1844 SO_2 allowances. **NO_x:** Banked allowances from the regional, seasonal SIP Call trading program can be traded 1:1 beginning in 2008.	**SO_2:** Banked pre-2009 Title IV SO_2 allowances carryover 1:1 for S.843 SO_2 allowances.
Additional Allocations for Out-of-Program Emission Reductions			**CO_2:** Additional CO_2 allowances for carbon sequestration are added to the annual CO_2 allowance cap. See “CO_2-Specific Allocation Methods” below. **CO_2:** Allowances from other international or U.S. CO_2 reduction programs may be used.[10]
Localized Reductions and National Ambient Air Quality Standards	The administrator may limit localized emissions to avoid significant adverse health impacts. **Non-Attainment:** Units contributing to non-attainment of	S. 1844 does not interfere with states continued authority over local compliance with NAAQS.	The federal or state government may limit emissions from a specific facility to address local air quality problems. **Non-Attainment:** After 2008,

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[9] For S. 1844, purchased allowances reduce the allowances (of the purchased type) that would otherwise be allocated the next year. If these allowances are not used, they are taken by the administrator (without refund). Prices are adjusted for inflation based on the Consumer Price Index. If more allowances are sold than would otherwise be allocated in the next year, then the allocation in the second next year is reduced (continuing as necessary).

[10] S. 843 establishes an independent review board consisting of members from the EPA, DOE, state governments, the electricity sector, and environmental organizations that must certify additional CO_2 allowance allocations.

Features	S. 366 – Jeffords (108th)	S. 1844 – Clear Skies (108th)[2]	S. 843 – Carper (108th)
(NAAQS)	the ozone standard must submit three NO_x allowances for each ton of NO_x emitted. Units contributing to non-attainment of the PM-2.5 standard must submit two SO_2 allowances for each ton of SO_2 emitted.		sources within non-attainment areas would no longer be required to obtain offsets for emissions.
Allowance Cap Reductions From Small Source Emissions	For 2009 and each following year, the allowance caps are reduced by the emissions from small electricity generators (< 15 MW) in the second preceding year.		
New Information "Re-opener"	Each year, any additional reductions the administrator finds necessary to protect public health and welfare may be made.		Within 15 years of enactment, the administrator must determine whether or not to adjust the annual allowance allocation caps. If it is determined that adjustments are required, they will take effect 20 years after enactment.
Allowance Banking and Trading Programs			
Banking Restrictions	**Mercury:** Cannot be banked.		
Trading Restrictions	**SO_2:** Allowances cannot be traded between regions. **Mercury:** Cannot be traded.	**NO_x:** Allowances cannot be traded between the two regions.	
Western Regional Air Partnership (WRAP)		Two measures trigger the start of the WRAP program: 1) After 2013, the third year after which the SO_2 emissions from WRAP states are *projected* to exceed 271,000 tons. **OR**	Two measures trigger the start of the WRAP program: 1) Any year from 2016 or later that is the third year after *projected* WRAP SO_2 emissions exceed 271,000 tons **OR**

Features	S. 366 – Jeffords (108th)	S. 1844 – Clear Skies (108th)[2]	S. 843 – Carper (108th)
		2) After 2018, beginning the third year after which *actual* SO_2 emissions from states in the WRAP exceed 271,000 tons. As of the start date, the administrator will allocate 271,000 SO_2 allowances to electricity-generating units (EGUs) in those states each year. Only these allowances may be used by EGUs in the WRAP states.	2) Any year 2021 or later that is the third year after *actual* WRAP SO_2 emissions exceed 271,000 tons. As of the start date, SO_2 emissions from WRAP states may not exceed the number of SO_2 allowances allocated to units in WRAP states. The administrator will determine the method and number of these allocations by 2013.
Treatment of Pre-existing NO_x Programs	The regional summertime NO_x SIP Call trading program would exist separate from S. 366.	The regional summertime NO_x SIP Call trading program would terminate after 2007.	The regional summertime NO_x SIP Call trading program would exist separate from S. 843.
Potential for Trading Across Pollutants		By July 1, 2009, the administrator will submit a study to Congress regarding the environmental and economic effects of inter-pollutant trading of NO_x and SO_2.	
Allowance Allocation Methods			
In General	Auctions with revenues returned to consumers and allowances set aside for impacted sectors.	Grandfathering.	Grandfathering for SO_2 and output-based allocations for NO_x, mercury and CO_2.
Methods Applicable to Multiple Pollutants	**Existing Sources; SO_2, NO_x, CO_2:** 10% of all SO_2, NO_x, and CO_2 allowances in 2009 will be grandfathered to affected units based on their share of electricity generation in 2001. Allocations decrease by 1% until 2018. **Transition Assistance; SO_2, NO_x, CO_2:** 6% of all SO_2, NO_x, and	**Baseline Heat Input; NO_x, Mercury:** Baseline heat input is the average annual heat input used by a unit during the 3 years in which the unit had the highest heat input for the period 1998 to 2002. See the NO_x and Mercury sections below for applicability.	**New Unit Reserve; SO_2, NO_x, Mercury, CO_2:** The administrator and the Secretary of Energy will determine the size of the new unit reserve every five years for the next five-year period based on projections of electricity output from new units.

Features	S. 366 – Jeffords (108th)	S. 1844 – Clear Skies (108th)[2]	S. 843 – Carper (108th)
	CO_2 allowances in 2009 are allocated to non-electricity generating firms for transition assistance. This amount declines by 0.5% until 2018. Of these allowances, 80% go to dislocated workers and adversely impacted communities. The remaining 20% go to producers of electricity-intensive products. **Renewable Generation and Clean Product Incentives; SO_2, NO_x, CO_2:** Not more than 20% of all SO_2, NO_x, and CO_2 allowances will be allocated each year to renewable generation facilities and owners of energy-efficient buildings, producers of energy-efficient products, entities that carry out energy-efficient projects, owners of new clean fossil-fuel electricity generating units, and owners of combined heat / power generators.[11] **Household Allocations; SO_2, NO_x, CO_2:** Any allowances not allocated to other sectors are given to electricity consumers through	**Early Reduction Credits; SO_2, NO_x:** Additional allowances will be allocated (1 allowance for each 1.05 ton reduction) for installation or modification of pollution control equipment or combustion technology improvements after the date of enactment but prior to 2010. No allowances will be allocated for equipment in operation or under construction prior to enactment, attributable to fuel switching, or required under federal regulation.	

[11] For S. 366, renewable electricity-generating units receive an allocation based on renewable electricity production and the national average emissions per MWh by all electricity-generating facilities. For energy efficiency, the allocation is based on electricity or natural gas saved and the national average emissions per MWh or cubic foot of natural gas. For new, clean fossil-fuel-fired electricity generating units, allocations are based on the previous year's MWhs produced by new, clean fossil-fuel-fired electricity generating units and one half of the national average emissions per MWh. For combined heat and power electricity generating facilities, allocations are the product of Btu produced and put to use by each facility and the previous year's national average quantity of emissions per pollutant per Btu.

Features	S. 366 – Jeffords (108th)	S. 1844 – Clear Skies (108th)[2]	S. 843 – Carper (108th)
	an appointed trustee. Households receive allowances based on the number of people in the household and their state's ratio of residential electricity consumption to national residential electricity consumption.		
SO_2 Specific Allocation Methods		**Grandfathering Rules; SO_2:** 93% of allowances are given to affected electricity-generating units proportional to Title IV SO_2 allowance allocations. **Non-Title IV Units and Additional Units; SO_2:** 7% of the SO_2 allowances are allocated (based on baseline heat input and SO_2 emission rates) to units that were non-Title IV units and additional units built after 2001. These allocations are made on a first construction basis. **Control Incentives; SO_2:** [12] A total of 250,000 allowances (out of the 4.5 million annual allocation) are allocated over the first three years of the program as incentives for SO_2 control technology.	**Existing Sources: SO_2:** Existing fossil-fuel-fired units (includes Title IV existing units and units built at least three years before the current year) receive allowances based on Title IV allowance allocation rules, pro-rated to comply with the difference between the S. 843 allowance cap and the new unit reserve for SO_2.[13] **New Sources: SO_2.** New units receive allowances based on future regulations promulgated by the administrator.
NO_x Specific Allocation Methods		**Grandfathering Rules; NO_x:** 95% of allowances (in each region) are given to affected electricity-generating units based	**Existing Sources; NO_x:** Existing fossil-fuel-fired units receive allowances equal to the product of 1.5 pounds of NO_x per MWh times

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[12] For S. 1844, in the first three years, the number of grandfathered SO_2 allowances is reduced by 0.083 million allowances. These allowances are offered via competitive bidding to coal-fired facilities that reduce their SO_2 emissions through improved technology.

[13] For S. 843, allocation to existing units that are not specifically mentioned in Title IV is determined by the administrator on a fair and equitable basis.

Features	S. 366 – Jeffords (108th)	S. 1844 – Clear Skies (108th)[2]	S. 843 – Carper (108th)
		on baseline heat input relative to total baseline heat input across all affected units. **Additional Units; NO_x:** 5% of the NO_x allowances (in each region) are allocated (based on baseline heat input) to units that commence operation after enactment of S. 1844. These allowances are allocated on a first construction basis.	the quotient of the average quantity of electricity generated during the most recent three-year period in MWh divided by 2,000 pounds of NO_x per ton. If this total is not equal to the difference between the allowance cap and the new unit reserve for NO_x, allowances are allocated on a pro-rata basis. **New Sources: NO_x:** New units receive allowances based on projected emissions.
Mercury Specific Allocation Methods	**Emissions Limitations; Mercury:** Mercury emissions are not to exceed 2.48 grams per 1,000 MWh. This is an emissions limitation, not an allocation of allowances, and may not be banked or traded.	**Grandfathering Rules; Mercury:** 95% of allowances are given to affected electricity-generating units based on baseline heat input relative to total baseline heat input across all affected units. **Additional Units; Mercury:** 5% of the Mercury allowances are allocated (based on baseline heat input) to units that commence operation after enactment of S. 1844. These allowances are allocated on a first construction basis.	**Existing Sources; Mercury:** Existing coal-fired units receive allowances equal to the product of 0.0000227 pounds of mercury per MWh multiplied by the average quantity of electricity generated during the most recent 3-year period in MWh. If this total is not equal to the difference between the allowance cap and the new unit reserve for mercury, allowances are allocated on a pro-rata basis. **New Sources; Mercury:** New units receive allowances based on projected emissions.
CO_2 Specific Allocation Methods	**Sequestration Incentives; CO_2:** Not more than 0.075% of total CO_2 allowances shall be allocated		**Sequestration Incentives; CO_2:** Additional CO_2 allowances are allocated for carbon sequestration

Features	S. 366 – Jeffords (108th)	S. 1844 – Clear Skies (108th)[2]	S. 843 – Carper (108th)
	to encourage biological carbon sequestration and not more than 1.5% of total CO_2 allowances shall be allocated to encourage geological carbon sequestration.		and for programs to reduce greenhouse gas emissions. In 2009, allocations are made for projects from 1990 to 2008, and these allowances are limited to 10% of the CO_2 allowance cap for 2009. After 2009, allocations are made for current projects, and there is no limitation on the number of additional allowances. **Existing Sources; CO_2:** Existing fossil-fuel-fired, nuclear,[14] and renewable[15] units receive allowances equal to their average generation over the most recent three-year period divided by the total average generation over the same period by all such units multiplied by the difference between the allowance cap and the new unit reserve for CO_2. **New Sources; CO_2:** New fossil-fuel-fired and renewable units receive allowances based on their projected share of total generation.
Compliance With Legislation			
Penalties for Excess Emissions	**SO_2, NO_x, CO_2:** Three times the excess emissions in tons (or failed allowance submissions) multiplied by the average annual market price	**SO_2, NO_x, Mercury:** The excess emissions in tons (for NO_x, SO_2) or ounces (for Mercury) multiplied by the average sale price between	**SO_2, NO_x, CO_2, Mercury:** Excess emissions must be offset in a future year, as determined by the administrator. Also:

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[14] For S. 843, nuclear units receive (and must submit) allowances based only on their incremental generation from 1990 levels.

[15] For S. 843, renewable units include wind, organic waste (excluding incinerated municipal solid waste), biomass, fuel cells, hydroelectric, geothermal, solar thermal, photovoltaic, and other non-fossil fuel, non-nuclear sources.

Features	S. 366 – Jeffords (108th)	S. 1844 – Clear Skies (108th)[2]	S. 843 – Carper (108th)
	for the appropriate allowances. **Mercury**: Three times the excess emissions in grams multiplied by the average cost of mercury controls.	holders of allowances. Excess emissions must also be offset the following year (a violator's allocation is reduced by the quantity of excess emissions).	**SO_2:** $2,000 (1990$) penalty for each ton of excess emissions. **NO_x:** $5,000 penalty for each ton of excess emissions. **CO_2:** $100 penalty for each ton of excess emissions. **Mercury:** $10,000 penalty for each pound of excess emissions. **SO_2, NO_x, CO_2, Mercury:** Fees are adjusted by the CPI.
Monitoring and Record Keeping Requirements	Each affected facility must install and operate a continuous emissions monitoring system. Facilities must provide the administrator with data on emissions and emissions per MWh for each covered pollutant. The administrator will keep an inventory of emissions from all small electricity-generating facilities (less than 15 MW). Coal-fired facilities with an aggregate generating capacity of 50 MW or more must monitor ambient air quality within a 30-mile radius of the facility.	Each affected facility must install and operate a continuous emissions monitoring system. Facilities must provide the administrator with data for opacity, volumetric flow, and emissions of SO_2, NO_x, and mercury.	The administrator will promulgate regulations for monitoring requirements. **SO_2:** Title IV reporting for SO_2 is required. **NO_x, CO_2, Mercury:** At least quarterly, facilities must submit to the administrator a report on the emissions of NO_x, CO_2, and mercury.
Modernization and the New Source Review Program (NSR) **Lowest Achievable**	Beginning on January 1, 2014, or 40 years after the beginning of generation at a facility (whichever date is later), the facility is subject to emissions limitations reflecting best available control technology	A unit whose hourly emissions of a pollutant increases at maximum capacity from modifications must either meet the national emissions standards for affected units or apply best available control	**NSR:** Construction of a new unit (including existing boiler replacement) or any modification to an existing unit that increases the hourly emissions rate of an NSR covered pollutant will subject

Features	S. 366 – Jeffords (108th)	S. 1844 – Clear Skies (108th)[2]	S. 843 – Carper (108th)
Emissions Rate (LAER) and Best Available Control Technology (BACT)	(BACT) on a new source facility of the same generating capacity.	technology. Facilities that are more than 50 kilometers from a Class I area can exempt themselves from new source review and best available retrofit control technology if they commit within three years to meeting a limit for particulate matter (PM) of .03 lb/MMBtu, have begun to operate control technology to reduce PM emissions, or otherwise reduce PM emissions according to best operational practices.	that facility to the NSR program. Beginning in 2020, each facility which began construction before August 17, 1971 must meet performance standards of 4.5 lbs / MWh and 2.5 lbs / MWh for SO_2 and NO_x, respectively. **LAER and BACT:** Identified biennially. The cost of LAER may not exceed twice that of BACT. **Non-Attainment:** As noted above, sources within non-attainment areas would no longer be required to obtain offsets for emissions after 2008.
Non-NSR Regulatory Relief		The bill delays until 2011 EPA action on petitions by downwind states to reduce emissions in upwind states under section 126 of the Clean Air Act.	Some units would be exempt from mercury emissions standards under section 112 of the Clean Air Act (CAA) and visibility protection requirements (haze) under section 169 of the CAA.

Appendix 3: Proposed and Final CAIR Rules

EPA Proposed SO_2 NO_x Rule: A Supplement to the RFF Legislative Comparison Table. [16]

EPA Proposed SO_2 NO_x Rule (Clean Air Interstate Rule CAIR) (Including June 10, 2004, Supplement)	
Federal Register Title (Date)	Part III Environmental Protection Agency 40 CFR Parts 51, 72, 75, 96 [Supplemental Proposal for the] Rule to Reduce Interstate Transport of Fine Particulate Matter and Ozone (Clean Air Interstate Rule); Proposed Rule (January 30, 2004) [Supplement: June 10, 2004]
Summary	EPA proposes implementing a cap and trade program for 28 eastern States[17] and the District of Columbia to reduce emissions of SO_2 and NO_x from electricity generating units. Participation in the regional trading program is optional for the 28 States and the District of Columbia. States that opt-out of the trading program must meet State-level emission caps.
Affected Facilities	Fossil fuel-fired[18] electricity generating units with a capacity greater than 25 MW, **AND** Fossil fuel-fired steam co-generation units with a capacity greater than 25 MW that sell more than 1/3 of their potential electric output.
Regional Annual Allowance Allocation Caps[19]	**SO_2:** 3.86 million tons by 2010 and 2.70 million tons by 2015. **NO_x:** 1.60 million tons by 2010 and 1.33 million tons by 2015.

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[16] Prepared by David Lankton.

[17] The 28 States are: Alabama, Arkansas, Delaware, Florida, Georgia, Illinois, Indiana, Iowa, Kansas, Kentucky, Louisiana, Maryland, Massachusetts, Michigan, Minnesota, Mississippi, Missouri, New Jersey, New York, North Carolina, Ohio, Pennsylvania, South Carolina, Tennessee, Texas, Virginia, West Virginia, and Wisconsin.

[18] Fossil-fuel fired units are those that fire: natural gas, petroleum, coal, or any fuel derived from such materials, alone or in combination with any other fuel.

[19] Allocation of NO_x emission allowances to electricity generating units in New York State as originally proposed in CAIR and as modeled in this analysis was 52,448 tons in 2010 and 43,707 tons in 2015. In the final version of CAIR, the New York State allowance was reduced to 45,617 in 2010 and 38,014 in 2015. The reduction raises costs to producers in New York State. Many state allocations were increased or decreased in the final rule.

EPA Proposed SO_2 NO_x Rule (Clean Air Interstate Rule CAIR) (Including June 10, 2004, Supplement)

Allowance Allocation Method	**SO_2:** Allowances are allocated to States proportional to a State's share of total Title IV allowances. States that choose to participate in the regional trading program must grandfather their allowances to facilities in a manner consistent with Title IV. States have flexibility in allocating any allowances created using a 3:1 retirement ratio (see Carryover section below). **NO_x:** Allowances are allocated to States based on a State's historic annual heat input and a NO_x emission rate.[20] States have flexibility in allocating their allowances, including auction, updating, and grandfathering allocation. Connecticut is subject to an ozone-season-only NO_x cap beginning in 2010. Connecticut, New Hampshire, and Rhode Island may opt-in to the annual trading program. States are responsible for creation and maintenance of any allowance set-aside programs. **Both:** States choosing to participate in either the SO_2 or NO_x trading program must participate in both the SO_2 and NO_x trading programs.
Banking	Allowances for the proposed regional trading programs may be banked without restriction.
Carryover	**SO_2:** Pre-2010 Title IV allowances banked before the implementation date of the proposed rule may be used in the regional trading program. The proposed SO_2 program would allow: ▪ Pre-2010 Title IV allowances to be used at a 1:1 ratio, and ▪ 2010 to 2014 Title IV allowances to be used at a 2:1 ratio, and ▪ 2015 and later Title IV allowances to be used at a 2.86:1 ratio **OR** retired at a 3:1 ratio, creating CAIR allowances equal to the difference between the retirement ratio and the cap.[21] EPA proposes that these ratios for Title IV allowances will prevent States that are not included in the new regional trading program from abusing the abundance of inexpensive Title IV allowances that would be created without these ratios. All states must use the same ratios. **NO_x:** Banked NO_x SIP Call allowances may be carried forward for use in the proposed cap and trade program at a 1:1 ratio.
Penalties	EPA proposes that any facility emitting pollutants in excess of their permits must surrender future year allowances in an amount equal to their excess emissions. In addition, EPA suggests than an unspecified automatic penalty also be imposed.

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[20] Historic annual heat input is a State's highest annual average heat input from 1999 to 2002. Historic annual heat input is multiplied by a NO_x emission rate (0.15 lb / mmBtu for phase 1 or 0.125 lb / mmBtu for phase 2) to determine a State's NO_x allocation.

[21] Because the proposed 2.86:1 trading ratio meets EPA's goals for SO_2 reduction, a 3:1 retirement ratio of Title IV allowances for CAIR allowances would result in reductions of SO_2 beyond these goals. If the retirement ratio method is used, CAIR allowances are created to close this gap.

EPA Final Clean Air Interstate Rule: A Supplement to the RFF Legislative Comparison Table.[22]

EPA Final Clean Air Interstate Rule (CAIR)	
Federal Register Title (Date)	Environmental Protection Agency 40 CFR Parts 51, 72, 73, 74, 77, 78, and 96 Rule to Reduce Interstate Transport of Fine Particulate Matter and Ozone (Clean Air Interstate Rule); Revisions to Acid Rain Program; Revisions to the NO_x SIP Call (March 10, 2005) [OAR-2003-0053; FRL] [RIN 2060-AL76]
Summary	Implements an **annual** cap and trade program for 25 States and the District of Columbia to reduce emissions of SO_2 and NO_x from electricity generating units. Implements a **seasonal** cap and trade program for 25 States and the District of Columbia to reduce emissions of NO_x from electricity generating units during the ozone season (May to September). Seasonal program replaces the NO_x SIP Call. Participation in the cap and trade programs is optional. States that opt-out of a trading program must meet State-level emission caps.
Affected States[23]	States included in **both** the **annual** SO_2 / NOx program **and** the **seasonal** NO_x program: AL, DE, FL, IL, IN, IA, KT, LA, MD, MI, MS, MO, NJ, NY, NC, OH, PA, SC, TN, VA, WV, and WI.[24] States included in **only** the **annual** SO_2 / NO_x program: GA, MN, and TX. States included in **only** the **seasonal** NO_x program: AR, CT, and MA.
Affected Facilities	Fossil fuel-fired[25] electricity generating units with a capacity greater than 25 MW, **AND** Fossil fuel-fired steam co-generation units with a capacity greater than 25 MW that supply more than 1/3 of their potential electric output to an electricity generator.

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[22] Prepared by David Lankton. This document can be found at Hwww.rff.org/multipollutantH/.

[23] States may opt-out of any or all trading programs. If states opt-out, they may achieve reductions from non-EGU sources (state allowance budgets would be adjusted to take this into account). If states opt-out of the trading program, they may choose allocation method and carryover ratios, among other options.

[24] A separate proposed regulation (EPA 40 CFR Parts 51 and 96 (March 10, 2005) [OAR-2003-053; FRL] [RIN 2060-AM95] Inclusion of Delaware and New Jersey in the Clean Air Interstate Rule) includes DE and NJ in the annual SO_2 / NO_x program. We assume this regulation will also be implemented.

[25] Fossil-fuel fired units those that fire: natural gas, petroleum, coal, or any fuel derived from such materials, alone or in combination with any other fuel.

EPA Final Clean Air Interstate Rule (CAIR)	
Annual SO_2 / NO_x Allowance Allocation Caps[26]	**SO_2:** 3.674 million tons by 2010 and 2.572 million tons by 2015. **NO_x:** 1.522 million tons by 2009 and 1.268 million tons by 2015.
Seasonal NO_x Allowance Allocation Caps	**NO_x:** 0.568 million tons by 2009 and 0.485 million tons by 2015
Allowance Allocation Method	**SO_2:** Allowances are allocated as prescribed by Title IV (grandfathering). **NO_x (Annual and Seasonal):** EPA allocates allowances to States according to each State's allowance pool. States are free to choose the method of allocating allowances (including auction, updating, and grandfathering) to individual units. However, EPA suggests that allowances be allocated to units based on their share of historic heat input (adjusted by fuel type). Also, a new unit allowance pool is created (5% of total permits from 2009 to 2014, 3% thereafter).
NO_x Supplement Pool	A supplemental annual NO_x program allowance pool of 199,997[27] permits is created. Units that reduce NO_x emissions beyond other Federal or State requirements in 2007 and 2008 or require additional permits for grid reliability may apply for these permits, which are distributed in 2009.
Banking	Allowances from the annual SO_2 / NO_x and seasonal NO_x programs may be banked for future use.
Carryover	**SO_2:** Pre-2010 Title IV allowances banked before the implementation date of the rule may be used in the annual trading program. The SO_2 program would allow: ▪ Pre-2010 Title IV allowances to be used at a 1:1 ratio, and ▪ 2010 to 2014 Title IV allowances to be used at a 2:1 ratio, and ▪ 2015 and later Title IV allowances to be used at a 2.86:1 ratio. **NO_x:** Banked NO_x SIP Call allowances may be carried forward for use in the seasonal NO_x cap and trade program at a 1:1 ratio. Vintage 2009 and later SIP Call permits may not be used.
Penalties for Excess Emissions	Any unit in non-compliance must surrender permits to cover excess emissions. That unit's next future year allocation is reduced by 3 times the amount of excess emissions. Additionally, the offending unit must pay fines under the Clean Air Act or any applicable State regulation.

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[26] Includes state budgets for DE and NJ. Without those states, the annual SO_2 allowance allocation caps are 3.619 M tons in 2010 and 2.533 M tons in 2015 and the annual NO_x allowance allocation caps are 1.504 M tons in 2009 and 1.254 M tons in 2015.

[27] This figure assumes that DE and NJ are part of the annual program. Without those states, the supplement pool is 198,494 NO_x permits.

Appendix 4: Proposed and Final EPA Mercury Rules

EPA Proposed Mercury Rule: A Supplement to the RFF Legislative Comparison Table. [28]

EPA Proposed Mercury[29] (Hg) Rule	
Federal Register Title (Date)	Part IV Environmental Protection Agency 40 CFR Parts 60 and 63 Proposed National Emission Standards for Hazardous Air Pollutants; and, in the Alternative, Proposed Standards of Performance for New and Existing Stationary Sources: Electric Utility Steam Generating Units; Proposed Rule (January 30, 2004)
Summary	The EPA proposes two options for reducing national Hg emissions from coal-fired utility units: 1. Maximum Available Control Technology (MACT), **OR** 2. National Mercury Cap and Trade Program. Choice of program will depend on legal interpretation of the Clean Air Act (CAA) and its amendments: ▪ EPA believes it has the authority, under section 111 of the CAA, to implement a national cap and trade program for mercury. ▪ However, some interpretations of sections 111 and 112 of the CAA and two (apparently contradictory) amendments passed in Congress may restrict EPA's authority. If this is the case, EPA suggests MACT.
Affected Facilities (Both Proposals)	Coal-fired electricity generating units with a capacity greater than 25 MW, **AND** Coal-fired steam co-generation units with a capacity greater than 25 MW that supply more than 1/3 of their potential electric output to an electricity generator.

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[28] Prepared by David Lankton.

[29] The rule also proposes Nickel emission limitations on oil-fired generators, which are not discussed in this summary.

<table>
<tr><th colspan="2">EPA Proposed Mercury (Hg) Rule</th></tr>
<tr><th colspan="2">Option 1: Maximum Available Control Technology (MACT)[30]</th></tr>
<tr><td>Existing Units: Mercury Emission Limitations

Input or Output Based (Unit’s Choice)</td><td>
<table>
<tr><th>Unit Type</th><th>Input Limitation (lb Hg / TBtu)</th><th>Output Limitation (10^{-6} lb Hg / MWh)</th></tr>
<tr><td>Bituminous-Fired[31]</td><td>2.0</td><td>21</td></tr>
<tr><td>Subbituminous-Fired</td><td>5.8</td><td>61</td></tr>
<tr><td>Lignite-Fired</td><td>9.2</td><td>98</td></tr>
<tr><td>IGCC Unit</td><td>19</td><td>200</td></tr>
<tr><td>Coal Refuse-Fired</td><td>0.38</td><td>4.1</td></tr>
</table>
</td></tr>
<tr><td>New Units: Mercury Emission Limitations

Output Based</td><td>
<table>
<tr><th>Unit Type</th><th>Output Limitation (10^{-6} lb Hg / MWh)</th></tr>
<tr><td>Bituminous-Fired</td><td>6.0</td></tr>
<tr><td>Subbituminous-Fired</td><td>20</td></tr>
<tr><td>Lignite-Fired</td><td>62</td></tr>
<tr><td>IGCC Unit</td><td>20</td></tr>
<tr><td>Coal Refuse-Fired</td><td>1.1</td></tr>
</table>
</td></tr>
<tr><td>Date of Compliance</td><td>Existing units must comply with the MACT standards within 3 years of the effective date of the final rule’s publication in the Federal Register.
New[32] units must comply with the MACT standards upon initial startup or upon the effective date of the final rule’s publication in the Federal Register, whichever is later.</td></tr>
<tr><td>Fuel Blending</td><td>Units that fire blended coals would have unit specific emission limitations. The emission limitations would be based on weighted average limitations over the different types of coal fired at that unit.</td></tr>
<tr><td>Emissions Averaging</td><td>The proposal would allow emissions averaging as a compliance option for existing coal-fired units located at a single contiguous plant.</td></tr>
</table>

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[30] MACT is based on the average emission limitation achieved by the best-performing 12 percent of existing sources in each category or subcategory.

[31] The bituminous category includes anthracite.

[32] A new unit is a unit that commences construction, modification, or reconstruction after January 30, 2004.

EPA Proposed Mercury (Hg) Rule

Option 2: National Mercury Cap and Trade Program

National Annual Allowance Allocation Caps	34+ tons[33] beginning in 2010. 15 tons beginning in 2018.
Allowance Allocation Method	A State is allocated allowances based on its relative baseline heat input[34] to other States, which the State would then allocate to its utility units. Though States are free to choose an allocation method for utilities, EPA proposes a 'model rule': that allocations to existing sources be based on a unit's share of baseline heat input and adjusted according to coal type: ▪ Bituminous Unit: 1.0 times the share of heat input. ▪ Subbituminous Unit: 1.25 times the share of heat input. ▪ Lignite Unit: 3.0 times the share of heat input. A supplemental notice will address set-asides for new units and / or an updating allocation method.
New Source Performance Standards (NSPS)	New[35] coal-fired utility units will be subject to the following emission limitations for Hg (lb / GWh): ▪ Bituminous: 0.0060, ▪ Subbituminous: 0.020, ▪ Lignite: 0.062, ▪ Waste Coal: 0.0011, and ▪ IGCC: 0.020.
Re-Opener	After the implementation of requirements by 2010 and 2018, EPA will evaluate the Hg emission levels, control methods, and health impacts of the trading program and allowance allocation caps.
Safety Valve	Facilities may purchase Hg allowances for $2187.50 (per ounce and adjusted for inflation). Purchased allowances reduce the size of the allowance allocation in the following year.
Trading	States may choose not to participate in the national allowance-trading program. If a State ops out of the trading program, facility specific emission limitations apply (using 'model rule' calculations).
Banking	Current Hg allowances may be banked for future use.
State Authority	States may require Hg emission reductions in addition to those proposed by EPA.
Allowance Auctions	The EPA asks for comment on the possibility of auctioning a portion of the allowances each year.

[33] The 2010 Hg allowance cap is not specified. Instead, the 2010 allowance cap is equal to the Hg reductions that result as a co-benefit of SO_2 and NO_x emission reductions proposed in a separate rule in the Federal Register (Part III, EPA, 40 CFR Parts 51, 72, 75, and 96, Rule To Reduce Interstate Transport of Fine Particulate Matter and Ozone (Interstate Air Quality Rule); Proposed Rule). The 34-ton allowance cap is based on EPA's analysis, and it is also the 2010 Hg allowance cap in the most recent version of the proposed Clear Skies Act (108th Congress: S. 1844).

[34] Baseline heat input is based on the average heat input at a facility over the highest of the three years from 1998 to 2002.

[35] A new unit is a unit that commences construction, modification, or reconstruction after January 30, 2004.

EPA FINAL Clean Air Mercury Rule: A Supplement to the RFF Legislative Comparison Table [36]

EPA FINAL Clean Air Mercury (Hg) Rule	
Federal Register Title (Date)	Environmental Protection Agency 40 CFR Parts 60, 63, 72, and 75 Standards of Performance for New and Existing Stationary Sources: Electric Utility Steam Generating Units (March 15, 2005) [OAR-2002-0056; FRL-] [RIN 2060-AJ6J]
Summary	Establishes a national annual cap and trade program for Mercury emissions from coal-fired[37] electricity generating units (EGUs). The program covers all 50 states and three EGUs in what the rule calls "Indian country."[38] States may opt-out of the Hg trading program. Any State that opts-out must meet State-level emissions caps equal to that State's share of the national allowance pool. Phase I of the program begins in 2010; Phase II, which further reduces Hg emissions, begins in 2018.
Affected Facilities	Coal-fired EGUs with a capacity greater than 25 MW, **AND** Coal-fired steam co-generation units with a capacity greater than 25 MW that supply more than 1/3 of their potential electric output (or 290,000 MWh, whichever is greater) to an electricity generator.
National Annual Allowance Allocation Caps	38 tons[39] beginning in 2010. 15 tons beginning in 2018.

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[36] Prepared by David Lankton. This document can be found at Hwww.rff.org/multipollutantH/.

[37] A coal-fired unit is any unit that fires coal or coal in combination with any other fuel.

[38] The three EGUs in "Indian country" are: Navajo Generating Station (Salt River Project; Page, AZ), Bonanza Power Plant (Deseret Generation and Transmission Cooperative; Vernal, UT), and Four Corners Power Plant (Salt River Project / Arizona Public Service; Fruitland, NM). In this document, the term "States" will refer to the 50 States and the three EGUs in "Indian country."

[39] EPA analysis suggests that the 38 ton emissions cap will be met through co-benefits from implementation of the Clean Air Interstate Rule.

EPA FINAL Clean Air Mercury (Hg) Rule	
Allowance Allocation Method	EPA apportions allowances to states according to each State's allowance pool. States are free to choose the method of allocating allowances (including auction, updating, and grandfathering) to individual units. However, EPA suggests that allocations to existing sources be based on a unit's share of baseline heat input and adjusted according to coal type: ▪ Bituminous Unit: 1.0 times the share of heat input, ▪ Subbituminous Unit: 1.25 times the share of heat input, ▪ Lignite Unit: 3.0 times the share of heat input. EPA also suggests that allocations to new units be based on their modified share of output (output in kWh * 7900 Btu / kWh) among total modified output of all new units. A new unit pool of 5% of total allowances is established from 2010 to 2014. In 2015 (and beyond), the new unit pool is 3% of total allowances.
New Source Performance Standards (NSPS)	New coal-fired utility units will be subject to emission limitations for Hg (* 10^{-6} lb / MWh): ▪ Bituminous: 21, ▪ Subbituminous (Wet Scrubber): 42, ▪ Subbituminous (Dry Scrubber): 78, ▪ Lignite: 145, ▪ Waste Coal: 1.4, and ▪ IGCC: 20.
Penalties for Excess Emissions	Any unit in non-compliance must surrender permits to cover excess emissions. That unit's next future year allocation is reduced by 3 times the amount of excess emissions.
Banking	Hg allowances may be banked for future use without restriction.
State Authority	States may require Hg emission reductions in addition to those proposed by EPA.

Appendix 5

Modeling State Multi-Pollutant Rules Affecting the Electricity Sector in Haiku for NYSERDA[40]

Connecticut					
Rules: 22a-174-19a (SO_2), 22a-174-22, 22a-174-22a, 22a-174-22b (NO_X)					
Pollutant	**Affected Sources**	**Enforcement Level**	**Target**	**Compliance Date**	**Modeling Compliance in Haiku**
NO_X	NO_X Fossil Budget Program sources	Facility (assumed)	.15lb/MMBtu annual	2003	Assumed: Typically forced annual operation of NO_X controls and switching from oil to natural gas.
SO_2	NO_X Fossil Budget Program sources	Facility	.5% sulfur fuel or .5 lbs./MMBtu monthly	2002	Assumed: SO_2 default rate for oil-fired boilers lowered.
	Acid Rain Program sources	Facility	.3% sulfur fuel or .3 lbs./MMBtu monthly	2003	

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[40] Based on major known approved rules or imminently pending rules as of fall, 2003.

Massachusetts

Rules: 310 CMR 7.29

Pollutant	Affected Sources	Enforcement Level	Target	Compliance Date	Modeling Compliance in Haiku
NO_X	MW >100 and vintage>1977 and never NSR-affected (6 plants)	Facility	1.5 lbs./MWh annual	2004	Known: Based on compliance plans reported to state.[41]
			3 lbs./MWh monthly max	2006	
SO_2		Facility	6 lbs./MWh annual	2004	
			3 lbs./MWh (6 lbs./MWh monthly max)	2006	
CO_2		Facility	Historic Cap (1997-1999 emissions)	2005	Not modeled.
			1,800 lbs./MWh	2007	
Hg	Four coal fired units		85% reduction from unknown base year	2008	Not modeled (rule in proposal stage when compliance assumptions last updated)

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[41] *Evaluation of The Technological and Economic Feasibility of Controlling and Eliminating Mercury Emissions from the Combustion of Solid Fossil Fuel.* www.mercurypolicy.org/new/documents/MApowerplantstudy1202.pdf *and* http://www.state.ma.us/dep/bwp/daqc/daqcpubs.htm

Missouri					
Rules: 10 CSR 10-6					
Pollutant	**Affected Sources**	**Enforcement Level**	**Target**	**Compliance Date**	**Modeling Compliance in Haiku**
NO_X	Fossil fuel, MW>25 Exemptions for infrequently used units.	State	Tradable performance standard based on *source's previous year's heat input.* EPA\IPM assumes 43,950 tons cap in 2005. Exchange rate between two regions.	May 1, 2004.	Known and assumed: Mostly SCR installations. We force compliance with EPA/IPM assumed cap. Regional exchange rate not modeled.

New Hampshire Rules: RSA X-125-O					
Pollutant	**Affected Sources**	**Enforcement Level**	**Target**	**Compliance Date**	**Modeling Compliance in Haiku**
NO_X	Merrimack 1, 2 Schiller 4,5,6 Newington 1 (all owned by PSNH)	State	3,644 Tons	2006	Assumed and known: Retirement, repowering to gas and biomass, combustion controls.
SO_2		State	7,289 Tons	2006	Assumed and known: Retirement, scrubber installation, repowering to gas and biomass.
CO_2		State	5,425,866 Tons	2006	Not modeled separately.

New York

Rules: 6 NYCRR Part 237 (NO_X), Part 238 (SO_2)

Pollutant	Affected Sources	Enforcement Level	Target		Compliance Date	Modeling Compliance in Haiku
NO_X	All fossil units >25MW	State	Cap for non-ozone season (Oct. 1-April 30): 39,908 tons		2005	Assume: Existing NO_X controls run annually.
SO_2	Title IV affected coal units.	State	Annual Caps	199,600 tons	2005	Modeled endogenously.
				133,000 tons	2008	

North Carolina

Rules: General Statutes Article 21B, Chapter 143 § 143-215.107D

Pollutant	Affected Sources	Enforcement Level	Target		Compliance Date	Modeling Compliance in Haiku
NO_X	Coal-fired Units owned by Progress Energy (Carolina Power & Light) and Duke Energy	Company	Annual Cap	Duke: 35,000 tons Progress.: 25,000 tons	2007	Known: Firm compliance plans[42]
				Duke: 31,000 tons Progress: 25,000 tons	2009	
SO_2		Company	Annual Cap	Duke: 150,000 tons Progress: 100,000 tons	2009	Known and assumed: Firm compliance plans[42] achieve caps in most cases using historic capacity factors. Haiku shows project increasing capacity factors so additional controls are assumed to maintain compliance with SO_2 caps.
				Duke: 80,000 tons Progress: 50,000 tons	2013	

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[42] As reported in; http://daq.state.nc.us/news/leg/CO2_912003.pdf

Texas						
Rules: TCEQ Chpt. 101., SubChpt. H, Div. 2, §§101 (implementing Senate Bill 7)[43]						
Pollutant	**Affected Sources**	**Enforcement Level**	**Target**		**Compliance Date**	**Modeling Compliance in Haiku**
NO_X	Grandfathered fossil-fuel-fired EGUs[44]	Region	Annual Cap	East: 255,510 tons	May 1, 2003	Assumed and known: Existing controls operated annually and SCR and SNCR retrofits (known plans from diffuse sources)
				West: 43,884 tons		
				El Paso: 2,157 tons		
SO_2	Grandfathered fossil-fuel-fired EGUs[44]	Region	Annual Cap	East: 532,021 tons	May 1, 2003	Assumed and known: Existing controls operated annually and SCR and SNCR retrofits (known plans from diffuse sources)
				West: 62,991 tons		
				El Paso: 0 tons		

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[43] There is also a NO_X emissions trading program that affects all sources of NO_X emissions annual emissions above 10 tons specifically in nonattainment regions that is not modeled in Haiku (30 TAC Chapter 117).

[44] List of affected sources and calculation of caps determined from data on TCEQ website.

Wisconsin

Rules: Cooperative agreement between Wisconsin DNR and WEPCO[45]

Pollutant	Affected Sources	Enforcement Level	Target	Compliance Date	Modeling Compliance in Haiku
NO_X	5 coal plants in WI owned by WEPCO	Company	.25 lbs/MMBtu	2007	Known: Firm compliance plan in NSR consent decree.
			.15 lbs/MMBtu	2012	
SO_2		Company	.70 lbs/MMBtu	2007	Known: Firm compliance plan in NSR consent decree.
			.45 lbs/MMBtu	2012	
Hg		Company	10% reduction from unknown year	Unknown	Not modeled separately due to uncertainty in plan. Planned NO_X and SO_2 controls will likely achieve goal.
			50% reduction from unknown year	2012	

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[45] WEPCO settlement for NSR violations also achieves these goals.